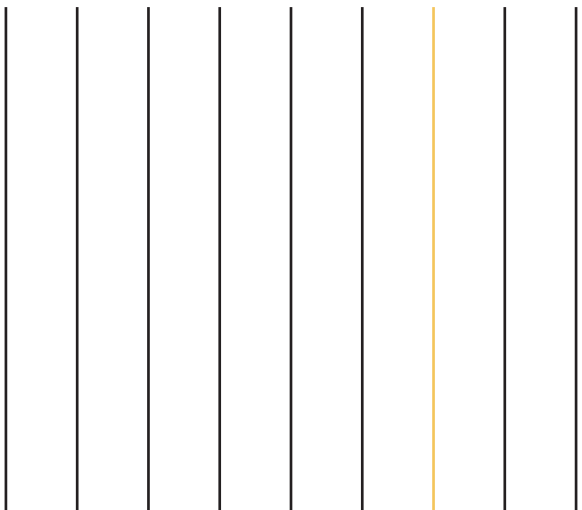
JUNE 2 - 4th, 2024

56TH ANNUAL CONFERENCE

KANSAS STATE UNIVERSITY
College of Veterinary Medicine



Conference Contact Information

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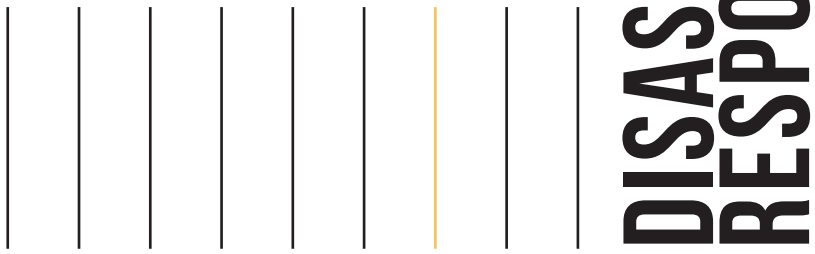
CONFERENCE EVALUATION

Thank you for joining us!

THE VETERINARIANS ROLE IN DISASTER RESPONSE

DEBRA ZORAN
DVM, PHD, DACVIM-SAIM



DISASTER RESPONSE



The Vet's Role in Disaster

Debra L. Zoran, DVM, PhD, DACVIM-SAIM

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Goals

Provide you the information that you need so that you can:

1. Be of most help to your community while protecting yourself and practice
2. Understand and be ready to integrate with local/state entities on a deployment seamlessly
3. Be prepared to deploy safely and understand your role within the system

2

Sections

ICS 101 and Understanding Your Role

- ICS 101 – Org charts and a new language
- Command staff, accountability and chain of command
- Veterinary Organizations – from local to regional to State

All Disasters are Local

- How will you be activated?
- What can you do to help your community?
- What should you know about your city/county and the EM structure

Preparing for Deployment 101

- How to prepare
- What to bring
- What to expect

3


Veterinarians are by nature, Helpers – they are not (without training) First Responders

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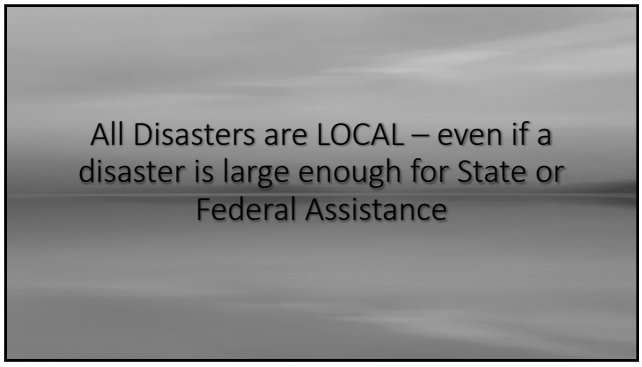
All Disasters are LOCAL – even if a disaster is large enough for State or Federal Assistance

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All Disasters are Local
Federal
Request
Resources
State
Request
Resources
Local
Image: A. Kingsbury, ISU, CFSPH

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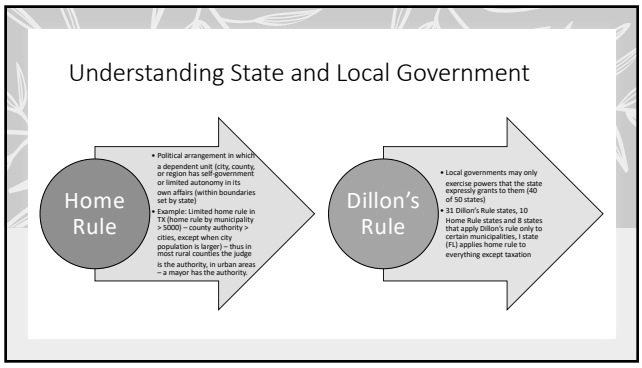
Understanding State and Local Government
Home Rule
• Political arrangement in which a dependent unit (city, county, or region has self-government or limited autonomy in its own affairs (within boundaries set by state)
• Example: Limited home rule in TX (home rule by municipality > 5000) – county authority > cities, except when city population is larger) – thus in most rural counties the judge is the authority, in urban areas – a mayor has the authority.
Dillon's Rule
• Local governments may only exercise powers that the state expressly grants to them (40 of 50 states)
• 31 Dillon's Rule states, 10 Home Rule states and 8 states that apply Dillon's rule only to certain municipalities, I state (FL) applies home rule to everything except taxation

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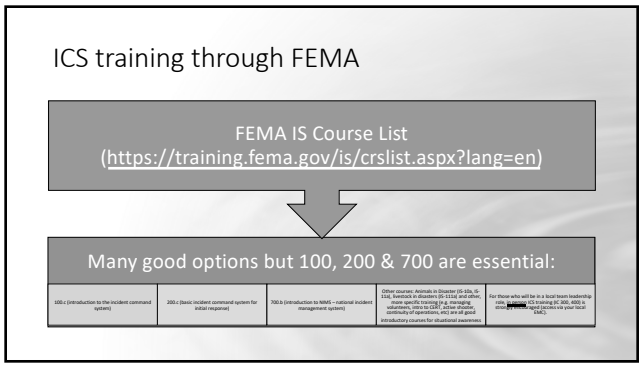
ICS training through FEMA
FEMA IS Course List
(https://training.fema.gov/is/crslist.aspx?lang=en)
Many good options but 100, 200 & 700 are essential:
100.c (introduction to the incident command system)
200.c (basic incident command system for initial response)
700.b (introduction to NIMS – national incident management system)
Other courses: Animals in Disaster (IS-10a, IS-11a), livestock in disasters (IS-111a) and other, more specific training (e.g. managing volunteers, intro to CERT, active shooter, continuity of operations, etc) are all good introductory courses for situational awareness
For those who will be in a local team leadership role, additional ICS training (IC 300, 400) is encouraged (access via your local EMC).

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ICS Basics – the structure we work under, the rules we play by, and a new language…

- EMC = Emergency Management Coordinator
  EMS/S – EM Director/Supervisor
- EOC = Emergency Operations Center
  OES = Office of Emergency Services
- Animal Branch = Group responsible for planning and/or response on behalf of animals in local org chart
- NGO/VOADs = Non-governmental organizations (non-profits)/Volunteer Organizations Active in Disaster
- Org chart – The Command Staff and why FLOP is so important
- ICS forms - mostly important to Command Staff, but you will have to use form 213 (official request) or 214 (personnel log/daily activities)

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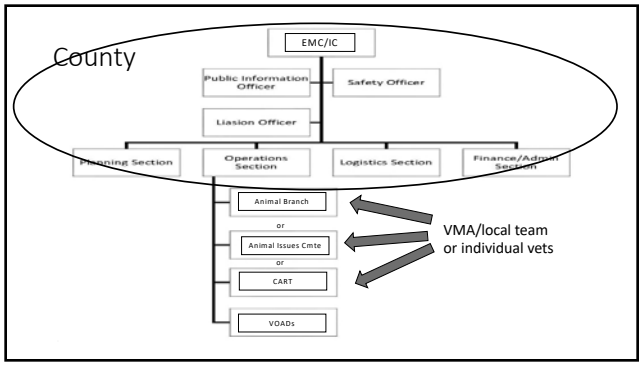

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People in your Community You Need to Know for Animal-based Disaster or Emergency Response

- Elected City/County Officials
- Emergency Management Officials
- AgriLife Extension Personnel or FFA
- Sheriff (LO)/Animal Control (ACO), Shelter personnel
- CART/VMRC or other local response organizations if they exist
- Members of any local emergency planning (LEPC) or animal response committee's (AIC, etc)

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AVMA Veterinary First Responder Certification:

New approach from AVMA disaster team

Challenging to obtain the all classes (but work on this in progress)

Excellent way to demonstrate you have a basic understanding of emergency response

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Responding on Behalf of Animals in Disaster: Organized Response Options

Local
- •CART – (Community/County Animal Response Team) volunteer organization, may become 501c3/NGO, and thus is a VOAD (like Red Cross as an example)
- •LEPC – (Local Emergency Planning Committee) – not specific to animal but all hazards
- •Volunteer on your own to local response / animal branch (shelter or local vet response under animal operations)
- •CERT (community emergency response team) – non-animal oriented but good intro to emergency response in your community/county

State
- •SART – State Animal Response Team – typically under Dept of Ag/State VET (LSART)
- •VET/CVET/FVETS – Veterinary Emergency Teams under Veterinary schools (TAMU, UCD, UF)
- •VMRC – Veterinary Medical Reserve Corps (application under HHS) e.g. CAVMRC (under California VMA) –local, regional or State level

Federal (Government based)
- •NVRT – National Veterinary Response Team – under HHS, previously DHS, and originally formed as VMAT
- •HERC – USDA Infectious Disease Response Team

NGOs (National Organizations)
- • Shelter – American Humane, ASPCA, Best Friends, American Red Cross, etc
- • Rescue (ASAR) – Code 3, ASPCA, others

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What are possible ways you may be involved?

Small and short duration events (1-2 day events)

- Likely handled strictly at the local level with volunteer involvement as part of the local jurisdiction's response
  - Ways to be involved (with appropriate training):
    - Planning (assist with team oversight at EOC, assist with organizing, set up)
    - Response (assist with shelter med, disaster medical triage and stabilization)

Larger and longer duration events

- Large scale event with state or federal declaration, or event too long for local /regional volunteers to sustain
- Join CART, VMRC, SART or National level group – will provide the organizational structure, equipment and inventory needed to sustain a large-scale disaster response

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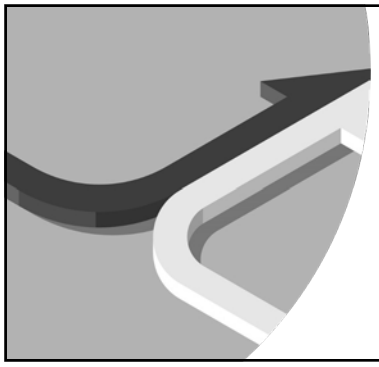

You Should NOT DEPLOY Without An Official Request or without a position on a requested team/group!

In other words: Self deploying is both dangerous and inappropriate – you are putting yourself and your livelihood at great risk

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Questions About Where or How You Fit?

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Preparing to Work in a Disaster Environment

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"Those that have responded are better planners, and those that have planned are better responders"

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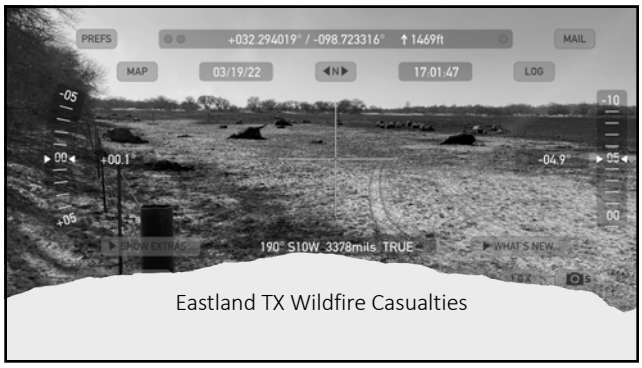

Eastland TX Wildfire Casualties

22

You have to do everything you can to make sure you, your family and your practice are prepared so that can you focus on the tasks at hand

Planning is Essential (HOPE is NOT a PLAN)
Resiliency, Stress Management/Self Care Skills
Self Awareness – Understand where YOU are at this moment

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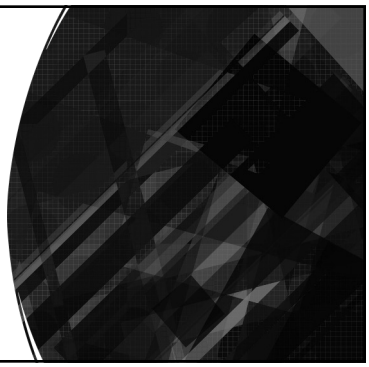
Understanding the Risks Around You:

Important for Both Preparedness and Response



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Natural hazards are only one aspect…. What are your man-made risks/hazards?

- Industrial (chemical, biological, radiological, explosives)?
  - Chemicals: EPA triexplorer
  - Radiological (power vs other sources)
  - Biological (Covid…)
- Transportation/Structural (roads/trains, dams, etc)?
  - Ohio and Georgia train/plant explosions just this past month
- Cyber/infrastructure (power/water/connectivity)?
  - e.g. loss of power from human activity (power grid)
- Human (active shooter)

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Plan B

Plan for the Worst, Hope for the Best, but PLAN

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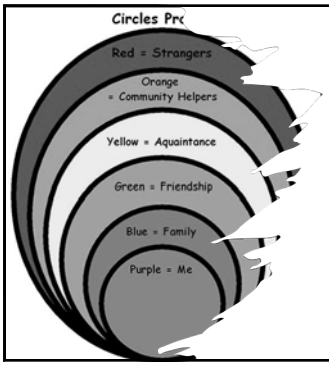
Personal Preparedness



- Personal Emergency Plan for you and your family
  - AVMA – Saving the Whole Family plans for personal pets and practice continuity planning – at AVMA website
    - https://ebusiness.avma.org/ProductCatalog/product.aspx?ID=140
  - Be Red Cross Ready
    - https://www.redcross.org/get-help/how-to-prepare-for-emergencies.html

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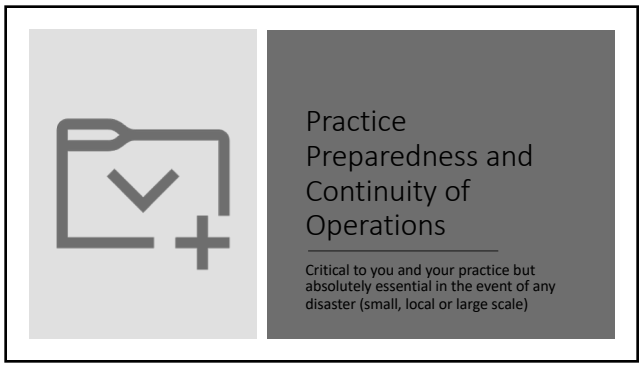
Practice Preparedness and Continuity of Operations
Critical to you and your practice but absolutely essential in the event of any disaster (small, local or large scale)

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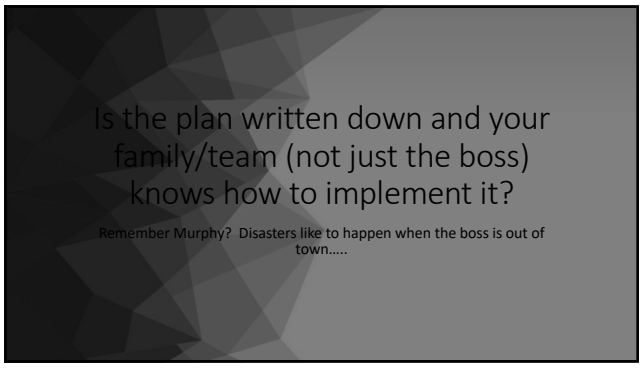
Is the plan written down and your family/team (not just the boss) knows how to implement it?
Remember Murphy? Disasters like to happen when the boss is out of town…..

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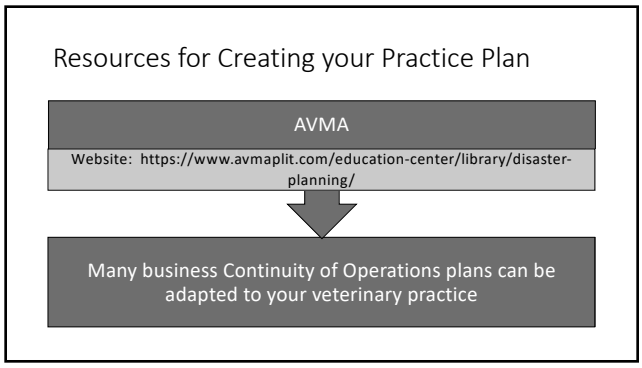
Resources for Creating your Practice Plan
AVMA
Website: https://www.avmaplit.com/education-center/library/disaster-planning/
Many business Continuity of Operations plans can be adapted to your veterinary practice

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A disaster (small or large) impacts your practice – by affecting you, your family, your practice (structure, people, resources), but also your clients and/or community – you must anticipate your response decisions and priorities

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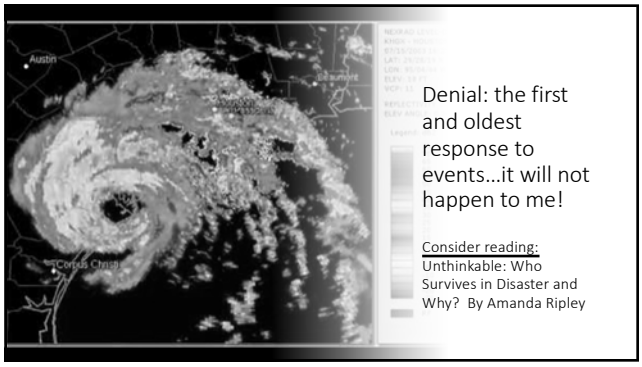

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Preparing Yourself and Your Family

- Family preparedness
- Animal family preparedness
- Work family preparedness

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Preparing Others for Your Deployment

Day to Day needs around the house….

- Handing off responsibilities to others (family, friends, pet care, etc)

Have your Work Life in Order

- Employer is all in on your participation and what it means
- Who is covering for you? Is this reasonable?
- What amount of time can you be gone? Some teams require 2 week commitments others are more flexible

Have your Personal Life in Order

- Medical (health issues, prescriptions, fitness)
- Legal (will, trust, etc)
- Financial
- Emotional (is your spouse all in with this? Do you have kids/pets with specific needs?)

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What to Bring in Your Go Bag

Minimum 3-days of self-sufficiency.

Pack 1 week of clothes/supplies into duffel, in event no laundry facilities available

- Extra underclothes in case of sparse showers, shower wipes/quick dry towel
- Sleep needs (eye cover, sound protection, pillow, etc)
- Rain and cold-weather gear, boots for day/comfort shoes at night
- Snacks or dietary needs for between meals
- Daily medications or other personal care items
- Book, ipad/charger, dominos/cards to pass time

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Personal Safety Gear

- Sunscreen and bug spray!
- Work gloves
- Cap or hat and sunglasses
- Sturdy shoes
  - Ankle support
  - Steel-toed shoes recommended
- Water additives (if that helps to stay hydrated!)
- Having a multitool / knife in your pocket
- Knee pads
- Safety helmet will be provided if needed as will other PPE

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Communication – The Key to Success or Failure

- Team communication
  - Radio's and Radio Etiquette – it's not a CB – know what you are going to stay, say it in the shortest possible way
  - We don't use radio call signs or typical radio short cuts (10-4, 20?, etc)
  - Team briefings (am/pm) and information movement up and down chain
  - All team members must learn that disaster communications are "short, direct, and not personal" – in other words, don't be too quick to take offense
- Interagency communication
  - Critical in large scale events involving multiple groups working in same area

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Team Briefings Are Critical

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First Day of Deployment

- BoO location/set up may not be known until we get to the area of operations
  - Expect down-time
  - Factors being considered
    - Safety
    - Access
    - Security
    - Efficiency
    - Infrastructure
    - Availability of buildings

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Using Existing Structures

47

Working in a building (fairgrounds)

48


PREFS
039.526731° N / 121.568592° W
90m
MAIL
MAP
01/11/19
09:06:34
LOG
-05
00
-01.4°
-04.6
+05
00
+10
Working in a Facility (Mental Hospital turned Animal Shelter)
ZERO
A-B
CAL
W
300
NIGHT
1.0 X

49

50


Sleeping Arrangements
Co-ed arrangements are necessary and often in large noisy rooms (exception Covid)
Bring Ear plugs or AirPods
We supply cots and have sleeping bags – but it is a good thing to invest in a cot and sleeping bag for you!

51

Anticipate difficulty with sleeping for the first few nights

Generators, miscellaneous noises, cots, adrenaline, lights

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Showers, laundry and personal care…

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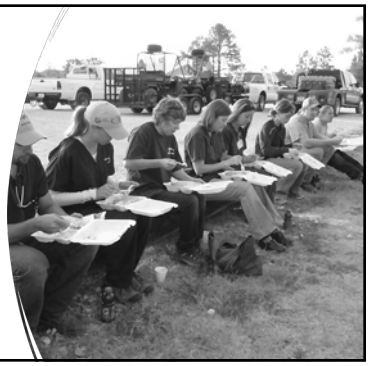
Meals and Timing of Them

- MREs may be necessary for a short period during early phases
- Live off the system
  - Typically hot meals for breakfast (0630) and dinner (1900) and a cold lunch (sandwiches) midday
  - Not necessarily a balanced diet – important to understand what you can and cannot eat for your own health
  - Consider bringing snacks if you have special needs
- STRONG coffee is a must!



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Medical Operations: The Many Faces of Deployment

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Typical Day: THERE IS NONE!

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Every day is different
Variety in pace, workload, and species seen
The days do typically start early (0600) and end late (2000)
Always have a morning briefing (after breakfast) – end of day brief too but depends on the situation (team all in one location, etc)

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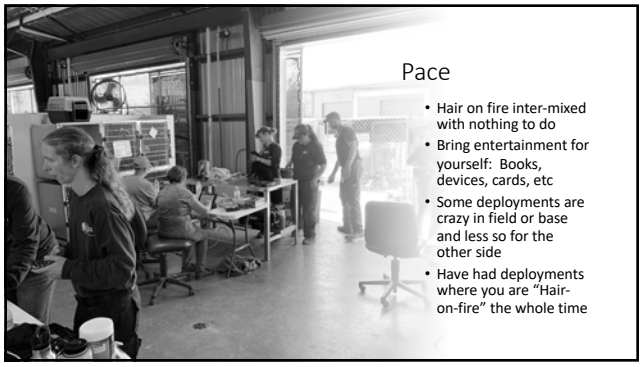
Pace
• Hair on fire inter-mixed with nothing to do
• Bring entertainment for yourself: Books, devices, cards, etc
• Some deployments are crazy in field or base and less so for the other side
• Have had deployments where you are "Hair-on-fire" the whole time

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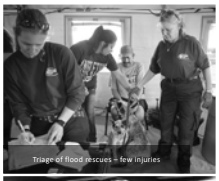
Deployments are ALL Different and Don't Always Involve "Disaster" Medicine


Triage of flood rescues = few injuries


Shelter care/management and medicine

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Sometimes your strike team will be assigned to non-"medical" missions: such as triage/admissions, decontamination oversight, field assessment of animals impacted and their needs, or other duties

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Decontamination: Our Important Role

- Triage of animals entering decontamination line for injuries/illnesses that need immediate care
- Assessment of animals for safety (behavior issues or fear)
- Will be required to be actively involved in decontamination of cats, small mammals or pocket pets/exotics due to need for appropriately handling, containment, and potential need for sedation
- We will likely have to train volunteers in proper handling and decon procedures

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Veterinary Medical Operations: Field Medicine

We are at the "tip of the spear" so to speak in the disaster – this means our care of the animals presented to us is often just the first step (triage and stabilize) before transfer to emergency shelter

We may not be able to take the treatment of an individual animal to completion (diagnosis and standard of care treatment) - but if it is humane to do so, and appropriate given our situation, we may attempt to "buy time"

64

Can we treat this patient?

Patient assessment
Fixable or not?

Yes, begin treatment

Do we have the medication/equipment necessary?

No, can we transport to a facility that can treat it

Yes, do we have a place to hospitalize if necessary?

No, can owner or other partner provide transport

Can shelter provide continuing treatment?

Yes, arrange transport

Yes, stabilize and arrange transport

No, consider euthanasia

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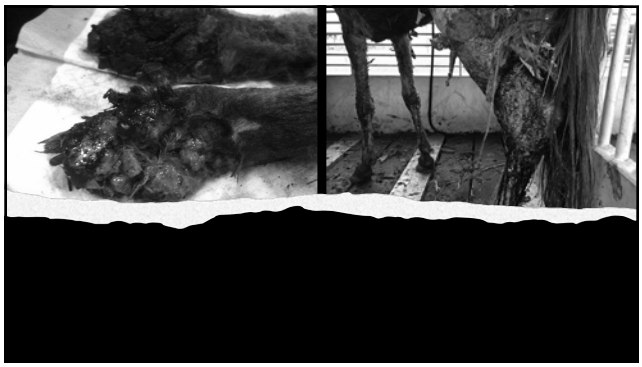

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Some will include support of S&R canines

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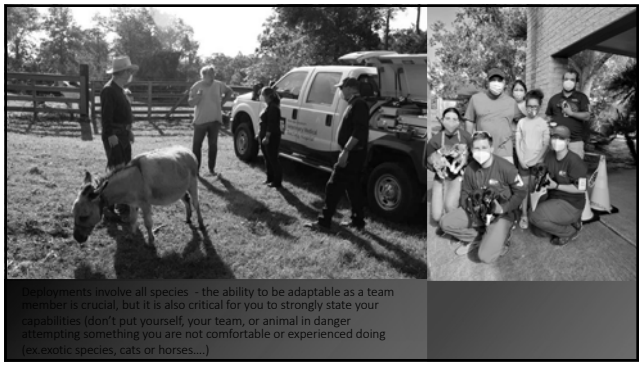

Deployments involve all species - the ability to be adaptable as a team member is crucial, but it is also critical for you to strongly state your capabilities (don't put yourself, your team, or animal in danger attempting something you are not comfortable or experienced doing (ex.exotic species, cats or horses….)

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Prepare to work outside a "normal" clinical environment: without your full complement of medical equipment or the drugs and supplies you are used to

We are working in a field medicine (triage and stabilize) mode where final diagnosis or treatment is not the goal or the expectation

69

Triage = "to sort" - but it's more than that

- Other things we must consider:
  - Is higher level care available? If not, it may impact decision making on more critical cases
  - What impact on our resources?
    - Can we provide humane treatment for the animal without harming our ability to continue to provide care for other animals (e.g. oxygen required for patient transport takes away oxygen from all other animals)
    - "the needs of the many out-weigh the needs of the one"
    - If we start to "hold onto" animals in our space – it will impact our ability to take in more patients but also increases work load

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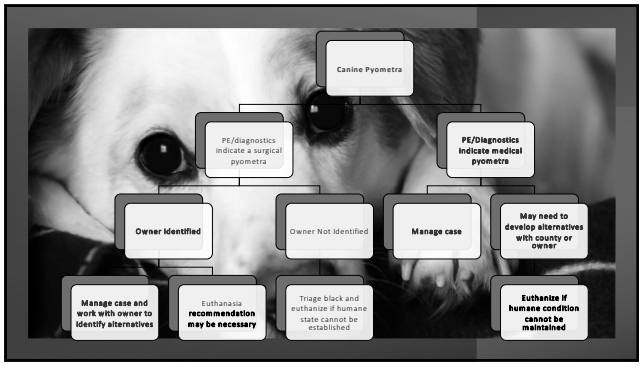

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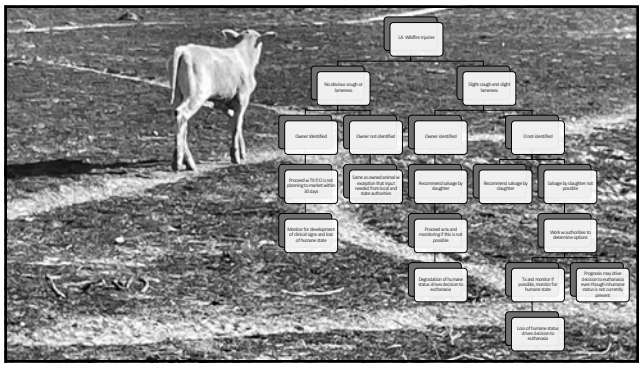

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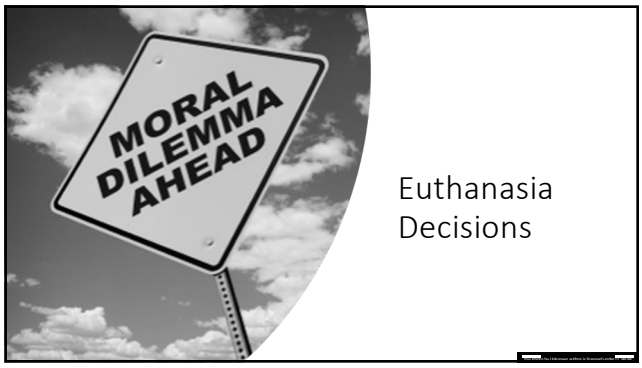

Euthanasia Decisions

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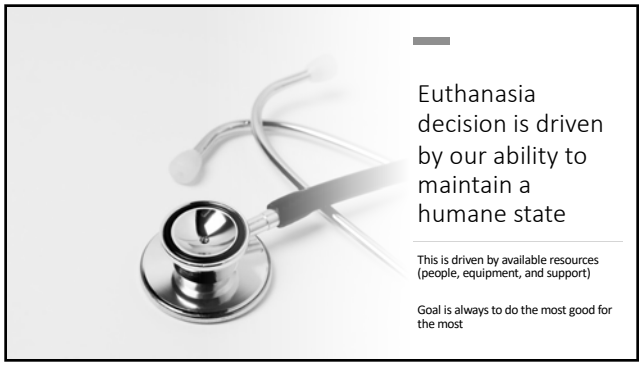

Euthanasia decision is driven by our ability to maintain a humane state

This is driven by available resources (people, equipment, and support)

Goal is always to do the most good for the most

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Texas A&M VET Euthanasia Decisions

- The VET SOG has all of the details and decision - making guidelines
- We follow AVMA Euthanasia Guidelines at all times

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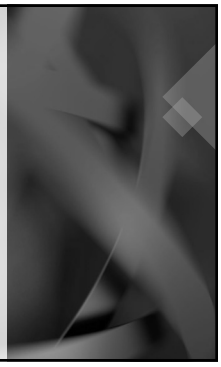
Difficult Euthanasia Situations

- All euthanasia decisions will require the concurrence of two team veterinarians and excellent documentation (including pictures)
- If there is any question or lack of concurrence, this question must be presented to the Director for additional consultation/concurrence
- Field teams may not have 2 veterinarians present – if at all possible (cell access) the use of telemedicine to get a second opinion is highly desired. If this is not possible, euthanasia can still be considered but the Director/Incident Commander should be included in the decision



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After you de-mobilize: AAR, and mental and physical wellness

- After action review - provide this to your strike team leader before you go home or within 1 week of getting home – critical to improving team
- Post-deployment wellness is important – the longer your deployment time the more it will affect you
  - Recognize that you will need more rest, you may be more irritable (after working in a disaster environment, the normal day-to-day irritants may become more intolerable) – this is a normal response!
- All deployments will have an impact on you!
  - You cannot predict what or when this will happen – self care is important
  - We need to know if you have any physical illness post deployment

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Team psychologist or clergy: Critical team assets

- Team members have used Michael during and long after deployments
- You can never predict when or how the events, sights or sounds of a response will impact you
- Self care is critical to being able to sustain your ability to deploy

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What do we do? We bring hope... And you will too for impacted people in your community!

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Thank you!

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TEXAS A&M UNIVERSITY
Veterinary
Emergency Team

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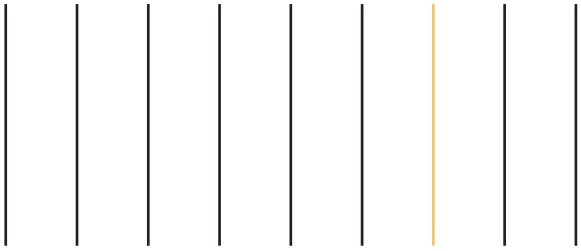
SEEING DIFFERENTLY: ANATOMY & PHYSIOLOGY OF THE EQUINE EYE

ANN DWYER
DVM



EQUINE

1. **SEEING DIFFERENTLY: EQUINE EYE EXAMINATION**

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Understanding the Anatomy of the Equine Eye

1. **The three layers and other items inside the globe can be thought of like a sandwich**
   - Outer layer is connective tissue: sclera and cornea (Think of this tunic as the "Bread")
   - Middle layer is vascular uvea: composed of iris, ciliary body and choroid (Think of this tunic as the "Tomato")
     - Uvea is derived from the Latin term for grape—pigmented, juicy!
   - Inner layer is sensory: retina and optic nerve—the business layer (Think of this tunic as the "Meat")
   - Lens splits the eye into anterior and posterior segments. (Think of as "Lettuce" inside sandwich)
   - Ocular media are wet sources of nourishment and transparent fluid volume that maintains ocular pressure.
2. **There is normally a blood ocular barrier. The interior of the eye is immune privileged.**
   - Lens proteins are not recognized as "self". If discovered by immune surveillance, intense inflammation results
   - Similarly many proteins in the retina are regarded as "foreign" and will incite an immune reaction if accessed by immune monitoring elements
   - Some proteins found in nature (f.g. leptospiral bacterial proteins) mimic molecules found in the eye (f.g. corneal or retinal proteins). If the immune system mounts a reaction to a foreign protein encountered outside the eye, it will "remember" and react to any similar proteins inside the eye if the blood ocular barrier is compromised.
3. **Chambers inside the eye normally hold clear media that are in liquid or gel form.**
   - Every clear substance that light passes through has a refractile influence. Light passes through the tear film, cornea, aqueous humor, lens, and vitreous to reach the retina.
   - The volume of the aqueous is about 3 ml and is normally a clear liquid that is an ultrafiltrate of plasma. The volume of the vitreous is about 26 ml and is normally a clear gel but often liquefies in aging horses or in disease conditions**.**
   - Disruption of blood ocular barrier lets components into these media that do not belong in the eye: ensuing altered clarity of ocular media, or obvious accumulation of cells in the chambers of the eye is proof of a compromised barrier. Manifestations include hyphema (accumulation of RBC), flare, hypopyon (accumulations of WBC), fibrin clots in the anterior chamber, and vitritis or hyalitis (accumulation of cells and debris in the posterior segment).
4. **Cornea:**
   - The equine cornea is the transparent oval window of the outer tunic of the eye. It measures approximately 33-35 mm in horizontal width and 25-28 mm in vertical height.
   - Cross section of the cornea includes the **precorneal tear film** plus several tissue layers: **Epithelium, basement membrane (Bowman's), stroma, basement membrane (Descemet's), endothelium**. All layers add up to a little less than one mm of cross sectional thickness in the non-inflamed eye.
     - The epithelium is thin with only 8-15 layers of cells. It comprises about 15% of the entire thickness of the cornea. The stroma makes up the bulk of the cross-sectional

area, a bit more than 80% of the corneal thickness. The combined thickness of Descemet's membrane and the monolayer of endothelium is very thin, less than 60 microns, or less than 5% of the corneal diameter. Clinicians must judge both the depth of corneal ulcers and the layers affected.

- Healing of non-infected epithelial defects can be *very fast*. The whole corneal epithelium normally turns over in about one week in a healthy eye.
- Healing of stromal defects can be *very slow*. Deep stromal defects may get covered with epithelium but persist as "facets" (depressions) until fibrosis and remodeling is complete. Normally the stroma is made of layers of connective tissue arranged in regular geometric planes that are transparent. Fibrotic areas will have irregular geometry and be opaque. Areas where inflammatory cells or infectious elements have infiltrated within the layers will be opaque.
- The endothelium is responsible for normal cornea transparency, as activity of the Na+/ K+ ATPase pump across this deep boundary layer of cells keeps the corneal stroma relatively dehydrated by pulling water out of the cornea and into the aqueous. This action can be likened to that of the defroster of a car windshield. If the endothelium decompensates or is damaged, the cornea will "steam up" in the compromised area. Endothelial cell density in this monolayer decreases with age, so geriatric animals are more susceptible to developing endotheliitis or endothelial dysfunction.
- A normal cornea is avascular but contains many nerve fibers that trigger pain if exposed. Nerve fibers are most abundant in the upper stromal layers and near the limbus. Corneas undergoing inflammatory processes often become vascularized with new vessels growing in towards the axis from the limbus. Vessel pattern geography gives a clue as to the location of the insult that triggered angiogenesis.

5. **Uvea: Iris**
    - The iris has no epithelium on the anterior face—heavily pigmented stroma and abundant blood vessels are readily visible. The posterior iris has TWO layers of epithelium.
    - The walls of uveal blood vessels are normally sealed by tight junctions between component cells. In addition there are active mechanisms that "police" vessel boundary activity to maintain the blood ocular barrier. With inflammation (uveitis) the uveal blood vessels become congested and the tight junctions are compromised. The vessels become LEAKY. Red blood cells, white blood cells inflammatory cytokines and other plasma components then enter the ocular tissues and media.
    - An inflamed iris is a "sticky" tissue. Iridal tissue can adhere to other parts of the eye like a weld. Most commonly the tissue sticks in a posterior direction to form posterior synechia between the posterior iris epithelium and the lens. Occasionally iris tissue migrates forward and forms anterior synechia between the iris stroma and the corneal endothelium.
        - When used to treat inflammation, atropine not only pulls the iris out of harm's way by dilating the pupil but also reduces the "leakiness" of the blood ocular barrier, and lessens ocular pain by blocking ciliary spasm.
    - If iris tissue prolapses out a hole in the cornea it looks like focal granulation tissue—more red than brown. In some cases this may effectively seal a leaking globe, but in other cases it is part of a complete endophthalmitis that will necessitate enucleation or globe compromise that will require advanced surgery.
6. **Uvea: Ciliary Body**
    - The ciliary body (CB) is one of the biggest multitaskers in the body!
        - It actively produces aqueous humor and filters plasma from circulating plasma, acting as a continuous "soaker hose" to inflate the anterior chamber

    - It is bordered anteriorly by the ciliary cleft and trabecular meshwork, and thus is adjacent to the region that is responsible for the outflow drainage of aqueous out of the eye
    - If inflamed, it acts as a regional immune surveillance site, harboring clusters of infiltrating lymphocytes that organize into a follicular pattern
    - It suspends the lens with zonular fibers arranged like the springs in a trampoline
    - The CB musculature pulls on the zonular fibers in response to visual stimuli, altering the lens curvature and resultant refractile properties. This process is called accommodation. It is more pronounced in primates and many carnivores than in horses.
- When the CB is inflamed all these functions are affected
    - Aqueous production decreases
    - Infiltrating lymphocytes form organized clusters that function as regional "nodes" for expansion of inflammatory activity
    - The lens may subluxate or fall down completely
    - Altered CB function can result in a globe that has too little fluid (hypotony from reduced production) or too much fluid (glaucoma from a drainage angle that is clogged with inflammatory debris, blocking aqueous outflow)
- In end stage ocular disease the CB stops functioning. The eye then deflates and becomes atrophied and scarred, a condition called "phthisis bulbi".

7. Uvea: Choroid

- A tremendous blood flow occurs through the network of choroidal vessels. The layer of wide choroidal vessels that appose the sclera (visible as red diagonal stripes on the fundus of a globe with sparse pigment in the non-tapetal region) is adjacent to an inner complex of capillary sized vessels, the choriocapillaris.
- The choroid in the horse is responsible for supplying nutrition to the entire retina, except the immediate peripapillary area. Disruption of the blood ocular barrier can result in exposure of retinal antigens to immune surveillance and leakage of blood between the choroid and the retina.
- When the blood ocular barrier is compromised, infiltrating WBC gain access to resident intraocular antigens. Some of the most reactive antigens are found within the retinal pigmented epithelium (RPE), the retinal layer adjacent to the choroid

8. Lens

- Normally the lens is a clear disc that is oriented in a vertical plane and held up by the zonular fibers, like a trampoline that is resting on its edge.
    - The lens can also be compared to a disc shaped candy (M & M or Junior Mint). The outer coating is similar to the lens capsule and the inner sweet is analogous to the cortex.
- The lens is nourished by the aqueous humor. The lens is transparent because it is maintained in a dehydrated state by the metabolic activity of the lens epithelial cells.
    - If enzymatic activity or lens metabolism is altered, a cataract ensues and the lens loses transparency.
- A lens that is diseased manifests as one or two problems: loss of position (luxation) or loss of transparency (cataract).
    - Intraocular inflammation can cause both conditions as the supporting zonular fibers fail if the ciliary body is compromised, and the metabolic and enzymatic activity of the epithelial cells of the lens is affected by inflammatory activity in the aqueous.

- Lens cortical proteins are autoantigens that cause intense immune reaction and may further cause cataractogenesis if exposed to intraocular WBC.

9. Neurosensory retina

- The retina is adherent to the outer layers of the eye in only two places: a boundary ring around the margin of the optic disc and a boundary ring "behind" the ciliary body.
  - Disruption of the blood ocular barrier can result in leakage of fluid between the loose plane that separates the choroid and the retina, causing retinal detachment and vision loss.
- The retinal layer called the retinal pigmented epithelium (RPE) contains abundant quantities of autoantigens, notably such molecules as IRBP, S antigen and CRALBP.
  - Lymphocytes that are found inside the eye of horses with uveitis mount intense responses to these antigens. This activity contributes to retinal degeneration and vision loss in ERU.
  - Retinal detachments are a common blinding sequellae of end stage uveitis. The RPE is the "cleavage layer" for detachment.
- Visual signals from the retinal photoreceptor cells are relayed towards the brain by a large population of retinal ganglion cells that comprise the nerve fiber layer of the retina.
  - Increased IOP in glaucoma causes interruption of axoplasmic flow in the optic nerve. This interruption eventually causes RGC death and vision loss. ERU is the primary risk factor for development of glaucoma.

Instrumentation to examine the equine eye

A direct ophthalmoscope can be used in general practice to examine the equine eye. The 3.5V coaxial direct ophthalmoscope head made by Welch Allyn is the most common model. A 3.5 V Halogen fiber-optic Finnoff transilluminator is recommended as a bright light source. It costs less than $150 from Welch Allyn. It can be ordered with a removable cobalt blue filter. The transilluminator attaches to the handle of the direct ophthalmoscope and is used to illuminate the periocular region and corneal surface as well as the interior of the eye. The transilluminator is very useful for quickly accessing a magnified view of the fundus of the eye that is similar to that seen with the direct scope head. Another handy item is an Optivisor®, a simple headband magnifying head loupe that provides reasonable magnification of ocular detail; available through online distributors for about $50. A tonometer is a handheld instrument used to measure intraocular pressure. Two models are available: the Tonopen (made by reichart.com) and the Tonovet (sold through icare.com) The Tonopen measures IOP through applanation, the force required to flatten the ocular surface as the instrument is hand-tapped on the ocular surface. The Tonovet measures rebound force when a disposable sterile probe is gently propelled on and off the corneal surface; this instrument requires no topical anesthetic and is the most practical choice for field exams. Each of these instruments costs around $4000. Practitioners with a special interest in ophthalmology will want to invest in a hand held portable slit lamp. Hand held slit lamps provide excellent magnification of surface and intraocular detail.

Ocular examination process

An ocular examination starts with an unsedated general assessment of the whole animal, with particular care paid to body condition, general "bloom", neurologic status, skin lesions and any clues of systemic disease that might accompany or influence ocular issues. The examination then moves to the head and periorbit. Skull symmetry, sinus anatomy, ocular position, and gaze of both eyes are assessed. A basic assessment of cranial nerve function is performed. Pupils are inspected and compared, and a bright light source is used to test dazzle and papillary light responses. Mildly threatening hand motions are used to assess menace responses of both eyes. The skin around the eyes is inspected closely for masses,

alopecia, swelling or inflammation. Blepharitis, tearing and excessive nasal discharge is noted. The angle of the lashes on both upper eyelids is compared, as a drooping of one side may indicate ocular pain. The conjunctiva and third eyelids are inspected for color, masses and inflammation.

The examination then moves to the globe. Many horses need no sedation, but some must be sedated for thorough globe inspection, and may require regional anesthesia of the auriculopalpebral nerve to block blepharospasm. This author uses xylazine as a sedative for ocular examination of nervous patients. Detomidine is used if the horse is extremely painful or requires deep corneal debridement and/or insertion of an SPL system. Thorough globe examination is aided by pupil dilation. This is achieved by instilling 0.5 ml of tropicamide drops onto the ocular surface. A normal pupil takes about 20 minutes to dilate; this time delay should be factored into the examination plan. The pupil function will return within a few hours.

The globe examination begins with a bright light source (transilluminator or slit lamp set on "spotlight" setting at one of the lowest illumination levels). All elements of the three-dimensional globe should be examined in a logical and systematic fashion with the operator consciously thinking about the anatomic region (i.e. "cornea", "anterior chamber", "iris", "lens") in sequence. When an abnormal finding is noted, the operator should localize it in terms of its geography on the anatomical region (f.g. "axial", "paralimbal", "equatorial", etc) and its depth on the parent structure (f.g. "anterior", "subepithelial", "subcapsular", "posterior", "mid stromal", etc) and be prepared to record the pertinent findings in a similar fashion in the medical record, taking care to include a thorough description of the character and size of the lesion(s). If a slit lamp is available, a narrow beam of light is used to systematically scan "slices" of the anterior segment, looking for cellular infiltrates in the tissue or ocular media, and assessing tissue areas that are swollen, thin or edematous, characterizing any abnormal infiltrates or masses from a three- dimensional perspective. The surface of the iris is inspected, as is the drainage angle behind the limbus. The lens is illuminated to look for cataracts or displacement.

An assessment of the posterior segment follows. Many practitioners will use a direct ophthalmoscope or transilluminator held close to their cheekbone for this purpose. The video setting on a cell phone camera can also be used to evaluate the posterior segment if the flash is dimmed by placing a small piece of elasticon tape over the light to dim the intense illumination of the light source. The bulk of observable pathology is located in the peripapillary region, and all these methods are acceptable techniques for field purposes. Some clinicians also incorporate indirect ophthalmoscopy using a Finnhoff transilluminator and handheld lens to expand the observable geography of the interior of the eye. Specialists may inspect the fundus using a hand lens that is illuminated by an indirect ophthalmoscope mounted on a headband.

Measurement of intraocular pressure with a hand held tonometer can be done before or after the ocular examination. Horses that present with ocular surface abnormalities or signs of ocular pain also undergo other diagnostic tests such as staining the tear film with fluorescein dye.

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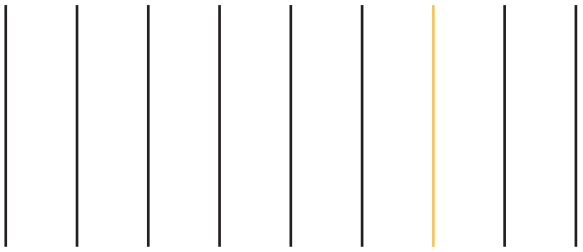
EQUINE OPHTHALMOLOGY FOR ROAD WARRIORS

ANN DWYER
DVM



EQUINE

2. ROAD WARRIOR OPHTHALMOLOGY PRACTICE TIPS

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A. **Stallside Diagnostic Tests** may include tonometry, Schirmer tear testing (STT), fluorescein and rose Bengal ocular surface dye tests, corneal culture and cytology. In some cases, blood may be drawn for serologic or other analysis.

Tonometry is used to measure intraocular pressure. The author uses a rebound tonometer (Tonovet-Plus, https://tonovet.com/products/icare-vet/ cost @$4000). Although the soft tapping pressure of the instrument tip on the cornea is tolerated without topical anesthesia, most horses are not very cooperative about having a piece of equipment the size of a small hammer very close to their globes. The normal IOP of a mature horse ranges between 10-30mm Hg. This author prefers to perform tonometry on patients who have been given light sedation (150-200 mg of xylazine, IV). Results are most consistent when the horse head is supported on a bale table in a normal resting position, and the upper eyelid motion is stopped by the use of an auriculopalpebral eyelid block.

Schirmer Tear Testing is used to quantify the volume of tear production. Fold the paper strip at the notch and then insert the notched end over the lower eyelid. Record how fast the strip is wet at 15, 30 and 60 seconds by the capillary wicking action of the paper strip, which has a metric ruler calibrated in millimeters. Normal tear production in horses is copious. Healthy horses have been reported to have a range of >30 mm of wetting in one minute and 15-20 mm in 30 seconds.

Fluorescein Dye testing is used to assess integrity of the corneal epithelium, find defects that expose Descemet's membrane, check for leakage of aqueous humor from the anterior chamber, test the patency of the nasolacrimal system, and assess tear film breakup time. Any area of the cornea that is devoid of epithelium will stain bright green as dye adheres to exposed stroma. Any corneal defect that is deep enough to expose Descemet's membrane will appear dark as dye does not adhere to this acellular membrane. Subtle lesions are best viewed through a cobalt filter blue light. Welch Allyn makes a cobalt blue filter that slips over the halogen lamp of a Finnoff transilluminator. (Part # 41102). https://www.welchallyn.com/en/products/categories/physical-exam/nose-and-throat-exam/illuminators/3-5-v-halogen-fiber-optic-transilluminators/parts-and-accessories.html

The orange end of the paper fluorescein dye strip can be applied to the bulbar conjunctiva as this will allow dye to merge with the tear film where it will turn green. Alternatively the orange end of the strip can be torn off, and put inside a 3 ml syringe and mixed with a small volume of sterile saline. The dyed saline is then sprayed on the ocular surface through the hub of a broken off 25-gauge needle.

Rose Bengal Dye testing is used to assess the mucin layer of the tear film. The red RB dye is irritating, so the paper strip should be torn off, put inside a 3 ml syringe and mixed with a few mls of sterile saline. The dyed saline is then sprayed on the ocular surface through the hub of a broken off needle attached to the syringe. Areas with abnormal tear film will stain a rosy pink pattern, which is often stippled or irregular. Corneas that have positive RB staining characteristics are suspect for keratoconjunctivitis sicca or for surface fungal colonization, but it should be noted that faint RB staining can be seen in many normal horses, particularly if they have just had a windy trailer ride or exercise session.

Cultures of corneal ulcers should be taken prior to cytology sampling. It is best to sample a cornea that has not been treated with topical anesthetic, but sometimes this is not possible due to patient

resistance. Calcium alginate swabs are preferable to other sampling devices. http://www.capitolscientific.com/Puritan-25-801-A-50-Pur-Wraps-Calgiswab-Sterile-Calcium-Alginate-Tipped-Urethro-Genital-Applicato The swab can be submitted to a diagnostic laboratory for analysis. Alternatively, a sample for in house analysis can be taken by scraping a small portion of diseased/disrupted cornea with the sterile blunt end of a scalpel blade. The blade can then either (a) be used to directly apply the contents to bacterial culture plates by making a series of small "C" shaped carvings into the growth agar, or (b) be dropped in sterile fashion into a tube of thioglycollate broth and placed in an incubator at 38 degrees C. If the broth becomes turbulent, the resultant growth can be plated out onto agar plates for identification and antimicrobial sensitivity analysis.

Corneal cytology is a recommended diagnostic test for all significant corneal ulcers and also for suspect neoplastic lesions. The sampling procedure is a simple skill that all equine practitioners should master. The horse should be sedated, and the mandible should be supported by a bale table. If the horse has severe blepharospasm or is uncooperative, an auriculopalpebral nerve block should be performed. About 0.5 ml of topical anesthetic (Proparicaine® or Tetracaine®) is applied to the corneal surface through the hub of a broken off 25-gauge needle attached to a small syringe. The blunt end of a scalpel blade (any standard size except #22 as the width of this size blade is not optimal) is applied at a 45 degree angle to the target lesion, with the operator using the foil wrapper of the scalpel blade to hold the blade in a sterile fashion and cover the sharp end. A firm scraping motion is used to dislodge cellular material from the corneal surface. The material is transferred from the blade edge to the dry surface of two glass microscope slides. The scraping process is repeated several times and the slides are inspected to make sure that several areas of visible material that is at least 0.5-1 mm in diameter is observed. The slides are placed in a slotted plastic slide box http://www.heathrowscientific.com/catalog/product?deptId=MICROSCOPY+SUPPLIES&prodId=15982 and allowed to air dry. After the slides are dried one is stained with DIFF-QUIK stain. If analysis of the Diff-Quik stain reveals an abundant population of bacteria, the other slide is gram stained to see if the bacteria are gram negative or gram positive. Clinicians are urged to gain comfort with interpretation of corneal cytology—the skills needed for most cases are simple and rapid access to this diagnostic information will provide key information for effective therapeutic decision-making. A sample from a normal cornea should contain nothing but epithelial cells, easily recognizable by their resemblance to fried eggs, and mosaic arrangement. Cytology analysis of a sample from an inflamed or ulcerated cornea should ask three questions:

(1) Are inflammatory cells present? If so, what kind of cells are there neutrophils, bands, eosinophils, or mast cells on the slide?
(2) Are infectious agents (bacteria or fungi) present? If so, what are the staining and morphologic features?
(3) Are there any foreign bodies or other non-cellular elements present? (plant material, crystals of calcium, parasites, etc.)

B. Subpalpebral Lavage systems (SPLs)

SPLs are commercial devices for delivery of topical liquid medication to the ocular surface in patients who have serious ocular disease or severe pain. These devices can be placed on horses at their home stable or in the clinic, and medication can be administered as often as needed by the owner or a hospital technician. SPL placement requires heavy sedation, topical and local anesthesia of the eyelid where the trochar is placed, and an auriculopalpebral block to induce short term paralysis of the upper eyelid. The system tubing is fixed to the face with one or more sewn on patches of tape, then woven through the patient's braided mane to a site close to the withers. An injection port is fashioned from a male catheter cap, tongue depressor, and adhesive tape and secured to a braid of mane. Medications are administered as needed through the catheter cap. Some clinicians administer medications "one at a time", injecting 01.-0.2 ml of drug into the cap, then flushing the drug onto the ocular surface with a

small bolus of air. Others have had success "stacking" medications in the tube, loading the tubing from exterior port to interior eyelid discharge opening with sequential medication in dose and type that reflect the prescribed treatment schedule. Clinicians who use the latter "stacking" method then achieve topical distribution of the medications onto the ocular surface with timed administration of small boluses of air to dispel the series of drugs that are adjacent to the cornea in small quantities, allowing a few minutes for each medication to mix with the tear film before applying the next bolus of air.

SPL systems can be used to treat an ocular problem for a month or more. If the tubing develops a leak or a break, it can easily be repaired by cutting the tubing near the damaged section so it has a clean lumen, then threading a 20 G, 1 ¼ inch catheter into each end of the open tubing, and securing the repaired tubing ends with adhesive tape. SPL systems are easily removed by trimming the tubing close to the face and pushing the tubing that penetrates the eyelid skin into the conjunctival sac using the cut end. The small remnant can then easily be retrieved from the inner eyelid region with a gloved finger. Specific instructions for insertion, management, repair, and removal of SPL systems are in reference #5 below.

C. Stallside Ocular Imaging for Road Warriors

Ultrasound of the globe, orbit and periorbit can be performed with standard machines that ambulatory clinicians use for reproductive or musculoskeletal evaluation. Ultrasound is appropriate for cases where the clinician is trying to check for orbital fractures, assess tissue density in a swollen eyelid to check for abscesses, or assess globe size in cases of exophthalmos or suspected orbital tumors. It is also useful for inspecting the anatomy inside the globe to look for evidence of cataract, lens luxation, intraocular masses, or retinal detachment. The author favors the use of a 7.5 mHz curvilinear probe for most ocular imaging, but also uses a 5.0 mHz linear probe for assessment of tissue behind the globe. A transpalpebral approach is suitable for most ambulatory cases. The author always performs ocular ultrasound with the horse's head supported by a bale table as this practice simplifies restraint. Images can be captured on a jump drive, photographed directly from the machine screen, or saved on the machine internal software. Clinicians should be aware that many referral institutions have access to **high frequency ultrasound machines** that can obtain very high detail of ocular structures. Certain cases may benefit from referral for this procedure.

D. Digital photography.

The advent of high quality, inexpensive compact digital cameras has brought the capability of high quality field imaging within the range of all practitioners. A few tips for great ocular photography:

- The most important concept is an understanding of the **autofocus system**. If the camera is set on the PROGRAM (P = automatic) setting with the MACRO option (flower icon) selected, the autofocus will be optimized for taking pictures of objects that are 12-20 cm away from the lens. This autofocus system is engaged when the shutter button of the camera is pushed half way down. This action causes an infrared beam to be emitted from the camera. This beam bounces off of the object that is in the center of the camera viewfinder and is "read" by a computer inside the camera. The processor then adjusts the lenses and the light aperture for optimum imaging of the object in the center of the viewfinder. It signals the operator that it is focusing on the area of interest by projecting a bracketed outline on the viewfinder. <u>If the camera shutter is depressed fully after the autofocus is engaged, and the distance from the camera lens to the eye has not changed at all, the image will be in sharp focus.</u>
    - Experimentation with a given camera model will demonstrate the optimum focal distance for imaging the eye. The autofocus will NOT engage if the camera is held too

close to the eye. The operator will know this because the bracket will not appear on the viewfinder.

- Horses become restless if too much time is spent "setting up" an image, so the best practice is to take several images in rapid sequence, making sure the autofocus is operating for each one. The operator can then review the images on the viewfinder and decide if the quality is acceptable. If necessary, shots can be repeated, or slightly different angles can be taken to image the area of interest.
- Photographs will be of the highest quality if they are taken indoors in a dark area with a flash. The operator must be aware of background and foreground detail that may impair quality—the corneal surface is glossy and reflective and it will pick up windows or other reflections that are present behind the operator.

The digital zoom feature should NOT be used when the picture is taken. However, the digital zoom feature is very useful to use AFTER the image is obtained to demonstrate lesions to the owner on the camera LED screen. The clinician can use the camera "review" feature to scroll through the images on the screen on the back of the camera, selecting the best ones. Then the digital zoom and positional buttons can be used to center and enlarge the area of interest to fill up the screen. Owners can then look at the lesions in a magnified view. Showing the problem to the owner on the camera LED screen (or cellphone screen) is a VERY important part of the treatment plan. It is hard for most owners to "see" lesions on the live horse, but it is easy for them to appreciate pathology on a camera screen. Treatment compliance and acceptance of the expense and effort involved in handling a tough problem will be enhanced by the stallside review of images.

Images obtained in the field should be downloaded to a viewing computer at the end of the day. The images will have superfluous detail of the animal's head that will need to be cropped with editing software. This task is easily performed with a variety of software programs (Apple iPhoto, Aperture, Microsoft Photo Editor, Adobe Photoshop). The detailed, magnified images can then be transferred to the medical record and/or emailed to the owner.

Modern smartphones have evolved to contain high quality cameras. These devices have great features that allow the fundus to be photographed through a dilated pupil; the procedure is well described in the reference by Dr. Dennis Brooks at the end of this paper, and further tips for cell phone fundic photography can be found at this website: https://www.facebook.com/equineeyeclinic/

Patience is required to master this technique but it can be very rewarding to capture images of fundic abnormalities.

In some situations, cell phones can also be used to take good photos of the ocular surface or anterior segment. However, the author has found that the images that are acquired with a digital camera are usually superior to those from a cell phone because one hand of the operator can be used to steady the digital camera and operate the shutter while the other hand holds the eyelids of the horse open. This sequence, which is not practical with the cell phone shutter operation, tends to produce superior images that are in very sharp focus. Moreover, the "autofocus" feature of cell phones may select the level of the tapetum inside the eye as a focal point rather than the ocular surface, and if this happens the image of the external globe will be out of focus.

Progressive photography of lesions that are being treated or followed is important. Assessing progress (or worsening) of a lesion is difficult when the operator is relying on memory for judgment, but is straightforward when sequential images are compared side by side.

E. Medical Record of Equine Eye Examinations

An examination is never complete without a **medical record:** findings that detail various regions of the cornea and globe should be recorded. Many clinicians use pre-made outline drawings of the cornea, iris/pupil, lens and fundus as templates on which to depict findings. Drawing can be supplemented with written detail. Reviewing ocular photographs will aid the description process for complicated findings A few tips:

- A STT strip makes a handy ruler to measure findings
- For reference, the average width of the equine palpebral fissure is about 40 mm and the width of the cornea is about 32-35 mm from 9:00 to 3:00. The height of the cornea is about 25-27 mm from 6:00 to 12:00.
- Any ocular region that is circular or ovoid (iris, cornea, optic disc, observable fundus) can be related to a clock face where findings can be compared to their "clock hour" position. Findings can also be related to a point of reference like the optic disc (f.g."the fundic lesion is located ½ disc diameter away from the 4:00 border of the optic nerve and occupies a region that is ¼ disc diameter in width") .
- A few vocabulary words reflect common anatomic descriptions: "**Axial**" describes a line bisecting the center of the cornea and the rear of the globe. "**Limbal**" describes the intersection between the cornea and sclera. "**Temporal**" describes the "outside" of the eye (what might be thought of as "lateral"). "**Nasal**" describes the "inside" (often also called "medial") . Although many clinicians refer to the "top" of the eye as dorsal and the bottom as "ventral", the most correct terms are **"Superior**" and "**Inferior**". The lens has a "**capsule**" that acts an outer skin and a "**cortex**" (everything inside the capsule, but thought of in terms of anterior and posterior regions). It also has an "**equator**" which is a term that describes the outer thin edge of the vertical disc shaped structure which is usually covered by iris.
- Terminology for areas of altered color or appearance on the cornea, lens or fundus may be quite descriptive. Examples of words used to describe the shape of ocular findings include: geographic, **floriform, stellate, focal, pinpoint, speck like, vermiform, serpiginous, dendritiform, staghorn, geographic, elliptic** and **corraliform**. Examples of terms that may be used to describe the character of an ocular opacity found within a normally transparent structure include **lacy, steamy, stippled, smokelike, opalescent**. Ophthalmic medical record detail will bring out your inner creative writer!

a. Conditions common to various equine lifestages:

Practitioners should be alert to detecting the following conditions as they examine horses through the stages of their lives:

Neonatal congenital conditions: present at birth

- Microphthalmos
- Lacrimal puncta agenesis or duct atresia
- Congenital strabismus
- Dermoids
- Aniridia
- PPMs (persistant papillary membrances)
- Anterior segment dysgenesis (may not be noticed till maturity)
- Congenital cataracts
- Coloboma
- Persistant hyaloid artery
- Congenital glaucoma or retinal detachment (rare)

Neonatal acquired conditions: follow birth process or develop in the first few days of life

- Entropion (be vigilant for this in sick foals)
- Subconjunctival hemorrhage
- Retinal hemorrhage
- Uveitis secondary to septicemia
- Jaundice secondary to neonatal isoerythrolysis (scleral icterus)
- Various manifestations of HIE (hypoxic ischemic encephalopathy)
- Ulcers: Uncomplicated, melting, infected, or persistent erosions
- Secondary manifestations of adenovirus, botulism

Pediatric conditions that are found in sucklings or weanlings

- Blunt head trauma—concussive during pasture roughhousing or training accidents—can cause acute blindness
- Blunt globe trauma—as above
- Sharp facial or lid trauma
- Uveitis secondary to R. Equi or strangles
- Corneal ulcers
- Vitiligo

Mature horse conditions that commonly occur during adulthood

- Trauma: blunt and sharp
- Corneal ulcers
- Uveitis
- Squamous cell carcinoma
- Sarcoid

Geriatric horses conditions often found in aged patients

- Sinus disease with ocular manifestations
- Periocular neoplasia
- Indolent ulcers
- Cataract
- Glaucoma
- Insidious uveitis
- Vitreal syneresis
- Asteroid hyalosis/synchesis scintillans
- Senile retinopathy
- Proliferative optic neuropathy

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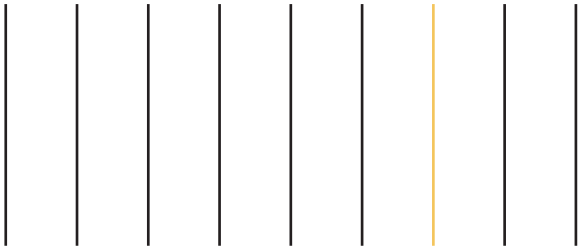
Resources for clinicians with a special interest in equine ophthalmology:

http://www.equineophtho.org/ Website for the International Equine Ophthalmology Consortium, an international professional organization that welcomes practitioner members. The group stages one meeting per year, early in June. The meeting alternates between a site in North America and a site in another continent.
http://www.wiley.com/WileyCDA/WileyTitle/productCd-VOP2.html Website for Veterinary Ophthalmology, the journal that is devoted to research on animal eye issues. The journal is now published online and a subscription purchase permits access to previous issues.
https://www.facebook.com/equineeyeclinic/ Facebook page with excellent, practical advice on ocular photography of equine eyes, including cell "Phoneoscopy" of the fundus.

EVERYTHING IS RELATIVE: THE EQUINE ORBIT & ADNEXA

ANN DWYER
DVM



EQUINE

3. EVERYTHING IS RELATIVE: PROBLEMS OF THE EQUINE ORBIT AND ADNEXA

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A. Orbit and Periorbit. The most common problems seen in the periorbital region involve trauma.

Chronic **facial deformity reflecting past trauma** is often encountered in mature horses in the form of dents or abnormal contour of the facial bones, especially in the sinus region. Practitioners must be alert to any acute facial deformity that could indicate recent fractures of the frontal, temporal or zygomatic bones, sequestra formation or local abscessation in the soft tissue, or the conchofrontal or caudal maxillary sinuses that border the orbit. Foreign body, abscess or fracture detection may require imaging with ultrasound, radiology, computed tomography or MRI. Occasionally sinus or orbital trauma will compress the extraocular muscles and other soft tissue structures around the globe, causing strabismus (deviant direction of gaze) and altered globe position/mobility.

Horses with acute **sinus fractures or sinus infections** secondary to trauma or dental disease are at risk for **orbital cellulitis.** Sinus fracture cases require aggressive antibiotic therapy for several weeks and/or sinus trephination and lavage. Horses with infections secondary to dental disease may require tooth extraction and/or sinus surgery. Horses with impaired eyelid function secondary to periorbital **oculomotor (CN VII) nerve trauma** are at risk for corneal ulceration secondary to exposure keratitis. They require frequent applications of topical lubricants and may need to have the corneal surface protected with a temporary tarsorrhaphy while nerve function is impaired. Horses that have sustained head trauma with **hyphema** where more than half of the anterior chamber is filled with blood have a guarded prognosis. If bleeding recurs the eye has a poor prognosis and may become phthisical. Horses that show any restriction or deviation in eye position or movement following blunt trauma are candidates for referral. Horses that have sustained enough trauma to the head to cause optic neuropathy may lose vision in the affected eye.

Horses may present with focal hard, non-painful enlargements of the skull in the periorbital region. Radiology will reveal that such masses develop along the suture lines where the facial bones knit together during development. This is a benign condition called **suture line periostitis** that requires no treatment, and the enlargements will usually reduce in size or disappear over a period of months.

Horses occasionally present with exophthalmos caused by **orbital tumors** or masses. Exophthalmos can be easily differentiated from buphthalmos by measuring globe diameter with transpalpebral ultrasound using a 5.0 or 7.5 MHz probe. Ultrasound of the orbit can also give an indication of the consistency and dimensions of any abnormal tissue behind the globe. The most common tumors that have been reported in the orbit are neuroendocrine tumors and extra-adrenal paraganglioma. Other neoplastic conditions that have been reported in the orbit include squamous cell carcinoma, anaplastic sarcoma, and lymphosarcoma. Rare reports of malignant rhabdoid neoplasia, fibroma, angiosarcoma, adenocarcinoma and juvenile neuroectodermal tumor exist. While some cases of orbital neoplasia are solitary, others can spread to, or originate from, other regions within the skull, including the sinuses, periorbital tissues and pharynx. Imaging of these areas with endoscopy and computed tomography is encouraged prior to surgery for prognostic reasons. Practitioners who attempt enucleation of horses with presumptive orbital tumors should be advised that hemorrhage during removal of orbital neoplasia

may be excessive, particularly if the tumor is an extra-adrenal paraganglioma. Patients undergoing enucleation of such a tumor are at risk of fatal intra-operative hemorrhage.

B. Eyelids and adnexa. The most common problems seen in the eyelid region involve trauma, allergy and neoplasia. Facial nerve paralysis, while uncommon, is a serious problem as it is associated with a loss of the capacity to blink.

Eyelid margin tears commonly occur when stabled horses rub their heads on prong like objects and avulse the eyelid margin. The incidence of eyelid trauma can be greatly reduced if owners tape up the J shaped bases of the handles of stall buckets. Repair of eyelid lacerations in the field will be facilitated if a "surgery table" is constructed for head support using stacked bales of hay or shavings. A bright LED headlight or tripod halogen light positioned near the patient will aid visualization. Practice tips for effective closure include cleansing the wound with liberal application of 2% Betadine solution, minimal sharp debridement with a small pair of Metzenbaum scissors, and closure of the subcutaneous tissues with knots that are buried and placed sparingly. Precise apposition of the torn tarsal margin is critical and should be achieved with careful placement of a figure of eight suture that does not penetrate the conjunctiva or have tags that rub on the cornea. The author obtains excellent cosmetic results with the use of 4-0 to 5-0 absorbable suture for all layers, placed using a 5 ½ inch Olsen-Hegar needle holder and a small pair of forceps. Repair of chronic lacerations that are several days old is often successful if done with great care for the preservation of anatomy.

Owners often call for emergency examinations of horses with very **swollen eyelids**. Many of these horses are suffering acute eyelid edema related to insect allergy or other seasonal irritant. If edema is the only problem, the pupil of the affected eye will be midrange and reactive, and the surface of the cornea will be transparent and show no fluorescein dye uptake. This problem responds quickly to topical corticosteroid application, but must be differentiated from chemosis accompanying a corneal ulcer or a deeper problem in the globe.

Neoplasia of the eyelid or periocular region is a difficult challenge for the practitioner. The most common tumors are **squamous cell carcinoma** and **sarcoid**, though melanoma, lymphoma, fibroma, mast cell tumors and other tumors may occur. Patients at risk for squamous cell carcinoma include draft horses (particularly Belgian Drafts), Haflingers and color dilute breeds like Paints, Pintos, Appaloosas and Hackney ponies that lack pigmentation in the lid region. Exposure to a high level of solar radiation is an additional risk factor. Field therapy for smaller eyelid tumors should include careful excision followed by local immunotherapy, cryotherapy or infiltration of the region with chemotherapeutic agents (cisplatin or 5-fluorocytourasil). However, many patients with periorbital neoplasia present when the tumors are advanced. Horses that present with lesions that occupy more than one third of an eyelid margin may be best served by prompt referral to a veterinary ophthalmologist that can perform excision with reconstruction and administer adjunctive therapies. Current adjunctive therapies include cryotherapy, hyperthermia, photodynamic therapy, brachytherapy and intralesional chemotherapy (cisplatin or carboplatin) either done as a standing local injection or using electrochemotherapy equipment which requires short term general anesthesia. Intralesional chemotherapy is usually administered over 3-4 sessions spaced a few weeks apart and involves the injection of cisplatin, carboplatin or other chemotherapeutic agents. Early referral gives the best chance of good long-term results.

Facial nerve paralysis affects the mobility of the face. Signs of unilateral dysfunction of the nerve include a droopy ear and an inability to blink on the ipsilateral side. The horse's nose will be pulled to

the contralateral side. Loss of eyelid mobility is associated with exposure keratitis which frequently leads to corneal ulceration.

Nictitans. The most common problems seen in the nictitans are trauma, neoplasia and burdock pappus bristle keratopathy. Minor tears of the nictitans may not cause a clinical problem. Lacerations that cause the nictitans to evert intermittently outside the eyelid margin may require excision or surgical revision of the leading edge of the third eyelid.

The most common neoplasia affecting the nictitans is **squamous cell carcinoma**. This tumor presents as a raised or ulcerated reddened region of abnormal mucosa. Most SCC of the nictitans originates on the leading edge of one third eyelid. The extent of the tumor may not be appreciated until the nictitans is everted with forceps for examination. Affected horses may show profuse mucopurulent discharge. Occasionally horses will present with bilateral SCC of the nictitans, particularly Belgian Drafts and Haflingers. A test is now available through UC Davis to test Haflinger and Belgian Draft horses for the genetic mutation that has been linked to both squamous cell carcinoma of the limbus and of the nictitans: https://www.vgl.ucdavis.edu/services/HaflingerSCC.php The test can be done on either hair or blood samples. Lymphoma, hemangiosarcoma and melanoma have also been reported as originating on the nictitans.

Treatment of tumors of the nictitans is either local excision of the mass (for small masses on the leading edge) or complete excision of the nictitans (for larger masses). Surgery may be performed as a standing procedure in the sedated horse. Practice tips for successful removal include supporting the horse's head on a table made of stacked bales, heavy sedation, doing the surgery within stocks, and judicious infiltration of the mucosa of the nictitans with local anesthetic, using a tuberculin syringe attached to a 25 G needle. The base of the nictitans is attached to a large pad of orbital fat which will be pulled out of the fornix during the surgery. Complications from orbital fat prolapse are rare if the fat pad that is attached to the gland is amputated along with the nictitans.

Burdock pappus bristle keratopathy is often seen in the fall in horses that live in temperate climates like the Northeast where burdock is a common pasture weed. The tiny bristles of the mature plant can become embedded in the mucosa of the nictitans that apposes the cornea or in the cornea itself. A hallmark of this condition is a cobblestone appearance of the inner mucosa of the nictitans, and adjacent scarring and ulceration of the opposing nasoventral corneal epithelium. Treatment involves topical anesthesia of all affected surfaces, eversion of the nictitans and debridement of both the nictitans mucosa and the affected cornea. Cytology samples should be taken to check for associated infection. Practice tips for successful resolution include using the open jaw of a small hemostat as a scraping instrument for the mucosa, and following hemostat debridement with judicious rubbing of the mucosa with a bit of gauze stretched over a gloved finger.

C. Nasolacrimal system and Conjunctiva

Dacryocystitis is a common problem in the field. Retrograde flushing of the system can be performed using a variety of thin tubes that attach to a syringe containing wash fluid including plastic teat cannulas, IV catheters, tomcat catheters and intranasal vaccine applicators. Stubborn blockages can benefit from passing a small 5 Fr nasogastric feeding tube (Mila International, NG522S, 5Fr x 55 cm) as far up the duct as it will pass. Practice tips for smooth flushing include the use of an LED headband light for illumination of the nasal puncta, application of a small dab of local anesthetic gel onto the nasal mucosa around the puncta and inclusion of a small amount of local anesthetic in the first volume of sterile wash that is

flushed into the duct. Cases that present seasonally with a lot of mucopurulent discharge may benefit from the topical application of an ocular preparation containing 1% hydrocortisone or 1% dexamethasone that will medicate the mucosa as tears drain down the duct.

Conjunctivitis is another common field problem. Practitioners must understand that conjunctivitis is rarely a primary diagnosis—it is usually a secondary symptom of more widespread ocular inflammation. Practitioners should look for allergic, infectious, immune mediated, neoplastic or parasitic disease elsewhere in the eye as the inciting cause.

Prolapse of orbital fat is a condition that is occasionally seen following trauma or surgery and may occur spontaneously. Weakened episcleral fascia allows fat to herniate under the bulbar conjunctiva or the conjunctiva of the nictitans, forming a fluctuant mass that may be mistaken for a tumor. The character of prolapsed fat is soft and pillow like, much like a marshmallow. Cytology on material aspirated from the fluctuant region of conjunctiva will differentiate this benign condition from neoplasia. The prolapsed fat is not harmful but will have an undesirable cosmetic appearance; a surgeon with ophthalmic expertise may be able resect the prolapsed fat and suture the underlying fascia to restore good cosmesis.

D. Orbital Imaging

General practitioners can use **ultrasonography** to assess periorbital masses, eyelid swelling or abscess, orbital fractures and look for foreign bodies. Machines commonly used for reproductive and orthopedic imaging have probes that are adequate for field examination of these problems. A transpalpebral examination will delineate the extent of fluid or soft tissue periorbital enlargements or abscesses and is useful to identify any breaks in bone continuity. Comparison of the depth measurements of both globes is indicated if one globe is more prominent than the other—if both globes have a similar axial diameter, a space occupying mass is probably present in the retrobulbar space.

Referral options for orbital imaging have advanced considerably in the last few decades; today many universities and specialty hospitals have machines that produce excellent three dimensional images of this complex region. **Computed tomography** produces the lifelike reconstructions of the orbit, providing excellent detail when there is a need to image the periorbital sinuses, an orbital mass or orbital fracture. Practitioners should offer patients with these problems the option of referral to a university for computed tomography but the owners should be aware that the procedure is fairly expensive. Recently many referral centers have invested “standing CT units”. When imaging of the equine head is indicated, referral to a site that has a standing CT unit is recommended over a unit that requires general anesthesia due to the risks and costs of anesthesia.

E. Surgery of the Orbit

Many equine practitioners offer **enucleation surgery** as an option for their patients. In recent years, many clinics have been performing enucleation as a standing surgery, restraining the horse in stocks and providing deep anesthesia through either a CRI infusion of sedation, or intermittent boluses of sedatives. The author has performed over 80 enucleations in standing patients with good results. Several reports have been published that detail practical techniques for this procedure.

In addition to advanced imaging, referral hospitals offer options for certain types of **orbital surgery**, including orbital exploration, repair of orbital fractures and enucleation, including exenteration (removal

of all orbital contents). A few horses have undergone orbital implantation where a cosmetic conformer (artificial corneal scleral prosthetic) is fitted to an orbital implant that is made of hydroxyapatite.

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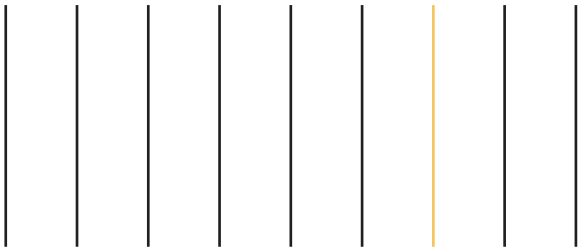
Genetic testing information for periocular tumors in Haflingers and Belgians:
https://www.vgl.ucdavis.edu/services/HaflingerSCC.php

EVALUATION OF THE SOFT TISSUES OF THE EQUINE STIFLE USING MAGNETIC RESONANCE IMAGING

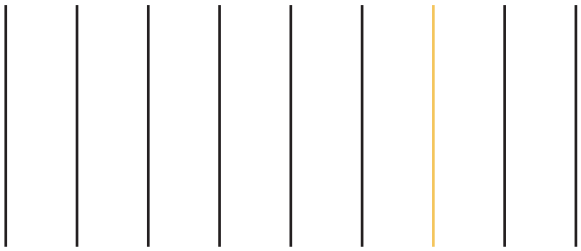
JOCELYN STEDMAN
DVM



EQUINE

TRACKS OF MY TEARS: ULCERATIVE KERATITIS

ANN DWYER
DVM



EQUINE

4. TRACKS OF MY TEARS: PROBLEMS OF THE EQUINE CORNEA

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A. Anatomy review.

The cornea is an oval structure measuring @28x35mm. It consists of several layers of tissue with an average total thickness of about 1 mm; the center or axial region is the thinnest portion.

The **corneal epithelium** is the relatively impermeable outer layer which is richly innervated and very thin (@0.14 mm and 8-15 cell layers thick) with an underlying basement membrane. The epithelium is covered by the **precorneal tear film** which many anatomists consider an additional layer of the cornea. Healing of non-infected superficial epithelial defects is rapid, involving "sliding leap frog" motion of adjacent cells to cover the wound followed by basal cell mitosis and migration.

The **corneal stroma** is about 0.8mm thick, making up 80% of the cross-sectional diameter. Stroma is primarily composed of Type I collagen fibrils that are arranged in a parallel lamellar lattice pattern. Disruption of the lattice causes opacity that is apparent as a corneal scar. The majority of the stroma is acellular but individual stromal keratocytes can be found interspersed sparsely between the layered lattice of collagen fibrils. Healing of stromal defects involves a balance of resorptive remodeling facilitated by proteinases that are released from bacteria, corneal cells and infiltrating PMNs, and restorative repair where fibroblasts lay down collagen to fill in the defect. Successful healing of defects begins with re-epithelialization and is followed by several months of new collagen production and lamellar remodeling that may return the tissue to its original transparency. In deep lesions, or lesions where healing is delayed, collagen is laid down in a random fashion, resulting in an opaque scar. In severe cases, proteinase activity is excessive, resulting in keratomalacia (melting), which can lead to perforation.

Descemet's membrane (DM) is the next layer of the cornea. DM is a thin, elastic, acellular basement membrane. It sits on top of the **endothelium** which has just a single layer of cells that form the inner boundary of the cornea. Endothelial cell membranes contain a NA+-K+ activated, ATP-ase dependent electrolyte pump that works constantly to keep the corneal stroma relatively dehydrated. Disruption of normal pump activity results in edema of the overlying stroma that can be permanent. The endothelium has poor regenerative capacity.

Veterinarians are frequently called out to examine and treat horses with corneal disease. A normal cornea is transparent and covered with smooth epithelium and a healthy tear film. Abnormal findings may include disruption of the normally smooth ocular surface (ulceration), and/or opacification of the normally transparent corneal layers.

B. Ulcerative corneal problems common in horses

Superficial corneal erosions are defects that involve only the outer few layers of epithelium. Non infected erosions usually heal quickly without visible scars. Topical mydriasis and antibiotic therapy is indicated.

Superficial keratitis may present as punctate areas of stain uptake, as focal vascularization, as pigment deposition, or as focal superficial opacities. **Punctate keratitis** may have a herpetic, fungal or an

idiopathic etiology. The lesions may be painful or comfortable. Epithelium shows fluorescein stain uptake in a dot like pattern that is scattered over the corneal surface. A trial of topical idoxyuridine may improve the condition. Topical NSAID products, especially 0.1% diclofenac, may be very helpful. Some forms of keratitis will respond to topical NSAIDs or antivirals, while others respond to topical antibiotics.

Non healing (indolent) ulcers: Shallow epithelial defects may fail to heal in older horses if the adjacent epithelium does not generate a normal basement membrane. These cases may be helped by debridement with a swab or blunt blade, or a temporary tarsorrhaphy. If a non-infected ulcer does not heal in two weeks, diamond burr debridement (DBD) with an AlgerBrush II® equipped with a 3.5 mm medium grit burr may stimulate healing. This debridement creates small defects in the superficial stroma providing a platform for adherence of new epithelial cells. In the past, many clinicians performed linear or punctate grid keratotomies on ulcers suspected to be indolent. The DBD procedure is simpler and less risky to perform and is rapidly replacing the former "grid" debridement technique. It is important to perform cytology on any non-healing lesion to rule out infection before attempting a DBD.

Ulcerative keratitis refers to defects that extend through the corneal epithelial layers and underlying basement membrane into the stroma. Healing of such defects is a balancing act: ideally, tear film proteinases remodel the stromal defect, and native fibroblasts restore stromal integrity. Bacterial or fungal infections, as well as various host factors, may tip the balance towards excessive resorption, resulting in melting of stromal collagen or even perforation of the globe. Ulcerative keratitis is very painful and accompanied by secondary uveitis, so the syndrome is complicated by patient objection to topical therapy. Adjunctive surgical therapy may involve debridement or keratectomy. Complex cases may need conjunctival grafts, amniotic membrane grafts, or tarsorrhaphy and thus may best be handled as referral cases. Very serious cases may require corneal transplantation.

Bacterial ulcerative keratitis is diagnosed by culture and cytology. Initial therapy choices are dictated by the type of bacteria seen on slides, and later may be adjusted according to clinical response and results of lesion culture/sensitivity. Therapy is intense, usually 4-6 x per day. Antibiotics are combined with mydriatics and topical antiproteinases. Systemic NSAIDs help control pain. Subconjunctival injection may be used to supplement topical therapy. Treatment of cooperative patients without obvious keratomalacia may be accomplished via topical ointments administered at home, and resolution may be straightforward. Treatment of fractious patients, or patients with deep defects is best via liquid medications administered through an SPL tube at home or at a referral hospital. Frequent monitoring will be necessary until it is clear that healing is occurring. The most common antibiotic drugs used on bacterial keratitis are fluoroquinolones (ciprofloxacin, ofloxacin, moxifloxacin), chloramphenicol, cefazolin, tobramycin, gentamicin, and amikacin. Atropine application should be to effect. Topical antiproteinase therapy using serum application is routine and may include a combination of other MMP inhibitors such as EDTA or acetylcysteine. Debridement should be judicious but may need to be repeated weekly.

Fungal ulcerative keratitis is common in humid southern climates, but reports of fungal keratitis in northern areas and desert climates have increased in recent years. Cytology of a scraping of the corneal lesion is essential to make this diagnosis. The presence of septate branching hyphae with parallel walls on a corneal cytology sample is diagnostic, but sequential cytology samples may be needed to discover fungal elements. Treatment is often begun empirically if the index of suspicion for fungus is high. Antifungal sensitivities vary from one region to the next, so it is helpful to know what medications have been most effective in a specific geographic area. Fungal infections are very painful and the host inflammatory reaction is extreme. Fungi have the ability to tunnel down to Descemet's membrane

where topical drug activity may be limited. Prognosis is always guarded; early surgical intervention may be necessary for resolution. Surgical treatment involves keratectomy with conjunctival grafting or corneal transplantation. Topical antifungal therapy may involve the use of voriconazole, miconazole, natamycin, itraconazole, or silver sulfadiazine. Systemic antifungal therapy may be instituted. Intrastromal injection of 1% voriconazole may optimize outcome.

Melting ulcers are stromal defects where host proteinase activity is severe enough to cause corneal "melting" that threatens globe integrity. In some cases, corneal melting may be related to bacterial infections particularly those caused by *beta hemolytic Streptococcus* spp or *Pseudomonas aeruginosa*. Melting ulcers are expensive and time consuming to treat and therapy must be immediate and aggressive. Outcome may be optimized if the horse is sent to a referral center where anti-infective and antiproteinase therapy (serum, EDTA, acetylcysteine, ilomastat) is administered every 1-2 hours around the clock.

Eosinophilic keratoconjunctivitis (EK) is a condition of immune mediated etiology where horse presents with limbal granulation tissue, chemosis, mucoid discharge, and/or limbal, axial or paraxial corneal ulcers that may have a rubbery or waxy texture, or may have white or yellow raised plaques with gritty chalk like material embedded along the margins. Cytology reveals an abundance of intact eosinophils and loose eosinophilic granules and may show scattered mast cells. Therapy includes debridement/debulking of the plaques using an AlgerBrush II® battery powered tool equipped with a 3.5 mm pterygium burr of medium grit (DBD). The corneal surface is then treated with atropine, and anti-infectives. In selected cases where the cornea is only mildly affected, topical steroids may be tried, but must be monitored closely, as therapy carries a risk of fungal keratitis. Cases of EK that present with extensive ulceration should not be treated with topical steroids, but a tapering does of systemic steroids in addition to systemic NSAIDs is beneficial. A sample dose regimen for a 450 kg horse would be one initial dose of 40 mg of dexamethasone (0.1 mg/kg) given IV or IM, followed by a few days oral or injectable dexamethasone at 0.04 mg/kg, then dropping the dose every 3 days by 0.01 mg/kg until reaching a dose of 0.01 to 0.02 mg/kg, then continuing on an every other day dose regimen until the condition is resolved. Recent reports on the addition of a systemic oral human antihistamine (ceterizine or Zyrtec®, 0.4mg/kg PO BID, administered for several weeks) have been encouraging. The condition has been noted to recur in the warm season and is most frequently seen on premises that are near water (wetlands or creeks) and woods. The etiology of EK is not well understood but it may be related to insect activity around the face. Constant use of a fly mask may prevent recurrence.

Calcific band keratopathy may occur as a complication of chronic uveitis or keratitis. It involves mineralization of the cornea with deposits of calcium and may be related to repeated topical steroid application. Gritty plaques of Ca+ are deposited in the corneal epithelium and upper stroma in the axial region where the lid aperture exposes the central band of corneal surface. Often the plaques protrude through the epithelium and are associated with erosions and ulceration. Removal of the irritating deposits may require diamond burr debridement, superficial keratectomy, and/or chelation with topical 1-2% EDTA. Recurrence is common.

Corneal foreign bodies embedded in the stroma or epithelium are occasionally discovered in horses. Superficial foreign bodies can often be flushed out with a pressure lavage of saline pushed through a broken off hub of a 25G needle, or "wicked" out with a sterile dry cotton bud, or "scooped" by careful undermining with the bevel of a 20G needle or small 2 mm biopsy punch. The remaining ulcer bed should be swabbed and lavaged with 2% povidone iodine/saline solution and treated medically. Very deep or penetrating foreign bodies must be referred for surgery and supportive care.

Burdock pappus bristle keratopathy: Horses that live in regions where burdock is a common pasture weed often present in the fall with tiny pappus bristles embedded in the cornea or nictitans. Large burdock thistles are commonly found tangled in the tail and mane. Affected horses present with signs of corneal ulceration or erosion, particularly in the medial canthus under the nictitans. The tiny burdock bristles are not visible in field conditions, but in chronic cases there may be vessel patterns on the nictitans conjunctiva or on the cornea that "point" to their location. All suspect areas should be debrided. Nictitans debridement is facilitated by everting the whole membrane with a small towel clamp or hemostat, and gently scraping the conjunctiva with the serrated edge of a sterile hemostat until it bleeds. Resolution is prompt if the bristles have been completely removed. Treatment involves topical atropine and antibiotics, plus systemic NSAIDs.

C. **Nonulcerative problems of the equine cornea** (Covered more extensively in talk #5 in this series)

Stromal abscesses (SA) are seen as single, or occasionally multiple, non-staining focal fluffy yellow to tan-white densities which reflect microabscesses located deep within the corneal stroma. These focal lesions are very painful and are usually accompanied by an intense ingrowth of deep vessels from the closest region of the limbus. Many of these lesions contain fungal hyphae so aggressive antifungal therapy is advised in addition to antibacterial and mydriatic treatment, and systemic NSAIDs. Recently, a technique of intrastromal injection of 1% voriconazole or other antifungal medication into the stroma surrounding a SA has been described. The technique requires expertise, a delicate touch and heavy sedation/regional anesthesia, but has resulted in successful resolution of many SA. While many superficial SAs respond to intense topical therapy or intrastromal injection, very deep SAs are sometimes completely refractive to medical therapy, intrastromal injections or debridement. Surgical options for SAs include several different types of corneal transplantation procedures. Outcome is improved if referral is made is early in the course of disease, and if the referral institution has broad experience in treating equine patients. Some patients with SAs end up requiring enucleation if they are not treated surgically at a specialty hospital.

Immune mediated keratitis/keratopathies (IMMK) are a group of conditions where corneal transparency is reduced. IMMK represents a spectrum of disease, and is poorly understood. IMMK tends to be chronic and tend to wax and wane in severity, often with periodic "flares". The variants described by the term IMMK demonstrate focal or diffuse regions of corneal opacity limited to the stroma or endothelium that retain an intact epithelium and thus do not take up ophthalmic stains. Spectral-domain confocal microscopy of opaque regions usually reveals an infiltrate of lymphocytes and plasma cells within the affected stroma and an absence of infectious elements. Although IMMK can be bilateral, most cases are unilateral and a careful history may reveal a previous episode of trauma in the affected eye. The observed opacity may reflect a cellular immune reaction to antigens expressed within the stroma. The intensity and regional pattern of observed opacification often varies over time. Areas that were previously opaque may clear only to have other geographical regions of the cornea lose transparency. Often there is vascularization of the opaque areas that will also change pattern over time. Pain is variable—some horses never exhibit pain while others may have episodes of severe pain that accompany increasing opacity. Topical treatment involves application of drugs that modulate the immune response (cyclosporine, tacrolimus, corticosteroids). Response to treatment is variable; severe cases may respond to superficial keratectomy.

Corneal tumors: Neoplasia of the ocular surface is seen less often than on the adnexa, but when it occurs, squamous cell carcinoma is the most common corneal or corneal limbal tumor, especially in

Haflinger, Appaloosa, Paint or draft breeds. Certain lines of the Haflinger and Belgian breeds have a genetic based risk for both corneal limbal and adnexal squamous cell carcinoma. Prompt referral for surgery, with added adjunctive therapy like beta irradiation, cryotherapy, photodynamic therapy or laser ablation is advised. Enucleation may be the best treatment for some cases.

D. Diagnosis, treatment and prognosis of equine corneal problems

Clinical skills required for equine practitioners to diagnose corneal problems include application and interpretation of ocular surface stains and Schirmer tear tests, collection and interpretation of corneal cytology samples, sample submission for corneal culture and sensitivity, and administration of topical and regional anesthesia. Photography should be used to document findings and assess progress.

Treatment of corneal ulcers ranges from simple application of mydriatic and anti-infective ointment a few times per day to hourly application of antiproteinases coupled with intense topical therapy with antibacterial and antifungal medication and application of atropine several times per day to effect mydriasis. The intensity of the therapy schedule is dependent on the depth of the lesion, degree of melting, the infectious agent(s), patient pain and cooperation, and owner resources.

Skills required for treating equine corneal disease include experience with insertion and management of subpalpebral lavage systems, administration of subconjunctival injections, as well as expertise in corneal debridement with cotton buds and blunt sterile metal blades. Practitioners with special interest in ophthalmology may pursue training in intrastromal injection of antimicrobials and in use of the Alger brush instrument for diamond burr debridement, but caution is advised as these two procedures are not without risk. Most serious ulcerative problems require insertion of a subpalpebral lavage system. Treating these conditions will involve extensive client communication, as well as owner dedication to home treatment and frequent veterinary recheck examinations.

Corneal problems range from simple traumas that resolve uneventfully, to progressive, painful conditions that are among the most complicated and expensive that horses experience. Prompt assessment and intense, evidence-based therapy is key for treating most conditions; choice of anti-infective therapy should be based on cytologic evidence of infectious agents. Administration of mydriatic therapy (atropine) is critical as prompt dilation of the pupil reduces ciliary spasm and thus blocks pain, decreases the leakiness of iridal blood vessels, and helps prevent posterior synechiae. Frequent administration of anti-collagenase therapy is essential to prevent melting in severe ulcers, and systemic anti-inflammatory agents are usually needed to decrease pain and inflammation. Practitioners should commit to seeing painful eyes on the date of occurrence and must perform appropriate diagnostic tests to make rational treatment choices. Owner resources for home treatment are often critical; if treatment options are limited, early referral to a specialist may result in the best outcome. The prognosis for fungal keratitis, stromal abscesses, desmetoceles and melting ulcers is guarded. Successful resolution of these complex corneal conditions often requires intense treatment and surgical intervention so referral is encouraged.

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CRY ME A RIVER: NON-ULCERATIVE KERATITIS AND COMMON INTRAOCULAR CONDITIONS

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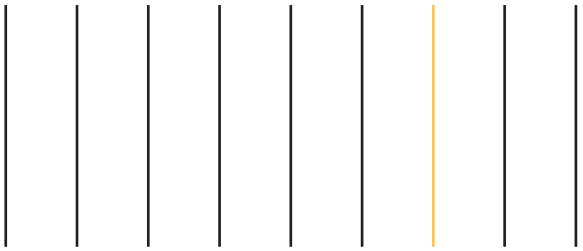

EQUINE

5. Cry Me a River: Non-ulcerative corneal disease and Common Intraocular Conditions

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A. Non-ulcerative corneal disease

Stromal abscesses: One of the most serious corneal conditions that presents without ulceration of the epithelium is a **stromal abscess** (SA). Stromal abscesses are seen as single or multiple non-staining focal fluffy yellow to tan-white densities which reflect microabscesses located deep within the corneal stroma. These focal lesions are very painful and are usually accompanied by an intense ingrowth of deep vessels from the closest region of the limbus. Many of these lesions have been found to contain fungal hyphae so aggressive antifungal therapy is advised in addition to antibacterial and mydriatic treatment, and systemic NSAIDs. Superficial SAs may respond to intense topical therapy, but deeper SAs may be completely refractive to medical therapy or debridement, and many patients with SAs end up requiring enucleation if they are not treated surgically at a specialty hospital. Surgical options for SAs include several different types of corneal transplantation procedures including penetrating keratoplasty (PK), penetrating lamellar keratoplasty (PLK), or deep anterior lamellar keratoplasty (DALK). Outcome is improved if referral is made is early in the course of disease, and if the referral institution has broad experience in treating equine patients.

Immune mediated keratitis" (IMMK): Less serious but still problematic transparency changes are seen in the group of conditions known as the **immune mediated keratopathies**. This group of diseases is poorly understood. The variants termed IMMK demonstrate focal or diffuse regions of opacity limited to the stroma or endothelium that retain an intact epithelium and thus do not take up ophthalmic stains. Many of these conditions are recurrent. Confocal microscopy of opaque regions usually reveals an infiltrate of lymphocytes and plasma cells within the affected stroma and an absence of infectious elements. Although some cases are bilateral, most are unilateral and a careful history may reveal a previous episode of trauma in the affected eye. The observed opacity may reflect a cellular immune reaction to antigens expressed within the stroma. The intensity and regional pattern of observed opacification often varies over time. Areas that were previously opaque may clear only to have other geographical regions of the cornea lose transparency. Often there is vascularization of the opaque areas that will also change pattern over time. Pain is variable—some horses never exhibit pain while others may have episodes of severe pain that accompany increasing opacity.

Management of IMMK cases requires lifelong monitoring. Treatment may involves systemic NSAIDs and topical anti-inflammatory therapy for horses that present with pain or increasing areas of opacity. Some horses will respond well to topical NSAIDs (diclofenac); others may be helped by topical immunomodulators (compounded cyclosporine (2%) or tacrolimus). Topical steroids (prednisolone acetate or dexamethasone) help some cases but the use of these agents requires close monitoring, as the presence of an undetected infectious agent deep in the stroma can never be fully ruled out, and topical steroids can exacerbate a flare up of infectious keratitis.

Endotheliitis: Occasionally the cornea can develop white to light blue regions of edema that appear foggy, particularly in older horses. The opacities often begin as triangular shaped patches that border the limbus and usually extend over at least 25% of the cornea. This condition is called **endotheliitis**. It occurs when the single layer of endothelial cells fails to perform its normal physiologic function of

removing water from the corneal stroma. Severe cases progress to **bullous keratopathy** where the entire cornea becomes opaque and swollen, and may develop small blisters on the epithelial surface. Endotheliitis is poorly understood and often refractory to treatment. The condition may be related to a loss of endothelial cell density, endothelial cell dysfunction, or rupture of Descemet's membrane. There may also be an immune mediated component.

B. Intraocular conditions.

Anterior Chamber

The anterior chamber normally contains about 3 ml of aqueous humor, a clear fluid that is a blend of plasma ultrafiltrate and actively processed fluid that circulates into the uvea. Aqueous is produced by the ciliary body, then it flows over and around the lens capsule, through the pupil, and inflates the anterior chamber. Intraocular inflammation can result in visible masses of cells or inflammatory components in the chamber manifesting as flare, hypopyon, hyphema, clouds of fibrin or a combination of all these things. Rarely the anterior chamber can contain foreign bodies (secondary to trauma), nematode parasites, or a lens that has luxated anteriorly.

Iris

Variations in the normal observed anatomy of the anterior uvea are frequently observed in practice, and include **uveal cysts, iris hypoplasia, heterochromic irises, persistent pupillary membranes, iris colobomas** and **hyperplastic granula iridica**. Neoplasia is rare but cases of **melanoma, medulloepithelioma** and **lymphoma** have been reported in the iris and other uveal tissues. Inflammation secondary to uveitis frequently deforms or damages the iris, causing atrophy of the margin of the pupil, "extra" pupils (colobomas), and synechia. Posterior synechia (iris adherent to the lens) are much more common than anterior synechia (iris adherent to the corneal endothelium); synechia are usually a sequellae of uveitis, but may occasionally occur after trauma.

Horses with silver dapple coat colors as well as many miniature horses are often found to have developmental abnormalities of their globes. This condition used to be called anterior segment dysgenesis but is now termed **multiple congenital ocular anomaly (MCOA**). MCOA is a syndrome that ranges in severity from minor variants like ciliary body cysts that do not cause clinical problems to small abnormally shaped pupils that fail to show a strong PLR, abnormal drainage angles, cataracts, glaucoma and blindness. A genetic test for MCOA is available through University of California at Davis; analytics can be performed on a hair sample, and the test is recommended for horses with silver dapple coloring.

Lens

Lens abnormalities commonly encountered in the field include cataracts and lens luxations. Both these conditions are common complications of uveitis but may also occur for other reasons.

Cataract evaluation is aided by short term mydriasis. Dilation is induced 15 – 20 minutes after 0.3 to 0.5 ml of tropicamide (Mydriacil) is applied to the corneal surface. Digital photography of cataracts is advised to document the extent of opacity, provide a baseline image for assessing progression and demonstrate the lesion to the owner. Lens opacities should be described using the classification system proposed by Matthews (see references below) which specifies the anatomic location (capsulolenticular, lenticular; zonal, anterior capsule, axial, sutural, perinuclear, equatorial, and complete), physical appearance (diffuse, crystalline, vacuolated, floriform, elliptic) and etiology (acquired or developmental) of the lesion.

Extracapsular phacoemulsification dissection and aspiration surgery is advisable for foals under 6 months of age that present with congenital cataracts. Phacoemulsification surgery may also be

appropriate for a some affected adult horses but case selection is important as post operative complications for of adult horses undergoing cataract surgery are common. Owners of horses that suffer severe blunt trauma should be cautioned that cataract formation often occurs several months after the trauma due to autoimmune reaction to lens proteins normally sequestered from the immune system.

Lens luxation is common in Appaloosa horses that suffer insidious uveitis and may be seen in other horses with uveitis or in horses that sustain blunt trauma. Posterior lens luxation is much more common than anterior luxation in the horse. Most posterior luxations are asymptomatic, but anterior luxations often cause severe pain. Intracapsular cataract surgery for removal of a luxated lens is associated with poor results in the horse.

Vitreous (Posterior Segment)

The vitreous is a clear, gel like substance that fills the posterior segment. The average volume of vitreous in the horse is about 26 ml. The most common abnormal field findings include the presence of optically refractile elements within the vitreous, liquefaction of the vitreous gel and inflammatory changes (vitritis).

Optically refractile elements in the vitreous are best appreciated by retroillumination against the tapetal reflection. They can appear as small dust like opacities, as thread like filaments, as focal highly refractile crystals or as tangled clumps of material. Larger densities may or may not be attached to the posterior lens capsule. Small focal densities are common and usually of no clinical significance.

Liquefaction of the vitreous is most commonly observed as a function of aging but may also accompany uveitis. Liquified vitreous is best appreciated when the horse's head is moved enough to cause ocular saccades (globe movements). Small densities present within a liquefied vitreous can be seen to swirl within the globe as if they are suspended in oil.

The most common causes of **vitritis** are posterior uveitis and ocular trauma. Following the influx of inflammatory proteins and blood cells into the posterior segment, the normally transparent vitreous assumes a yellow to orange hue and appears cloudy. The observable fundic image then appears hazy and the optic disc appears orange tinted when seen through the filter of the inflamed vitreous. In sequential examinations, resumption of a sharp fundic image of normal color is a sign that vitritis has subsided, while persistence of a hazy orange tinged disc image and blurred fundic detail indicates continued inflammation.

Fundus

Many equine practitioners use direct ophthalmoscopy or inspection of the fundus with a Finnhof transilluminator to perform fundic examinations in the field. Recently some practitioners have started using cell phone cameras that have been modified to facilitate fundoscopy. The video smartphone function, coupled with illumination from a phone camera flash lens that has been reduced by applying a small piece of elasticon tape over the lens creates an excellent imaging system that can also be used to record findings of significance. Assessment will be most complete if the examination is done in the dark and the pupils are dilated with topical application of 0.3 ml of tropicamide/eye (Mydriacil). Induction of dilation takes 15-20 minutes so the timing of the examination must be planned accordingly.

Identification of the major structures that can be seen on fundic examination (tapetal and non-tapetal portions of the fundus, optic nerve head, retinal vasculature and choroidal vasculature) is relatively easy as these structures can be seen just ventral to the axis, and each is distinct in shape, color and position. The major challenge that practitioners face is recognizing the wide variation in "normal" clinical findings that occur, and discriminating these from true pathology. Most aberrations and common pathologic changes are visible within one to two disc diameters of the optic disc border and thus are readily observable.

Skills in fundic examination will be enhanced by studying photographs of normal and abnormal fundic images in textbooks (See references at the end of proceedings: Barnett, Gilger, Brooks, Gelatt) and by performing a large number of fundic exams on horses of various ages, colors, breeds and sizes. Observable **pigment patterns** of the tapetal fundus and non-tapetal fundus are highly variable and often correlated with coat color. The degree to which the **choroidal vasculature** can be seen is dependent on the intensity of the pigment expressed. Slight variations in the observable shape of the **optic disc**, the contour of its border, and the pattern of vessels that cross the disc surface are common. Practitioners must be able to recognize these normal papillary variants and also identify findings such as **circumpapillary pigment variants , ectopic myelination of ganglion cell axons, persistent hyaloid artery remnants, tapetal pigment variations, partial albinism, tapetal naevi** and certain small **colobomas** of the fundus as variants of the peripapillary region.

Practitioners must also learn to recognize the footprints of previous or chronic disease in the fundus. The most common lesions observed are pigmentary retinopathies. The most common of these are **focal chorioretinitis** (also termed "bullet hole lesions"), **peripapillary chorioretinitis** (sometimes called "butterfly lesions") and **senile retinopathy**. While lesions of focal or peripapillary chorioretinitis are probably acquired presumably from previous inflammation or blunt trauma, the determination of their clinical significance in an individual horse can be difficult. These lesions can be problematic in the prepurchase examination. Senile retinopathy is a common bilateral finding in horses over the age of fifteen years.

Other fundic pathology may be observed, and the practitioner should study texts to interpret the significance of observed lesions. **Focal proliferative optic neuropathy** is not uncommon in older horses and must be distinguished from optic neuritis, neoplasia or traumatic neuropathy. Practitioners must also be able to discern signs of **retinitis**, **retinal** or **optic nerve atrophy** and **retinal detachment**. Horses that present with weakness and weight loss should undergo a fundic examination as this may reveal evidence of Equine Motor Neuron Disease (EMND). The non-tapetum of an EMND horse will have a bizarre mosaic appearance that looks like a "gaudy granite countertop". The mosaic pattern of dark and light tissue represents the deposition of ceroid lipofuscin within the choroidal tissue. Such a finding should prompt testing for blood levels of Vitamin E/Selenium as EMND is related to very low blood levels of Vitamin E.

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BONUS NOTES: THE MANY FACES OF UVEITIS

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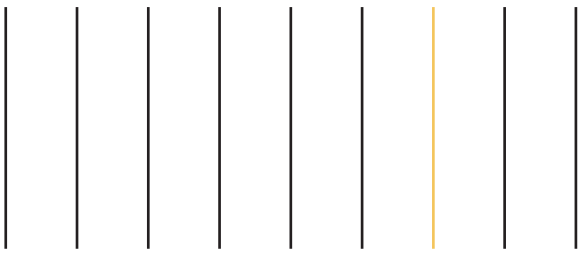

EQUINE

6. BONUS NOTES: THE MANY FACES OF UVEITIS

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FOR KANSAS STATE 2024 Conference attendees: *The 2024 lecture series was scheduled for five talks, and those covered 1. anatomy and physiology, 2. examination and treatment practice tips, 3. orbit and adnexal problems, 4. ulcerative keratitis and 5. non-ulcerative keratitis and intraocular problems. One major equine ocular disease complex that was not covered is uveitis, also known as ERU (equine recurrent uveitis) or moon blindness. This topic is a complex one that needs its own lecture, but time limitations did not allow scheduling of this subject. These notes are offered as "bonus" material for attendees.*

By definition, **uveitis** is inflammation of the uvea of the eye (iris, ciliary body and choroid). The complex of diseases known as "Equine Recurrent Uveitis (ERU) refers to intraocular inflammation that recurs or persists causing various degrees of inflammation, scarring, degeneration and dysfunction of multiple components of the eye.

A. Diagnosis, pathophysiology and etiology of uveitis

Diagnosis of uveitis is simplified by understanding that a horse may present anywhere along the spectrum from acute to end stage, and as either a recurrent or insidious case. Horses that present with three or more signs of intraocular inflammation and a history that is suggestive of either recurrent disease or breed-associated insidious disease can be given a presumptive diagnosis of ERU or persistent uveitis. Examination of these horses may reveal a combination of signs reflecting acute or recent inflammation and other signs that reflect chronic ocular damage from previous episodes. Inflammation is always present on a cellular basis in both quiescent and insidious cases, so sequential examination may discover progressive ocular deterioration in horses that have seemed "normal" to their owners.

Pathophysiology: Normal horses have a blood ocular barrier that functions to keep the aqueous and vitreous ocular media clear. Tight fenestrations between ocular capillary cell walls prevent circulating cells and large molecules from passing through the blood vessels of the iris, ciliary body and choroid into the surrounding stroma. The blood ocular barrier also serves to isolate intraocular structures from the normal cellular immune surveillance traffic, making the tissue of the inside of the eye an immune privileged site. Uveitis begins with *compromise of the blood ocular barrier*. The blood vessels in the iris, ciliary body and choroid thicken and become congested. Soon these vessels become "leaky", allowing cells and inflammatory mediators to cross the compromised blood ocular barrier and enter the inside of the eye.

Most cells that first cross the barrier are neutrophils. The invading cells may be seen grossly as hypopyon, aqueous flare, and vitreous haze. Neutrophils that enter the eye are soon replaced by large numbers of lymphocytes, some of which infiltrate the connective tissues of the ciliary body and iris, forming spherical organized follicles within the stroma of various regions of the uvea. The lymphocytes produce antibodies and inflammatory cytokines that are detectable in the ocular media and within ocular tissues. These substances react with host and (in some cases) infective factors to contribute to ongoing pathologic changes. Numerous heavy exudates appear on intraocular tissue surfaces, most notably on the epithelium of the iris and ciliary body, on the capsule of the lens, and in the layer

between the retinal pigmented epithelium (RPE) and the photoreceptors of the retina. The exudates interfere with the function of adjacent ocular tissue. Cytokine activity mediates additional tissue destruction. With repeated or persistent inflammation chronic changes occur within the ocular tissues, affecting, variably, the cornea, uvea, lens and retina. Vision loss results when dense cataract and synechiae obscure acuity, when the retina detaches or degenerates and no longer can transmit processed light signals to the brain, or when glaucoma causes ischemic damage and degeneration of the axonal processes of the retinal ganglion cells and optic nerve.

Etiology: Recurrent uveitis is an immune mediated disease. However some external conditions, as well as host genetic risk factors have been associated as triggering events for the syndrome. These factors include bacterial, viral and parasitic infections as well as host conditions like septicemia or severe trauma.

Of all infectious triggers, leptospirosis is the most significant worldwide. Leptospiral associated ERU cases account for at least 60% of the cases seen in the Genesee River Valley where the author practices. This temperate river valley is in western New York, directly south of Toronto, Canada. The most significant serovars associated with disease are *L. interrogans* serovar *Pomona* (seen often in the USA) and *L. interrogans* serovar *Grippotyphosa* (seen often in Germany and central Europe, but also in some regions of North America). Factors that increase the risk of leptospirosis in horses include pasture access to wildlife, cows or pigs, close proximity to streams or ponds, rat infestation in the stable and a rainy season with persistent ground water. Horses become infected when they drink water contaminated by the urine of a carrier animal (often a cow, deer, raccoon, pig or rat). The spirochete gains access to the horse's bloodstream by mechanical penetration of mucous membranes. Bacteremia results in clinical illness, manifested by anemia, fever and flu like symptoms. Acute clinical disease is mild and self-limiting, thus rarely diagnosed. Resolution of signs occurs in a few days to a few weeks. However, the spirochetes colonize the kidneys of the horse during the acute phase, and may persist for a few months, being shed in the urine. *L. pomona* has also been associated with late term abortion in mares, as well as placentitis, stillbirth and neonatal illness.

Ocular signs of leptospiral associated uveitis (LAU) do not occur during the acute infection; they begin months later. The ocular inflammation observed during the initial episode of LAU is variable but often severe. Inflammation usually subsides with or without therapy but then may recur at unpredictable intervals. Subsequent episodes of ocular inflammation may be more or less severe than the initial one. Inflammation and damage to ocular tissues associated with repeat episodes eventually compounds and creates visual deficits. Blindness is a common final outcome.

Although systemic infection with pathogenic strains of leptospirosis is clearly a common trigger for vision threatening ERU, the genetic makeup of an affected horse, specifically the genes that determine the MHC complex and ELA (equine lymphocyte antigen) profile of that individual, probably play a major role in determining both susceptibility to leptospirosis as an inciting trigger, and severity of subsequent inflammatory episodes.

Testing horses for exposure to leptospirosis: The author routinely submits serum from horses diagnosed with uveitis to the diagnostic laboratory at Cornell University for MAT analysis against a panel of leptospiral serovars (https://ahdc.vet.cornell.edu/). Many non-uveitic horses will show low titers to the bratislava, autumnalis, hardjo or canicola serovars; these findings are judged to be insignificant in the author's practice geography. Titers above 1:400 to *L. interrogans* serovar *Pomona* or *L. interrogans*, serovar *Grippotyphosa* are judged to be significant in horses with ERU and are a likely indicator of

leptospiral associated etiology. Seroreactivity to *L. interrogans* serovar *Icterohemmorhagica* is often paired with reactivity to *L. interrogans* serovar *Pomona,* The titer levels to the Icterohemmorhagica serovar are consistently much lower than those reported for serovar *Pomona.*

Research has shown that horses with uveitis can be seronegative for antibodies to leptospira and still have leptospiral DNA or live organisms that can be cultured from the eye. A negative leptospira titer thus does not fully rule out leptospirosis as an etiologic factor. However a positive titer to either serovar *L. Pomona or L*. *Grippotyphosa* is a strong cause for concern. The "gold standard" for diagnosing LAU is a positive "C value", that is, an aqueous to serum leptospiral MAT ratio that is greater than 3 or 4. Determining a C value requires an anterior chamber tap to sample aqueous humor. This is an invasive procedure not often performed in the field. However the author has performed C value testing on several eyes from enucleated or deceased horses with ERU where previous serologic testing has suggested LAU. In every case to date, the testing has confirmed LAU (C value higher than 4).

Breed and Uveitis: Recent work has also shown that certain breeds are at risk for uveitis, most notably Appaloosas, European warmbloods and draft horses. A survey done by the author found the Appaloosa breed to be 8.3x more at risk than other breeds for uveitis. Appaloosas that have insidious disease often have overall roan or light coat colors rather than dark coats with a rump blanket. The skin around the lids of affected Appaloosas is often mottled or pink in pigmentation. Mane and tail hair may be sparse. Recent studies performed at the University of California Davis and at the University of Saskatchewan have found that affected individuals have a genetic proclivity to uveitis due to aberrations in the MHC (major histocompatibility complex, specifically in their ELA or equine lymphocyte antigen subtype. Recent research from Germany has supported this concept in German warmbloods susceptible to disease. Substantial research in this subject is ongoing in many universities, and genetic testing for mutations associated with uveitis may be available in the future.

Unilateral vs Bilateral disease: Recurrent uveitis can be a unilateral or bilateral disease. In a study of 160 cases reviewed by the author:

- 50% of horses seropositive for a pathogenic strain of leptospira had unilateral disease and 50% had bilateral disease
- Over 80% of the Appaloosas had bilateral disease
- 62% of the non-Appaloosa horses that were seronegative for pathogenic strains of leptospira had unilateral disease

Uveitis may begin in one eye and later occur in the fellow eye. However, if a case is unilateral and no attacks are seen in the other eye for two years after the initial attack, it is uncommon for uveitis to occur in the contralateral eye.

B. Therapy of uveitis

Mydriasis is essential therapy for all cases of acute uveitis. Initial application of atropine should be BID until pupil is fully dilated, then reduced to SID with frequent monitoring to assure that the pupil stays dilated. Severe cases may show poor response to the action of mydriatics.

Topical corticosteroids and systemic NSAIDS are the core elements of anti-inflammatory field therapy for acute attacks. Therapy should be intense for about two weeks and may be tapered over another two to four weeks depending on response. Subconjunctival and/or systemic corticosteroids are indicated in severe cases.

Intravitreal injection of gentamycin: Recently many horses with ERU have shown fewer flares and a reduction in intraocular inflammation after intravitreal injection of 4 mg of preservative free gentamycin sulfate. This is a delicate procedure usually administered by specialists as it carries some risks.

Surgical options: Suprachoroidal cyclosporine implant surgery may reduce the frequency and/or severity of ERU and persistent insidious uveitis. The best candidates for this referral procedure are early ERU cases that have only experienced a few "attacks" who show little or no permanent ocular scarring. Pars plana vitrectomy is frequently performed on ERU horses in central Europe with reported good results but is frequently complicated by the development of post surgical cataracts. The procedure is not often performed in the United States.

C. Common challenges

Insidious, persistent uveitis is a challenging condition that is common in Appaloosas, some draft horses and many Warmbloods. Therapy does little to alter the progression of disease in affected horses, and many cases progress to blindness.

Secondary glaucoma is a complication seen in many of horses who suffer from uveitis, particularly Appaloosas. Glaucoma therapy is often unrewarding in the long term, but topical timolol maleate, dorzolamide or a combination of these two drugs may be tried. Judicious topical steroids and/or mydriatic therapy may help as well.

Calcific band keratopathy may be a complication of topical corticosteroid therapy especially in horses with leptospiral associated uveitis. The troublesome calcium deposits should be treated with diamond burr debridement followed by EDTA chelation.

Secondary corneal ulcers are diagnosed in 25% of horses with ERU or persistent uveitis at some point in their disease course (statistics compiled by author). This fact is not surprising given the pain associated with uveitis and the propensity of horses to suffer self-trauma. Corticosteroids are contraindicated in these cases. Practitioners must warn owners that they should refrain from applying topical steroids to an inflamed painful eye without a full veterinary exam, as signs thought to be a "flare" of ERU may instead be secondary to a corneal ulcer.

D. Prognosis of uveitis

Visual prognosis for horses suffering from multiple acute attacks of uveitis or insidious chronic disease is always guarded. Data on the statistical incidence of blindness in uveitic horses is lacking, but it is clear that uveitis is the leading cause of blindness in horses worldwide.

The author has observed ocular inflammation serious enough to threaten vision in at least 1-2% of her practice population. Analysis of the visual outcome of 160 cases followed over 11 years revealed the following trends:

- 56% of the case series ((89/160) lost vision in one or both eyes.
- 20% of the cases (32/160) became completely blind
- 36% (57/160) lost vision in one eye

Breaking the cases down further into those that were seropositive or seronegative to *L. interrogans* serovar *Pomona,* and those that were Appaloosas or "non-Appaloosas", the following trends were seen:

- Appaloosa horses seropositive to *L. pomona* had a very poor visual prognosis: 100% lost vision in at least one eye and 50% went completely blind (n=14).

- Appaloosa horses that were seronegative had substantial occurrence of blindness: 72% lost vision in at least one eye and 29% went completely blind. (n=28)
- Other breeds of horses that were seropositive to *L. pomona* had a slightly lower rate of blindness, but 50% still lost vision in at least one eye and 17% went completely blind (n=86)
- Seronegative non-Appaloosa horses had the best visual prognosis: 34% lost vision in at least one eye, and just 6% went completely blind. (n=32)

Secondary complications and degeneration of ocular tissues are common sequellae; the following findings are frequently seen in insidious cases that are longstanding or in cases where several flares have occurred:

- **Cornea**: Focal scars, folds, calcium deposits and other corneal opacities are common. LAU cases are noted to experience a high rate of calcific band keratopathy. Striae and dense corneal folds are common in Appaloosas and highly correlated with blindness.
- **Iris:** Iris atrophy and color change are common, especially in Appaloosas and LAU horses. Anterior synechiae are rare unless phthisis bulbi is present, but posterior synechia occur in a large % of affected horses.
- **Lens**: Diffuse cataract(s) develop in a high % of all cases, and affect nearly 75% of the Appaloosas. These cataracts are a common cause of blindness. Lens luxation is common in Appaloosas.
- **Posterior segment**: Severe vitritis is often observed. Peripapillary scarring (focal or alar) occurs in some horses. Cataracts and synechiae often obstruct posterior segment evaluation, so inflammatory changes in such changes may not be detected.
- **Glaucoma and phthisis bulbi:** Appaloosas have a high rate of glaucoma. Phthisis bulbi is a frequent end stage finding in uveitic horses that become blind.

Many horses with ERU, particularly those with glaucoma or calcific keratopathy, experience chronic pain even after vision is lost. These patients benefit from enucleation and may show a dramatic positive change in temperament after the offending globe is removed.

E. Blindness

Recurrent or insidious uveitis is the leading cause of blindness in horses. It is a challenging disease to treat and manage, and it affects large portions of the horse industry worldwide. Every year many thousand horses suffer vision loss as a consequence of intraocular inflammation. In some cases, horses with vision loss are euthanized. However many owners are motivated to manage blind horses in their home situations. Successful management of a blind horse is highly dependent on temperament and owner dedication. Owners can be referred to this website which links to reference #4** below: www.blindhorses.org

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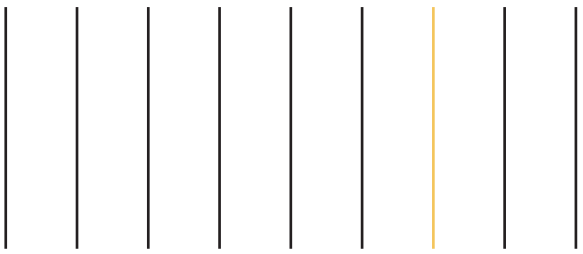
EQUINE INTRAVENOUS REGIONAL LIMB PERFUSION

JARROD TROY
DVM, DACVS-LS, CERP



EQUINE

Equine Regional Limb Perfusion

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1

Conflict of Interest Disclosure:

I have no financial interest, arrangement, or affiliation with any company or organization.

2

Objectives

- Discuss clinical use of intravenous regional limb perfusion (IVRLP) in horses
- Perform IVRLP in horses
- Discuss variations in IVRLP technique in horses

3

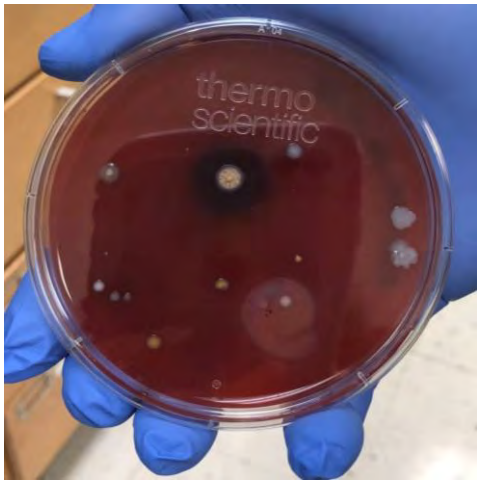
Outline

- IVRLP indications and clinical use
- Performing a traditional IVRLP
- IVRLP technique variations

4

IVRLP

- Generates locally high antimicrobial concentrations
- Concentrations to 91 times higher than bacterial MIC



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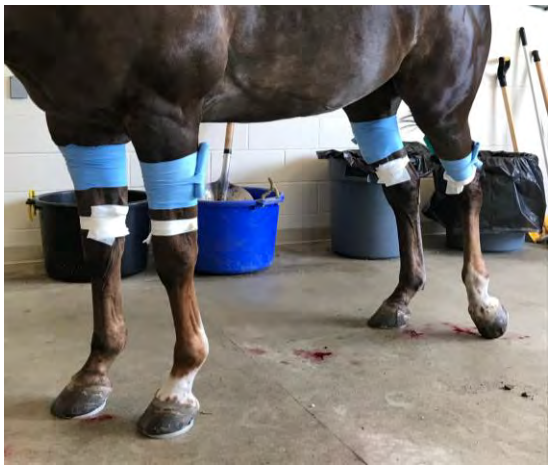
IVRLP

- Intravenous antimicrobial administration
- Administered in isolated vasculature
- Tourniquet placed proximal for isolated



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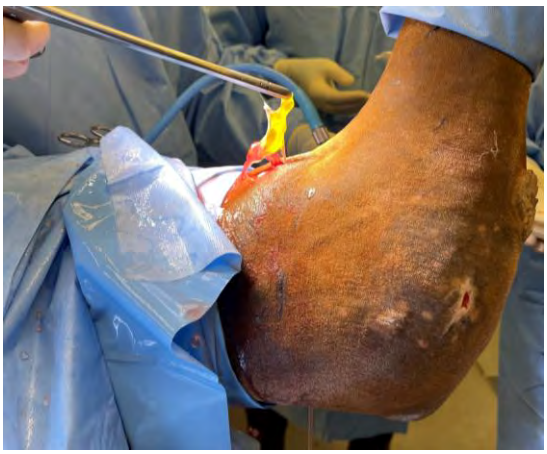
IVRLP Indications

- Orthopedic infections
- Synovial sepsis
- Cellulitis
- Penetrating wounds



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IVRLP Indications

- Three reports on clinical IVRLP

Indwelling Cephalic or Saphenous Vein Catheter Use for Regional Limb Perfusion in 44 Horses with Synovial Injury Involving the Distal Aspect of the Limb

Gal Kelmer[1], DVM, MS, Diplomate ACVS & ECVS, Amos Tatz[1], DVM, and Tali Bdolah-Abram[2], Msc

Meropenem Administered via Intravenous Regional Limb Perfusion for Orthopedic Sepsis in Horses: A Clinical Retrospective Study

Allison P. Mosichuk[1], Joseph S. Smith[2,3], Dane M. Tatarniuk[4], Jarrod R. Troy[4] and Amanda J. Kreuder[5]*

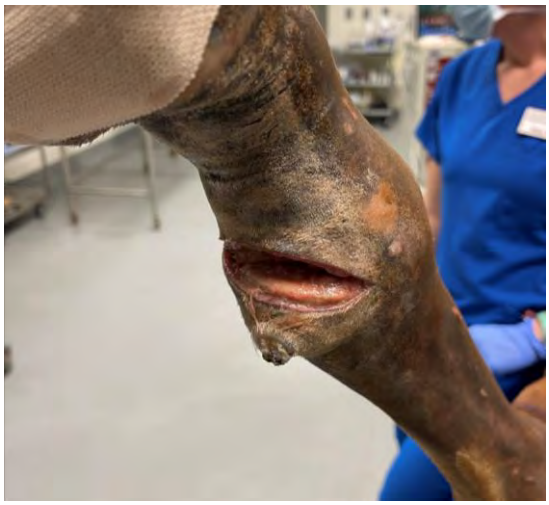
Clinical use of antimicrobial regional limb perfusion in horses: 174 cases (1999–2009)

Luis M. Rubio-Martínez, DVM, PhD, DACVS; Colette R. Elmas, DVM; Belinda Black, BVMS; Gabrielle Monteith, BS

8

IVRLP Indications

- Synovial sepsis – 71-87% survival
- Return to exercise – 61-80%
- Further clinical study needed



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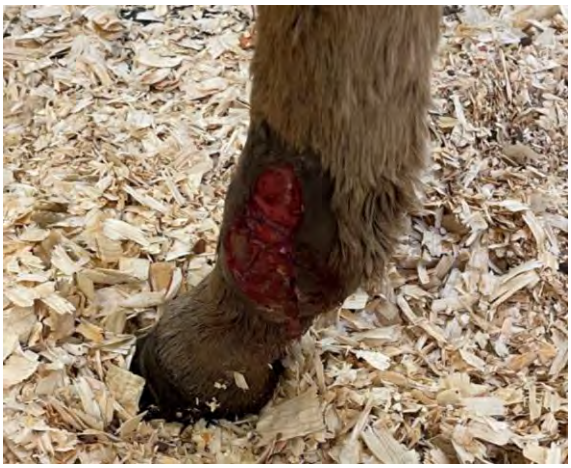
IVRLP Indications

- Retrospective study 2010-2020 from Iowa State (unpublished data)
- Evaluated IVRLP treatments
  - Septic synovitis
  - Penetrating synovial wounds

10

Septic Synovitis Qualifiers

- Positive bacterial culture
- Bacteria on cytology
- ≥3 of cytology criteria



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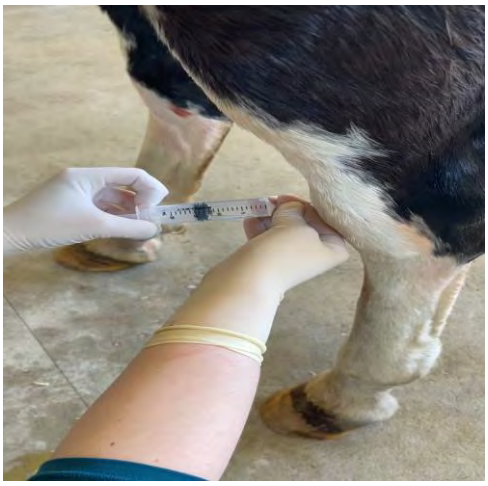
Septic Synovitis Qualifiers

- WBC > 30,000 cells/uL
- >90% PMN or degenerative PMN
- Total protein >4 g/dL
- Fibrin present in synovial space



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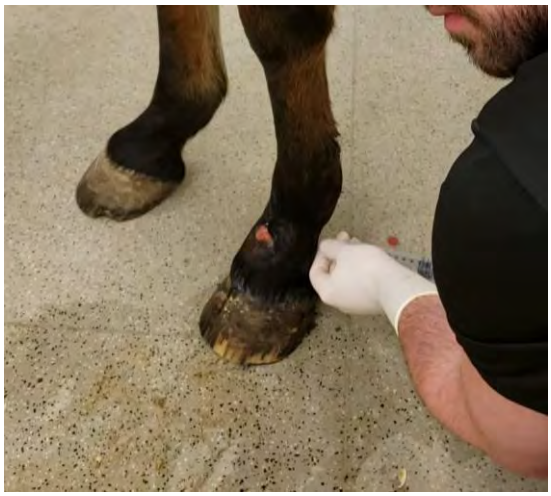
Penetrating Wound Qualifiers

- Wounds involving distal limb synovial structures
- Fluid observed exiting wound during distension
- 1-3 septic synovitis qualifiers



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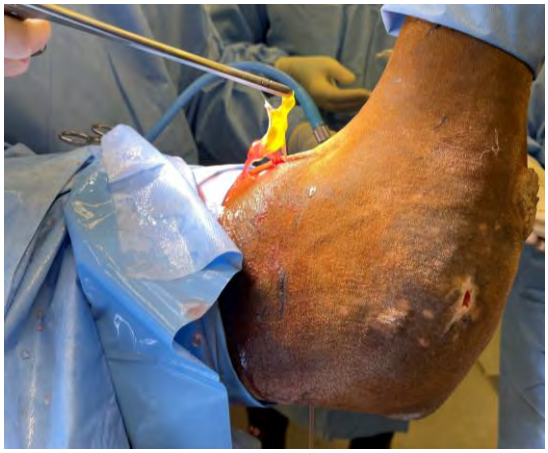
IVRLP Indications

- 163 cases
- All cases treated with IVRLP
- Gentamicin the most common antimicrobial used

14

Septic Synovitis

- 63 cases
- Septic synovitis survival to discharge – 88% (56/63)
- Survival >1 year – 61% (25/41)



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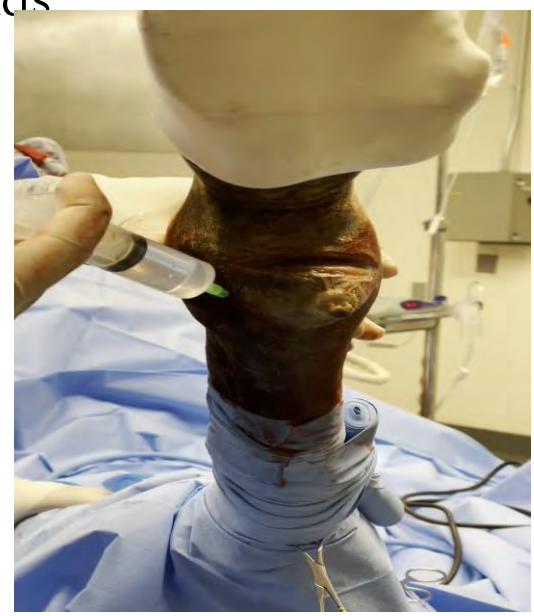
Penetrating Synovial Wounds

- 100 cases
- Penetrating wound survival to discharge – 99% (99/100)
- Survival >1 year – 84% (46/55)



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IVRLP Indications

- Clinical reports – IVRLP overall helpful
- Clinical reports – few

17

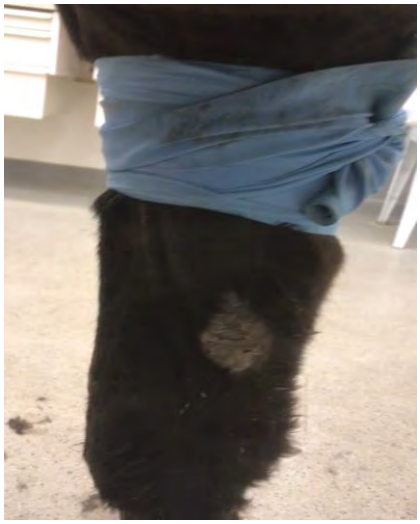
Outline

- IVRLP indications and clinical use
- Performing a traditional IVRLP
- IVRLP technique variations

18

Performing IVRLP

- Supplies
- Sedation
- Traditional technique



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IVRLP Supplies

- Antimicrobial (1/3 systemic dose)
- Wide rubber (Esmarch) tourniquet
- Butterfly (over the needle) catheter 19-25 g (21 g author)

20

IVRLP Supplies

- 5 cm (2”) gauze roll
- Local anesthetic (mepivacaine 2%)
- Isotonic IV fluid solution
- Syringes large enough to hold entire perfusate volume

21

IVRLP Supplies

- Sedation
- Adhesive tape with 1-2 gauze 4x4 sponges
- Chlorhexidine scrub & 70% isopropyl alcohol

22

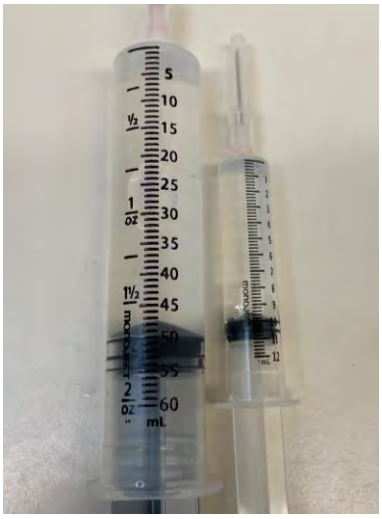
IVRLP Perfusate

- Create before sedation when possible
- Total perfusate volume – 60 mL
- Antimicrobial 1/3 systemic dose volume
- Remaining volume with isotonic fluid

23

IVRLP Perfusate

- 1 or 2 syringes
- 2 syringes – antibiotic & isotonic solution
- Antibiotic first in case vein develops hematoma/inflammation



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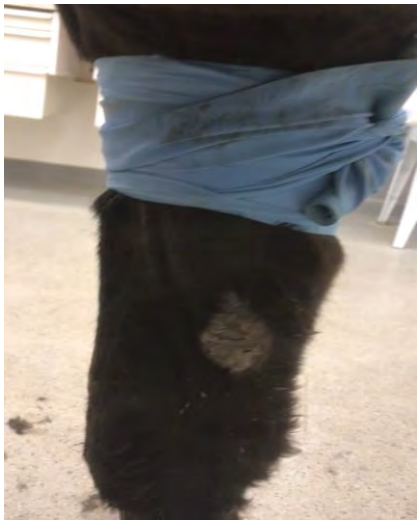
Performing IVRLP

- Supplies
- Sedation
- Traditional technique



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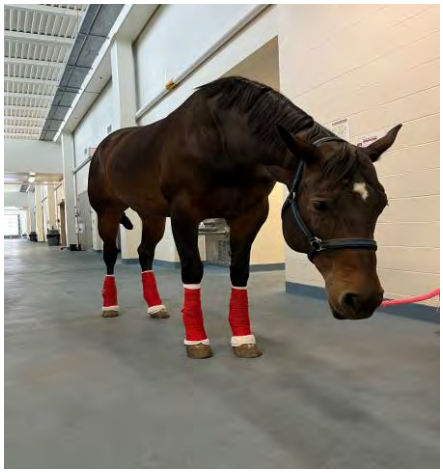
IVRLP Sedation

- Very important to minimize patient movement
- Limb movement increases release into systemic circulation
- Over sedation causes stumbling & limb movement

26

IVRLP Sedation

- Detomidine (0.01 mg/kg) IV
- Butorphanol (0.01 mg/kg) IV
- Xylazine (0.02 mg/kg) IV – often used as re-dose to limit movement



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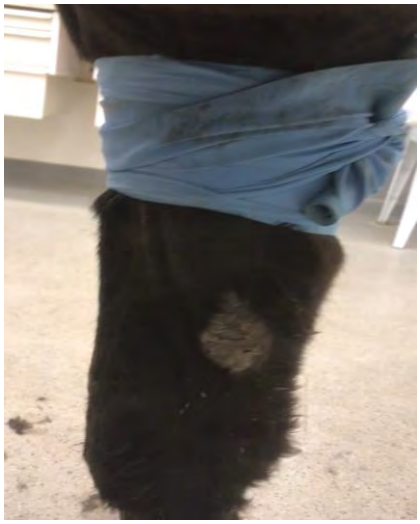
IVRLP Sedation

- Horse should remain standing & still for 30 minutes after IVRLP
- Re-dosing of sedation during IVRLP is common
- Perineural anesthesia can aid in movement reduction

28

Performing IVRLP

- Supplies
- Sedation
- Traditional technique



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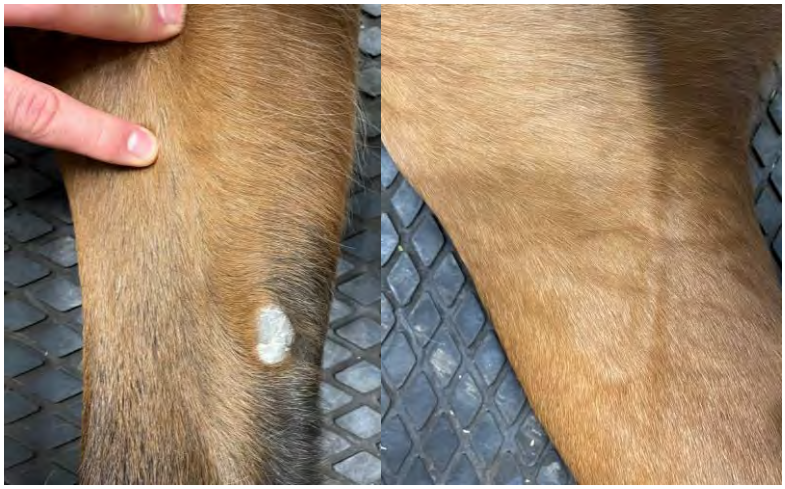
Traditional IVRLP

- Preparation
- Administration
- Post-administration

30

IVRLP Preparation

- Identify target vein
- Cephalic
- Saphenous
- Digital veins



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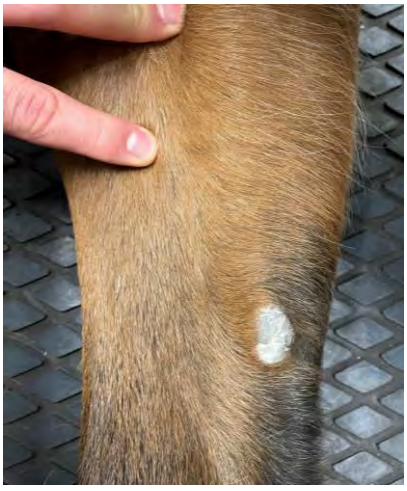
IVRLP Preparation

- Aseptically prepare target vein
- Peripheral nerve blocks
- Ensure can visualize or palpate target vein
- ± Perform before sedation



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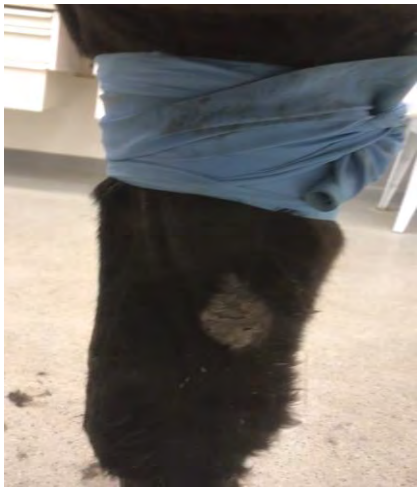
Traditional IVRLP

- Preparation
- Administration
- Post-administration

33

IVRLP Administration

- Tourniquet placed at least 10cm proximal to target site when possible
- 5cm (2”) gauze roll placed over target vein with tourniquet wrapped over top



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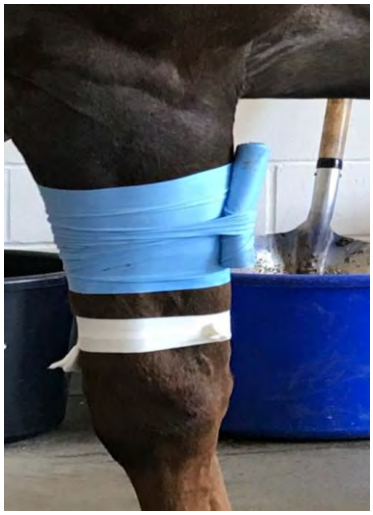
IVRLP Administration

- Tourniquet should be wrapped as tightly as possible without breaking
- Secure tourniquet so does not unravel before 30 minutes



35

IVRLP Administration

- Butterfly catheter can be placed in target vein as proximal as possible
- Distal vein can be used in case of phlebitis
- Allow blood to prime the line

36

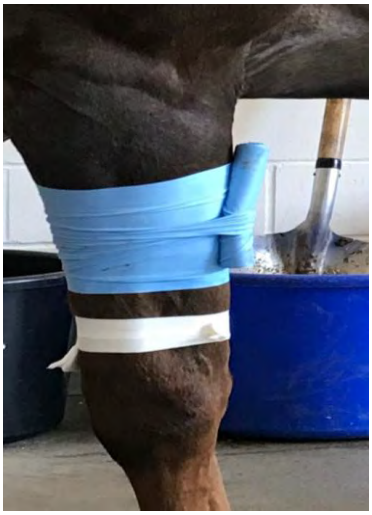
IVRLP Administration

- Whenever possible aim for single venipuncture to reduce leakage
- Do not pullout previous catheters if hit vein but not working – reduce leakage
- Pull later and wrap with bandage

37

IVRLP Administration

- Whenever possible aim for single venipuncture to reduce leakage
- Do not pullout previous catheters if hit vein but not working – reduce leakage
- Pull later and wrap with bandage



38

IVRLP Administration

- Administer perfusate slowly over 1-3 minutes
- Check to ensure blood returning into catheter line
- Once completed remove catheter and place bandage

39

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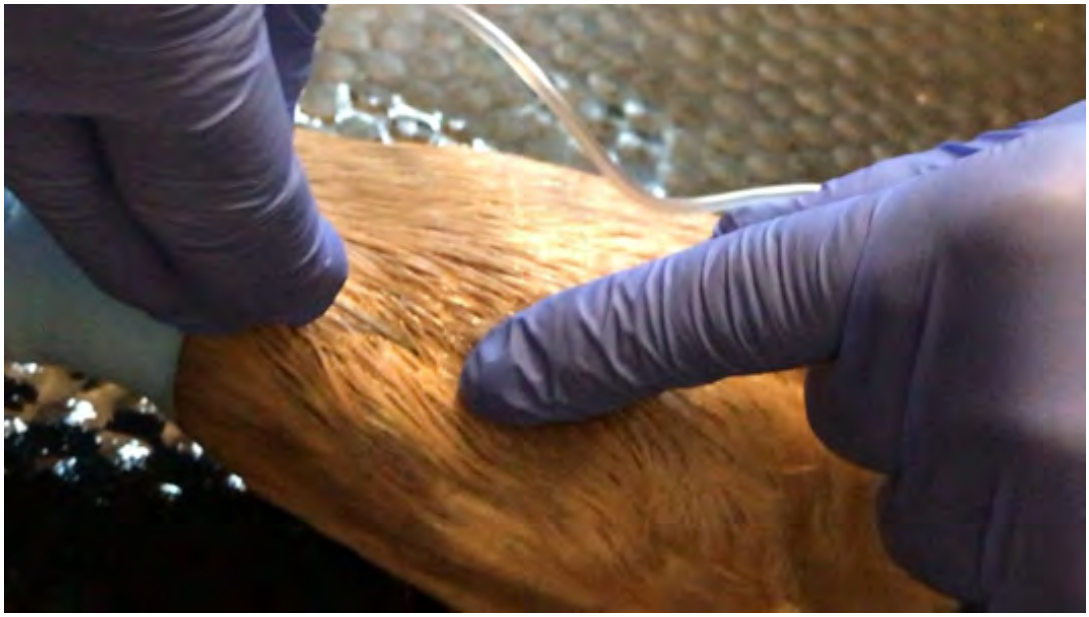


41

IVRLP Administration

- If swelling (phlebitis) occurs…
- Continue if blood returning to catheter and swelling not large
- Try more distal with a second line
- Place compression bandage over site

42

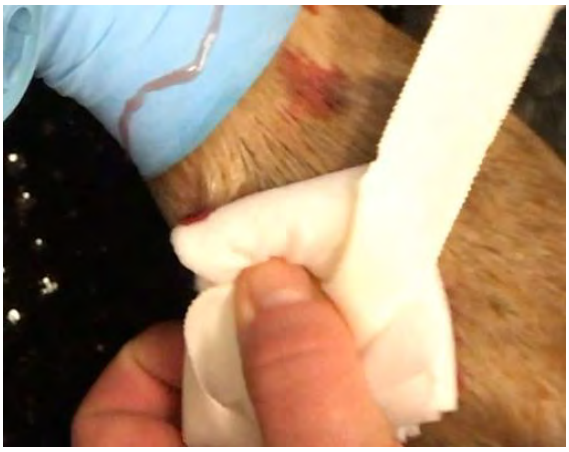
Traditional IVRLP

- Preparation
- Administration
- Post-administration

43

IVRLP Post-administration

- Tourniquet remains in place for 30 minutes with no limb movement
- **Ensure** tourniquet removal after 30 minutes



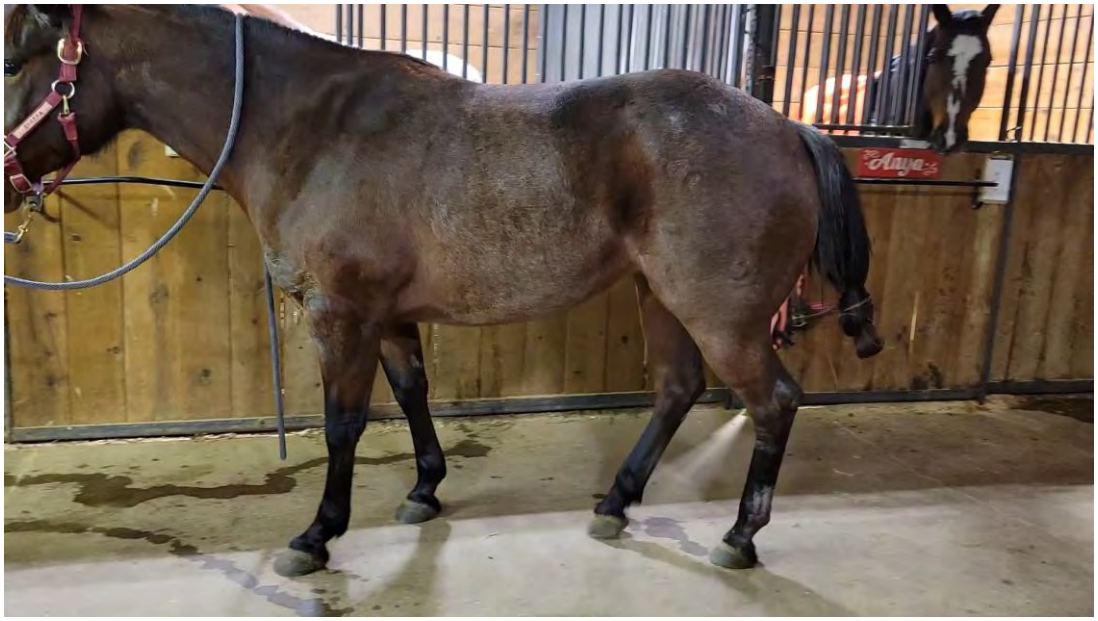
44

IVRLP Post-administration

- Re-dose every 24 hours for 3 days when using aminoglycoside antibiotics
- Break after 3 days to reduce chance of phlebitis & re-assess
- Can continue for another 3 days

45

46



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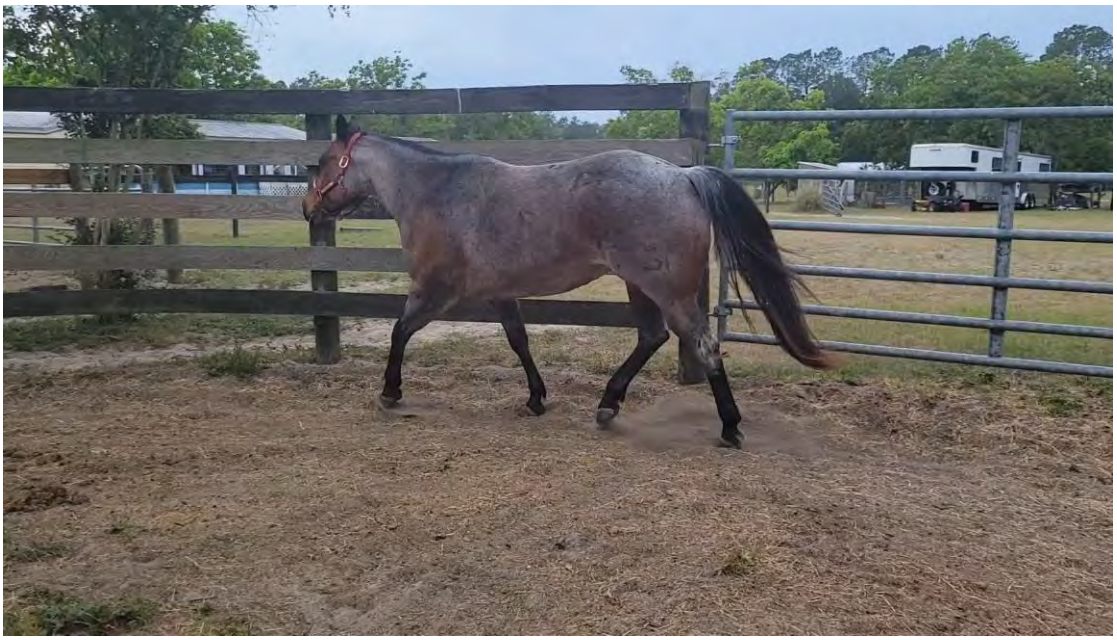

48

Outline

- IVRLP indications and clinical use
- Performing a traditional IVRLP
- IVRLP technique variations

49

IVRLP Modifications

- IVRLP performed often in equine veterinary medicine
- Few clinical reports assessing IVRLP treatment
- Numerous scientific IVRLP concentration & technique studies

50

IVRLP Modification Studies

- Local anesthetic perfusate
- Antimicrobial choice
- Perfusate volume
- Tourniquet duration

51

Local anesthetic perfusate

- Peripheral nerve blocks to reduce motion
- Mepivacaine 2% - 25 mL added to the perfusate reduced sensation

The Effects of Mepivacaine Hydrochloride on Antimicrobial Activity and Mechanical Nociceptive Threshold During Amikacin Sulfate Regional Limb Perfusion in the Horse

Aimée C. Colbath[1], Luke A. Wittenburg[2], Jenifer R. Gold[3], C. Wayne McIlwraith[1], and Valerie J. Moorman[1]

52

Local anesthetic perfusate

- Mepivacaine added to the perfusate reduces additional needles for blocks and wait time
- No change in amikacin synovial concentration

53

Local anesthetic perfusate

- Either option seems to be effective anecdotally
- No difference at ISU (unpublished data) in survival
- Maybe horse dependent

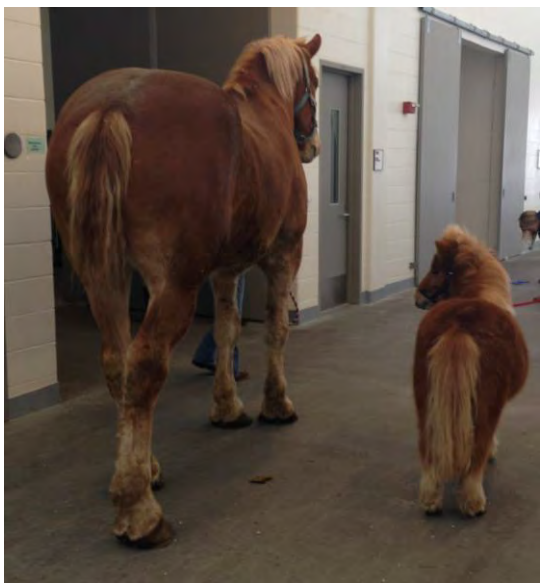

Photo courtesy of Dr. Stephanie Caston

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IVRLP Modification Studies

- Local anesthetic perfusate
- Antimicrobial choice
- Perfusate volume
- Tourniquet duration

55

Antimicrobial choice

- Aminoglycosides traditionally
- Dosing every 24 hours
- 1/3 systemic dose
- Full systemic dosing or 2/3s?

https://www.jefferspet.com/rx-amikacin-1gm-4ml-injection-10-x-4ml-vials/p

https://pipevet.com/gentamicin-sulfate

56

Antimicrobial choice

- Beta-lactams
- Enrofloxacin
- Meropenem
- ±Dosing schedule changes

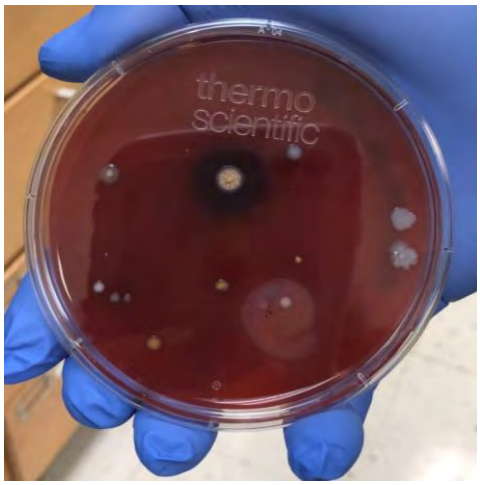
https://www.jefferspet.com/rx-amikacin-1gm-4ml-injection-10-x-4ml-vials/p

https://pipevet.com/gentamicin-sulfate

57

Antimicrobial choice

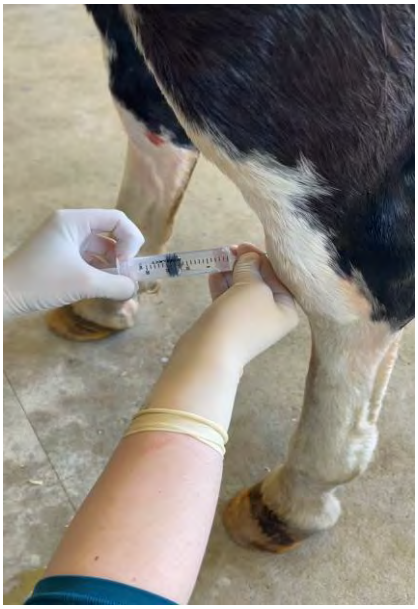
- Bacterial culture is important
- Treating empirically – reach out to local lab that does the cultures
- ISU gentamicin commonly effective



58

Antimicrobial choice

- Intrasynovial antimicrobial injection
- No data on concentrations reached when doing intrasynovial & IVRLP administration



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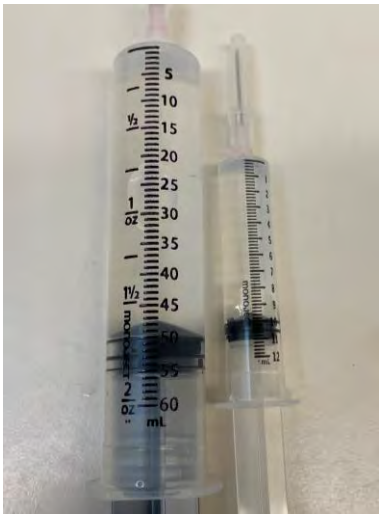
IVRLP Modification Studies

- Local anesthetic perfusate
- Antimicrobial choice
- Perfusate volume
- Tourniquet duration

60

Perfusate Volume

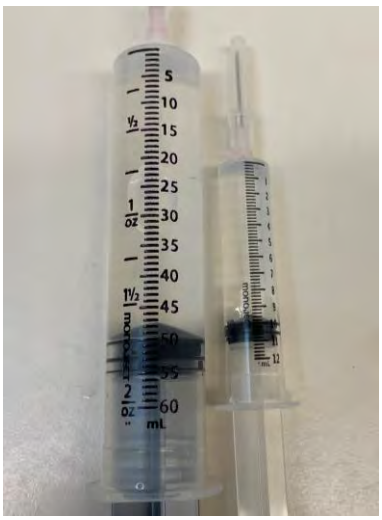
- IVRLP mechanism of action unclear
- Perfusate volumes ranging from 10 – 1000 mL
- Optimum volume is unknown



61

Perfusate Volume

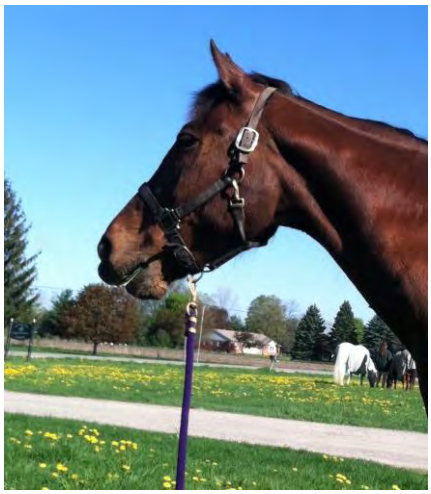
- Clinically 60 mL & 100 mL perfusate volumes have been reported
- Experimentally these different volume ranges can produce clinically high antimicrobial concentrations



62

Perfusate Volume

- Optimum perfusate volume is unknown
- Unpublished data no difference in survival to discharge from perfusate volume – most volumes were 20 or 60 mL



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IVRLP Modification Studies

- Local anesthetic perfusate
- Antimicrobial choice
- Perfusate volume
- Tourniquet duration

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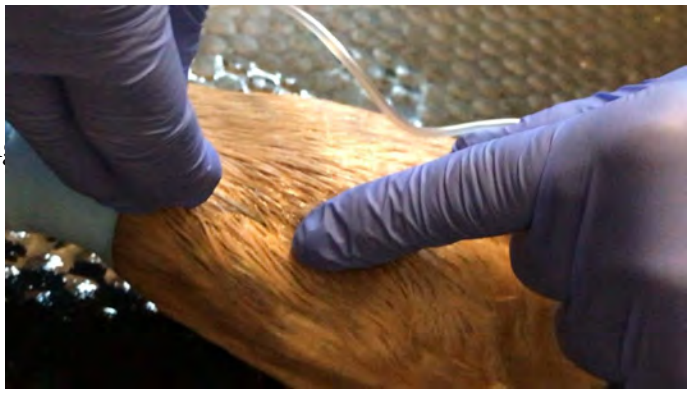
Tourniquet Duration

- 30 minutes can feel a lot longer
- 20 minutes has been evaluated showing no difference when using amikacin



65

Tourniquet Duration

- Further studies are needed to identify optimum tourniquet time
- Ensure tourniquet removal at end of procedure

66

Outline

- IVRLP indications and clinical use
- Performing a traditional IVRLP
- IVRLP technique variations

67

Summary

- IVRLP is a useful technique for distal limb orthopedic infections, cellulitis, or septic physitis in horses
- Appears to be clinically effective
- Still much more to learn regarding optimum IVRLP use in horses

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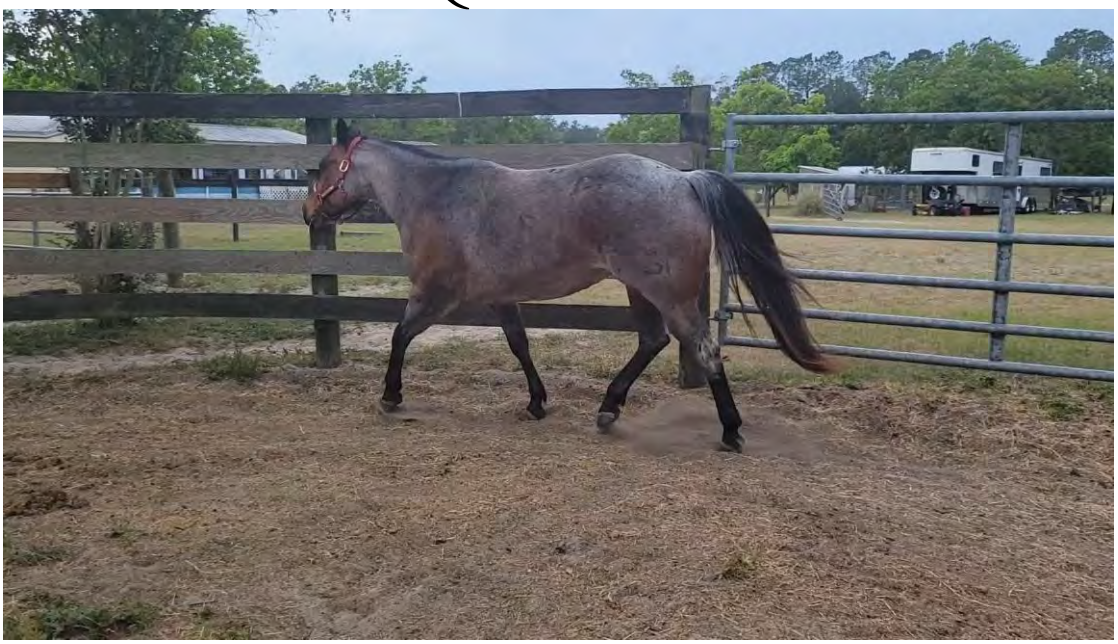
Questions?



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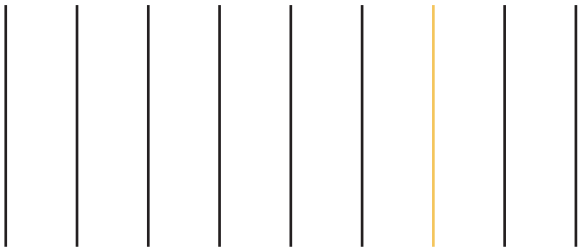
EQUINE EMERGENCY SURGERIES IN THE FIELD

JARROD TROY
DVM, DACVS-LS, CERP



EQUINE

Equine Emergency Surgeries in the Field

Jarrod Troy DVM; DACVS-LA; CERP
Assistant Professor
Iowa State University Veterinary Clinical Sciences

1

Conflict of Interest Disclosure:

I have no financial interest, arrangement, or affiliation with any company or organization.

2

Objectives

- Identify and manage penetrating wounds
- Utilize additional options or tips regarding wound repair
- Perform and utilize additional tips for tracheostomy
- Identify the need and perform a perineal urethrotomy (PU)

3

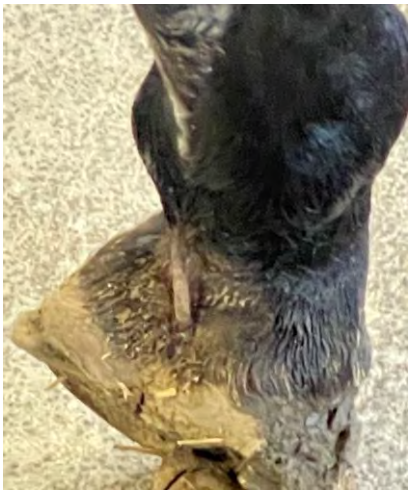
Outline

- Laceration/wound repair
- Tracheostomy
- Perineal urethrotomy (PU)

4

Wounds

- Penetrating
- Non-penetrating



5

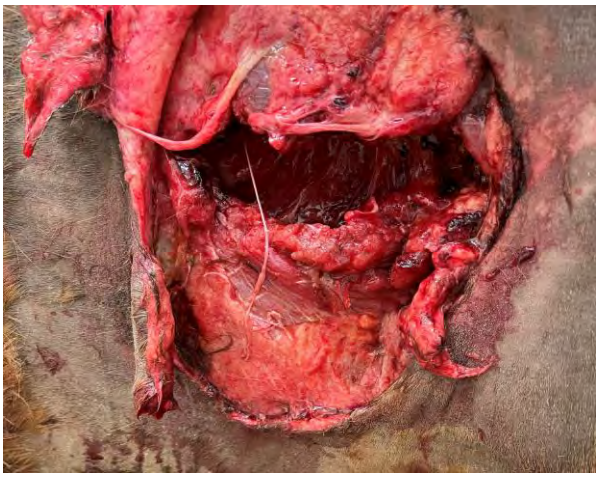
Penetrating Wounds

- Thoracic cavity
- Peritoneal cavity
- Synovial structures

6

Thoracic Penetrating Wounds

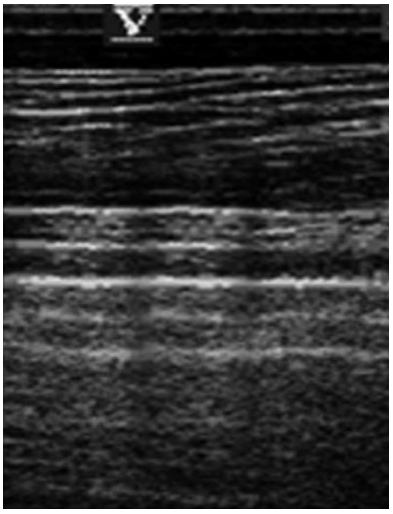
- Pneumothorax diagnosis
- Pneumothorax treatment



7

Pneumothorax diagnosis

- Tachypnea/dyspnea/cyanosis
- Reduced lung sounds dorsally
- Ultrasound – no glide sign
- ± Radiographs
- Decreased PaO_2



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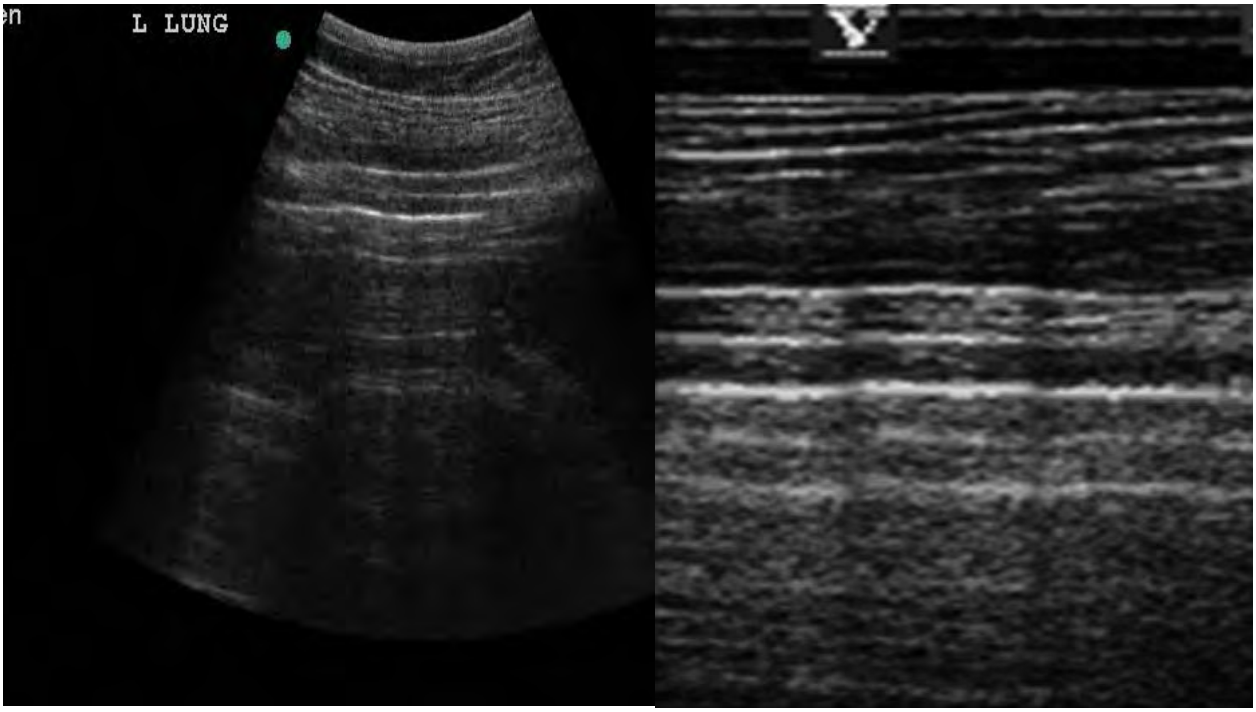
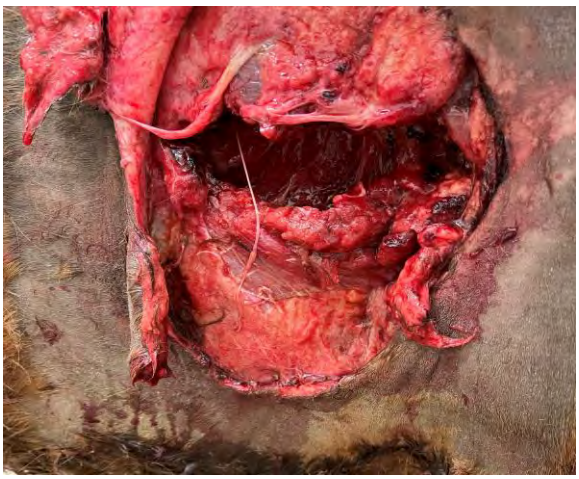


9

Thoracic Penetrating Wounds

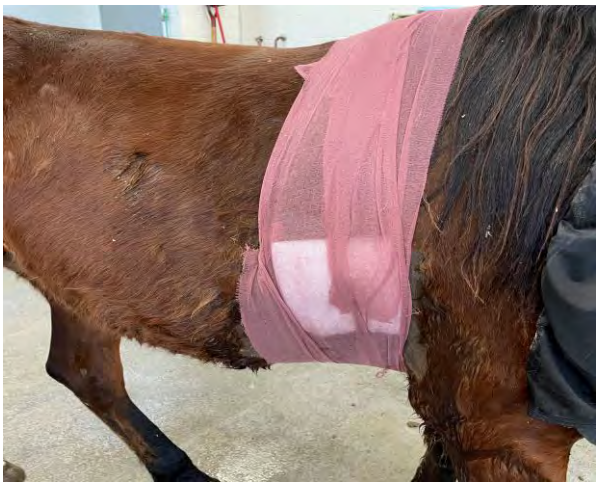
- Pneumothorax diagnosis
- Pneumothorax treatment



10

Pneumothorax treatment

- Seal with sterile bandage
- Plastic wrap/tie over bandage/bandage material
- Thoracocentesis
- Thoracostomy drain



11

Thoracocentesis

- Rib space 12-15 below epaxial muscles
- 14 g IV catheter/teat cannula/thoracostomy tube
- 60 mL syringe + 3-way stopcock remove air slowly
- >3-4 times in 24 hours – need thoracostomy tube

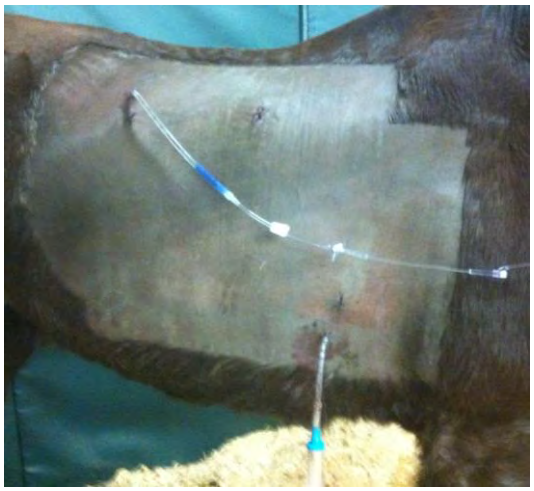
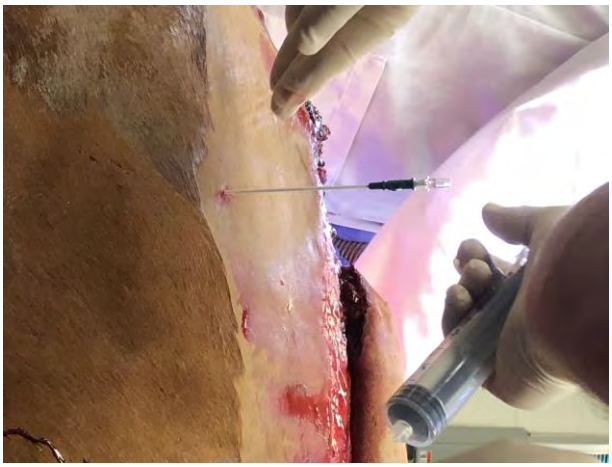


Photo courtesy of Dr. Jamie Kopper

12

Thoracic Penetrating Wounds

- Pneumothorax diagnosis
- Pneumothorax treatment
- After pneumothorax treated manage wound as non-penetrating wound



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Penetrating Wounds

- Thoracic cavity
- Peritoneal cavity

14

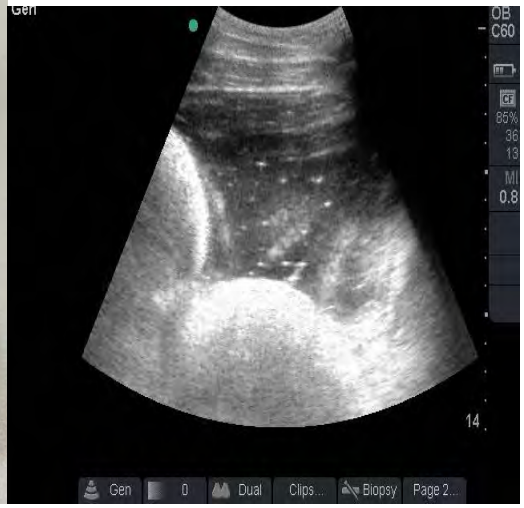
Peritoneal penetrating wound

- Diagnosis
- Treatment

15

Peritoneal penetrating diagnosis

- Abdominocentesis
- Ultrasonography
- Palpation



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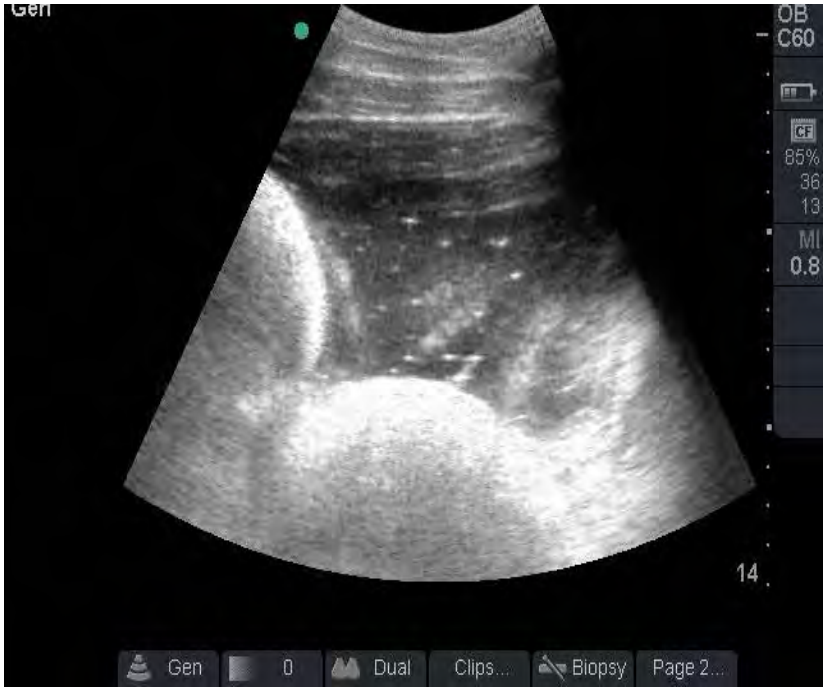


17

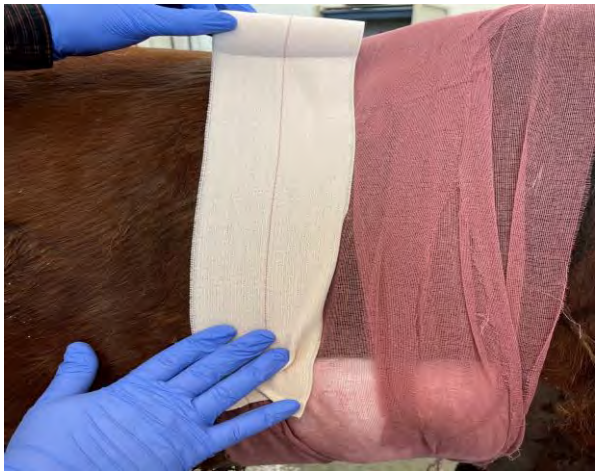
Peritoneal penetrating wound

- Diagnosis
- Treatment

18

Peritoneal penetrating wound Treatment

- Seal wound with plastic wrap or sterile bandage that will not fall into peritoneum
- Surgical repair
- Wound management



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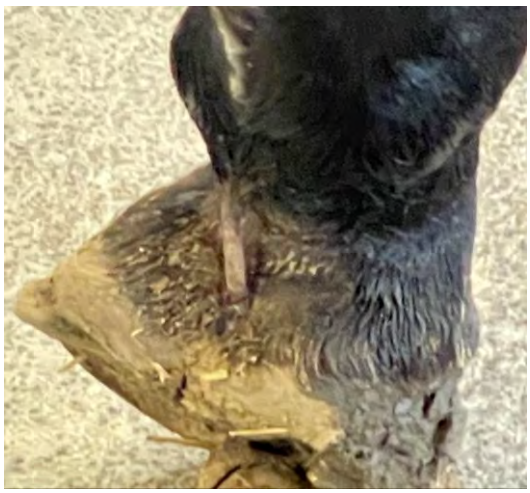
Penetrating Wounds

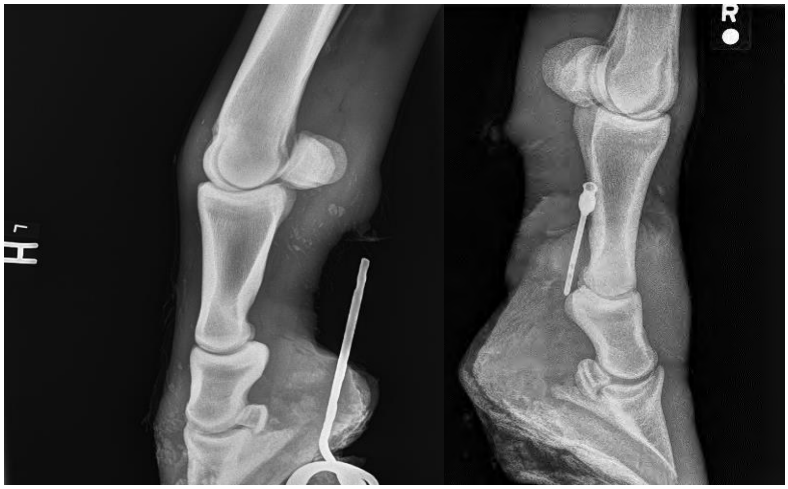
- Thoracic cavity
- Peritoneal cavity
- Synovial structures



20

Synovial structures

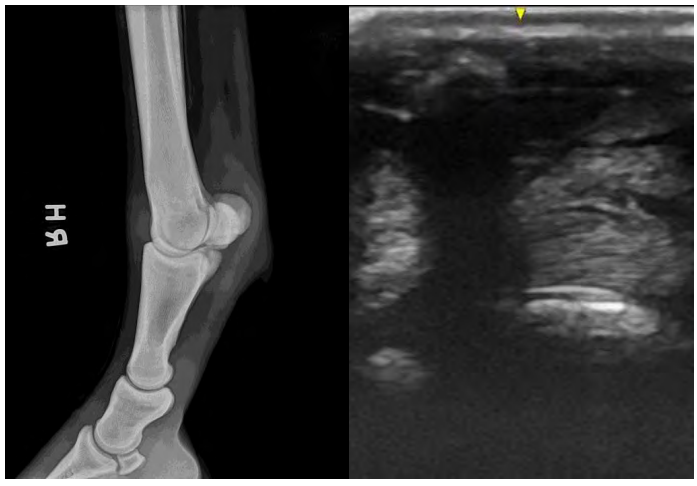
- Diagnosis
- Treatment



21

Synovial structures Diagnosis

- Radiographs – 2 or more orthogonal views ± contrast
- Ultrasonography – especially with wood foreign bodies
- Synoviocentesis & analysis



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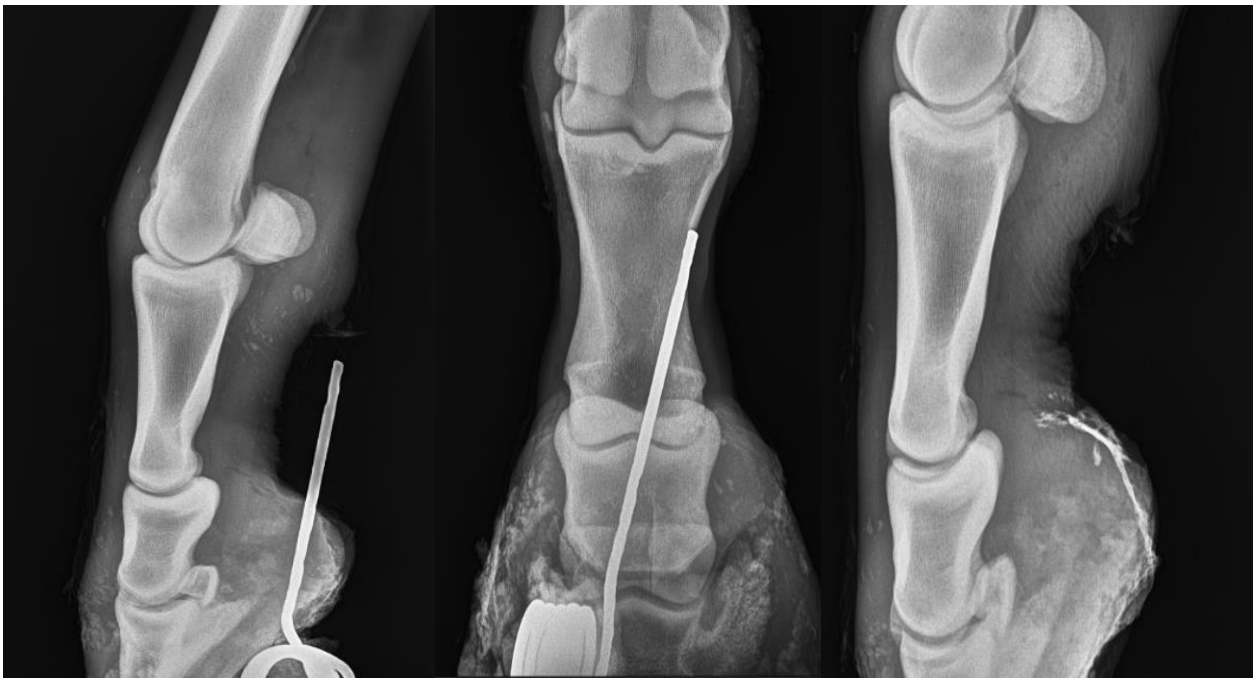

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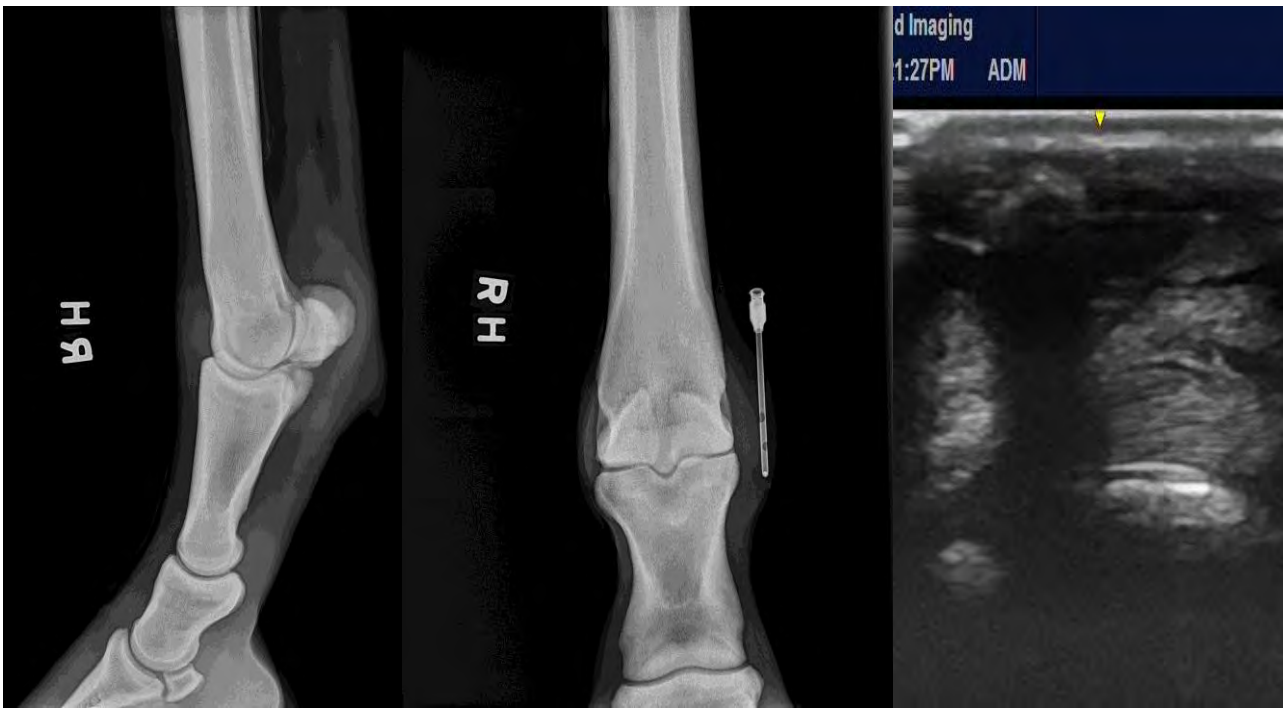

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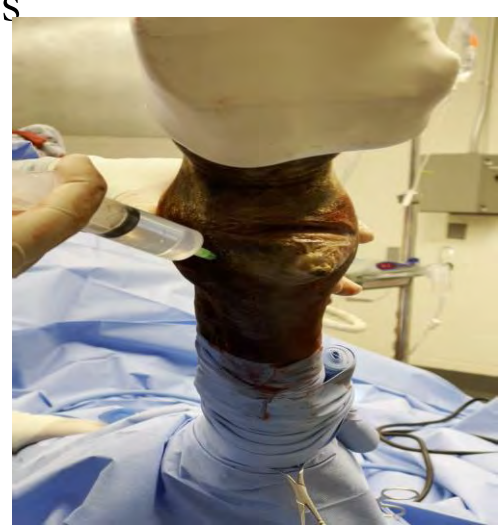
Synoviocentesis & Analysis

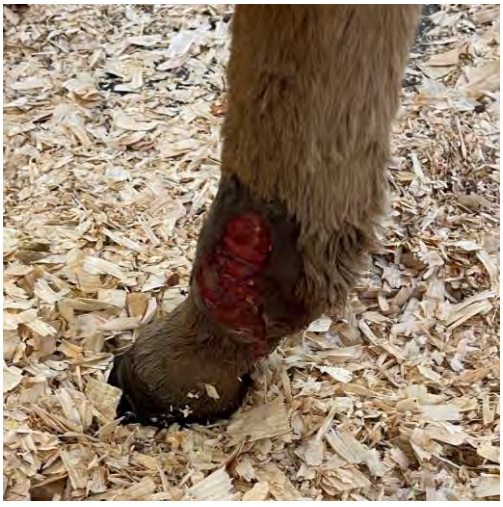
- Fluid analysis & culture
- Structure distension looking for communication
- PPG mixture for easier visualization



25

Analysis synovial sepsis

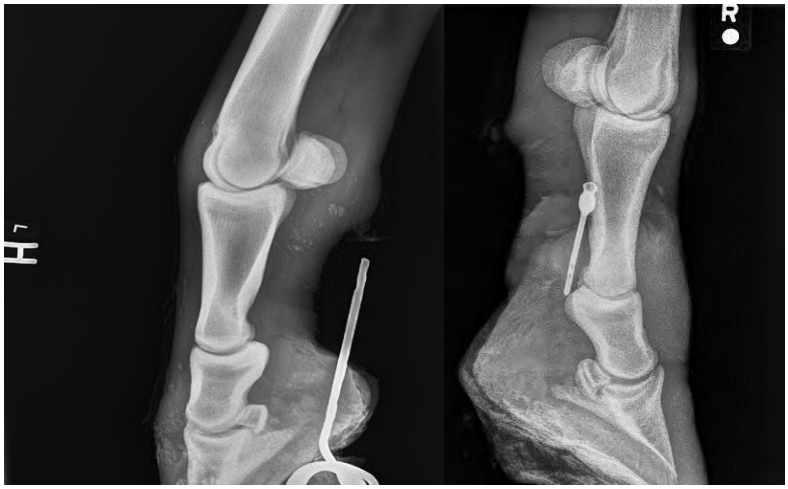
- WBC >20,000 /μL
- TS ≥ 3.5 g/dL
- Degenerate neutrophils >90%
- Bacteria seen or positive culture



26

Synovial structures

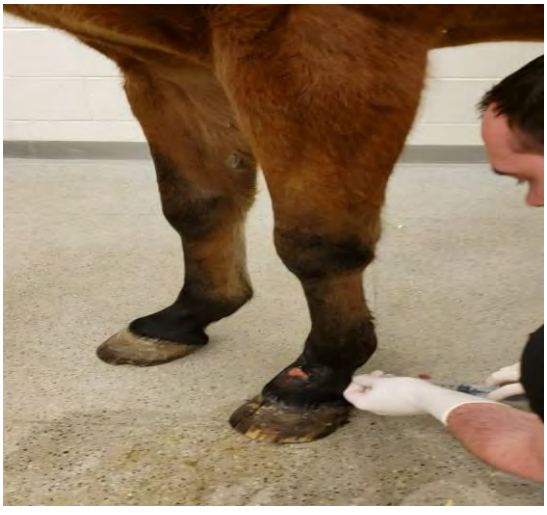
- Diagnosis
- Treatment



27

Synovial structures Treatment

- Needle through needle lavage or arthroscopy
- Intrasynovial antibiotics
- Intravenous regional limb perfusion



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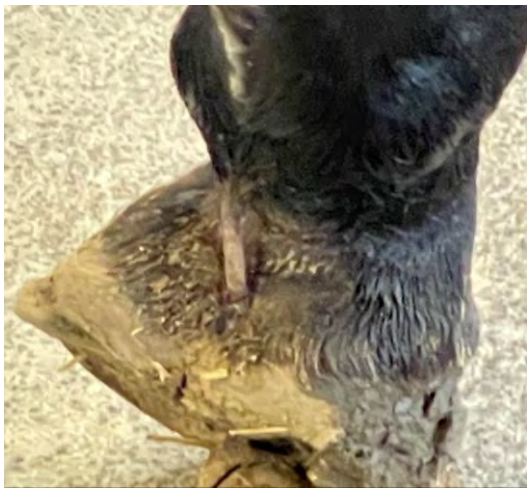
Penetrating Wounds

- Thoracic cavity
- Peritoneal cavity
- Synovial structures



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Wounds

- Penetrating
- Non-penetrating

30

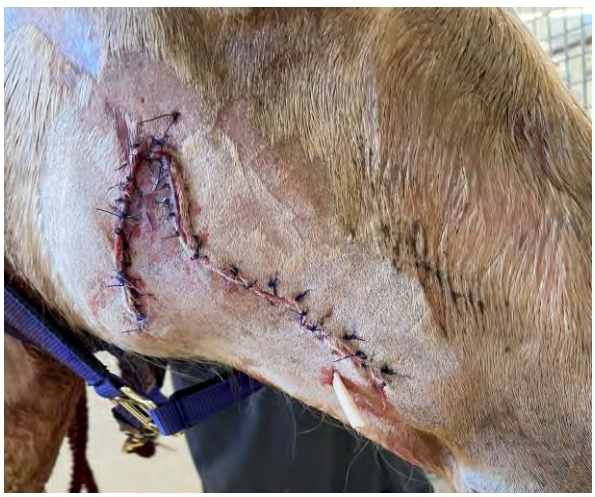
Non-penetrating Wounds

- Standing sedation – patient response
- Local anesthesia
- Wound debridement & repair
- Drains & bandaging

31

Wound debridement & repair

- Leave skin flaps if possible
- Sharp debridement & lavage
- Mattress sutures
- Near-far-far-Near sutures



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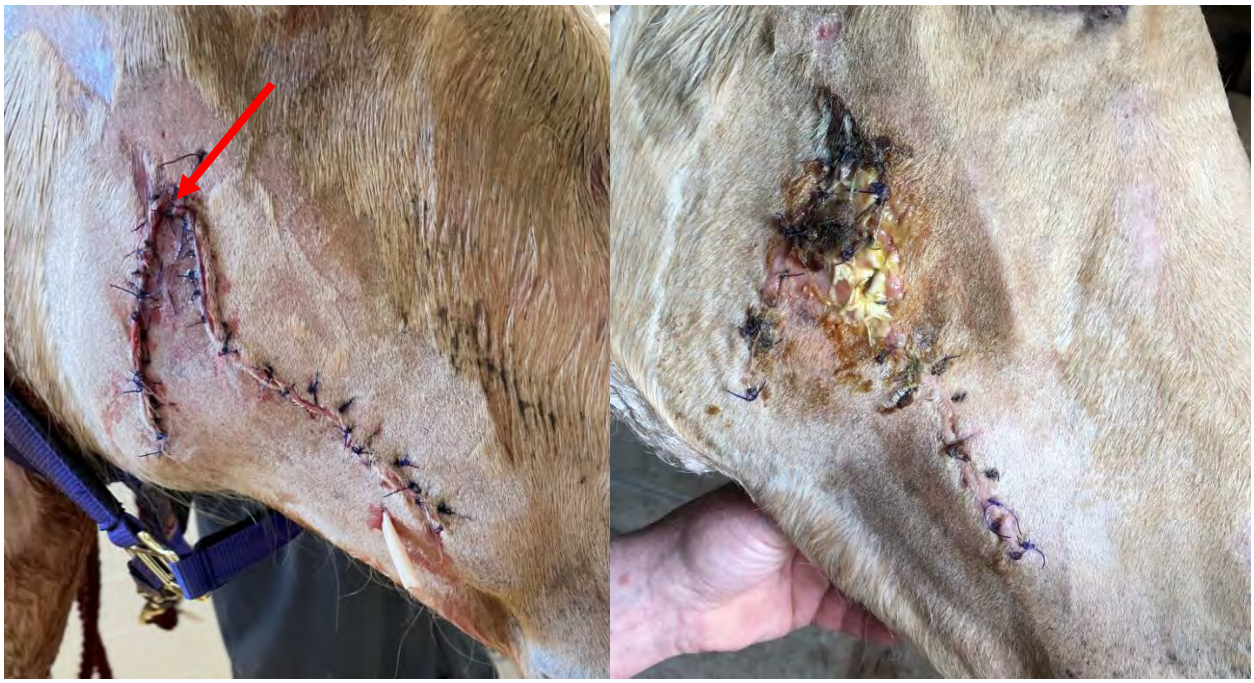

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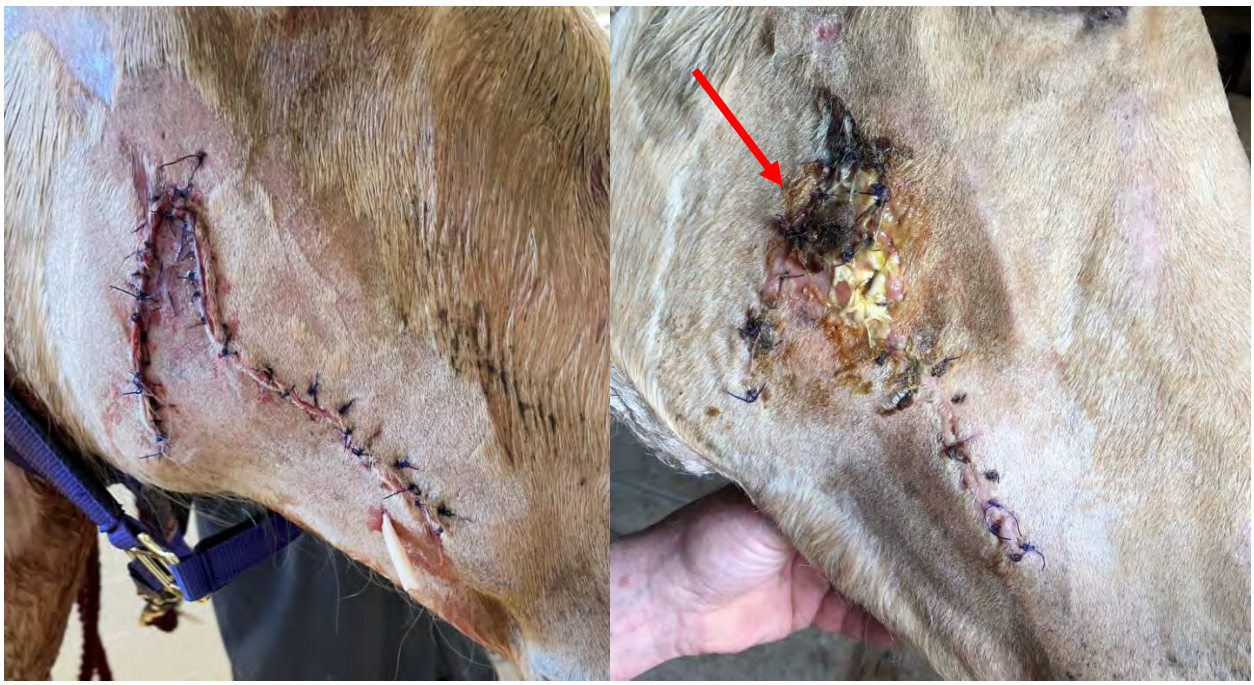

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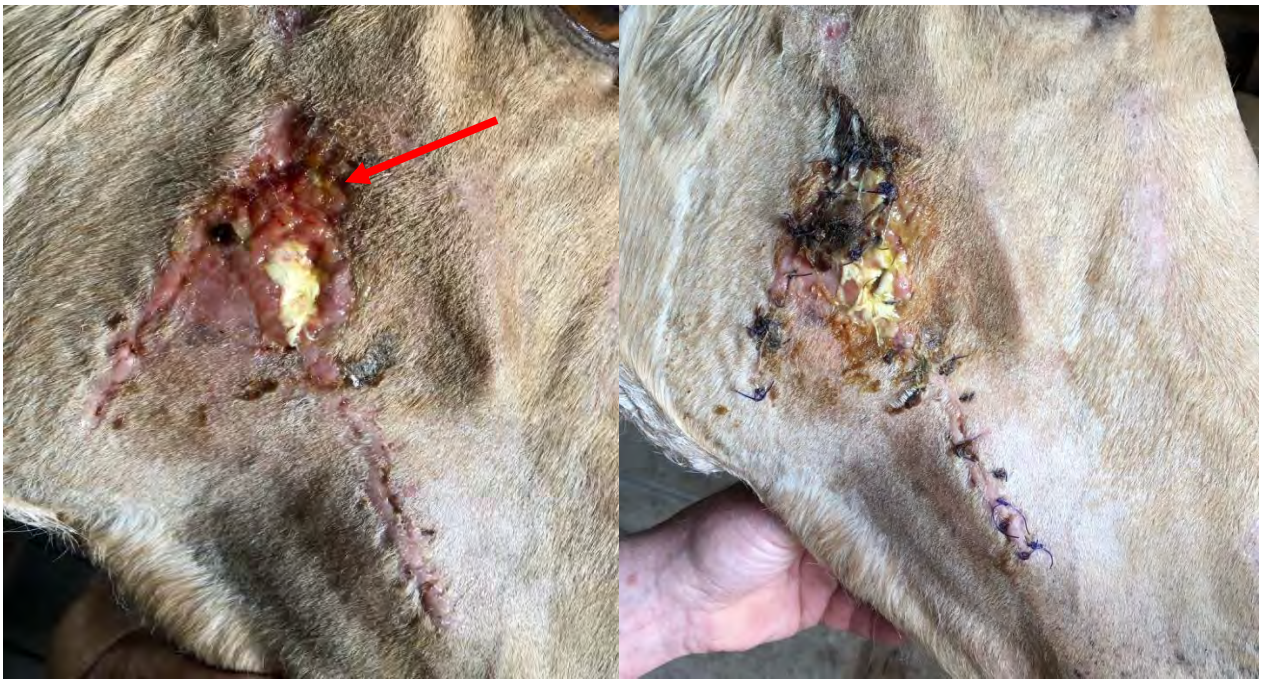

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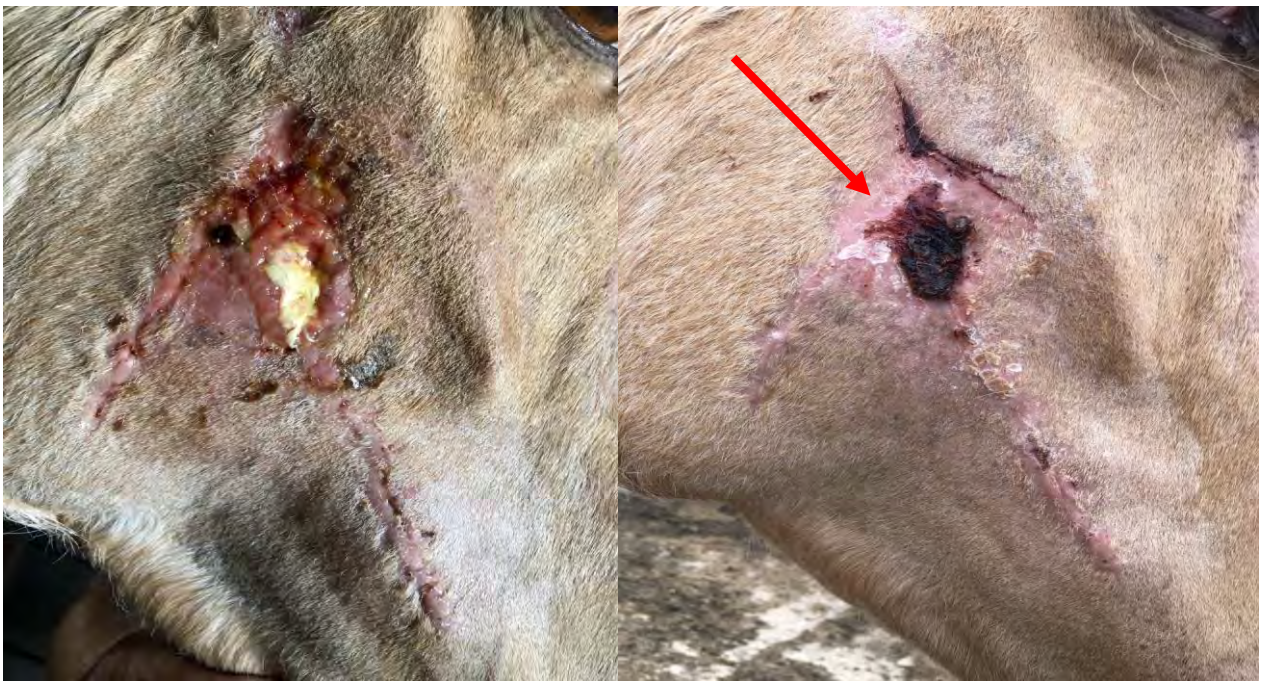
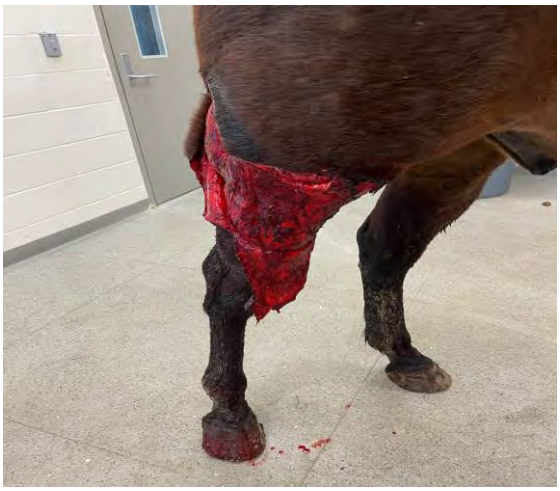


36

Drains & bandaging

- Large or deep defects
- Penrose drains
- Tie over bandages
- Petroleum jelly & cayenne pepper



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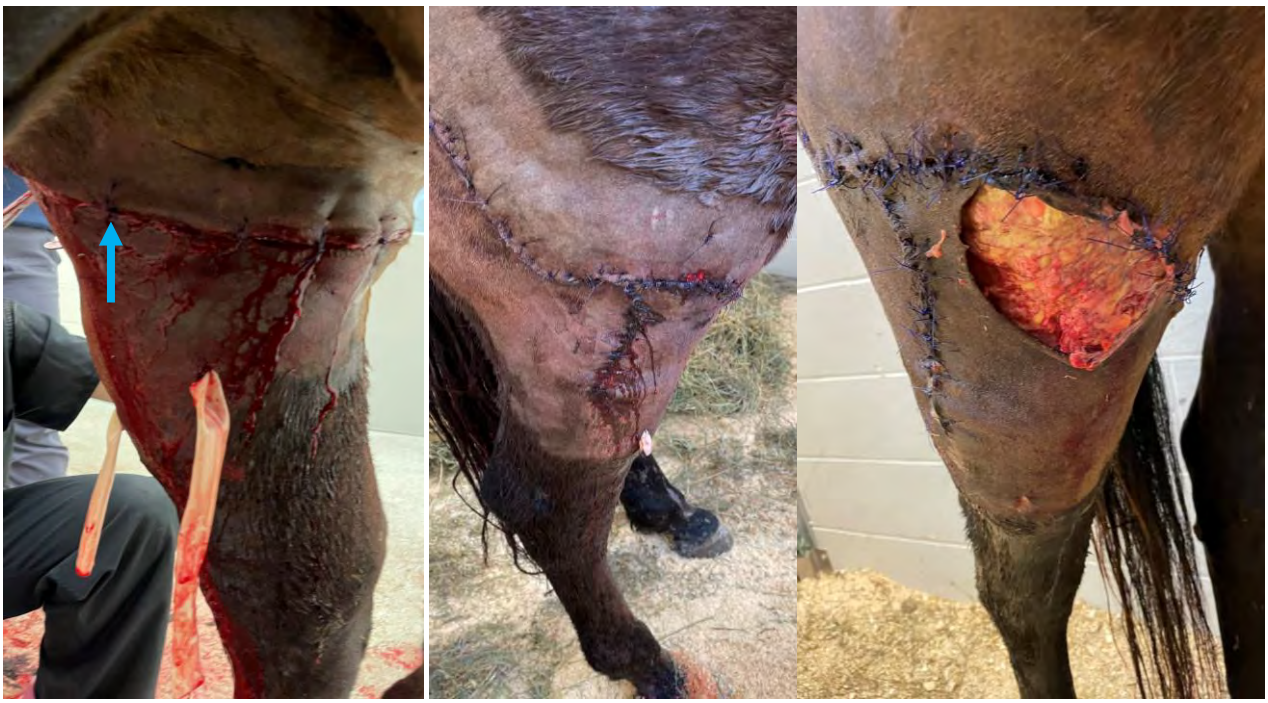

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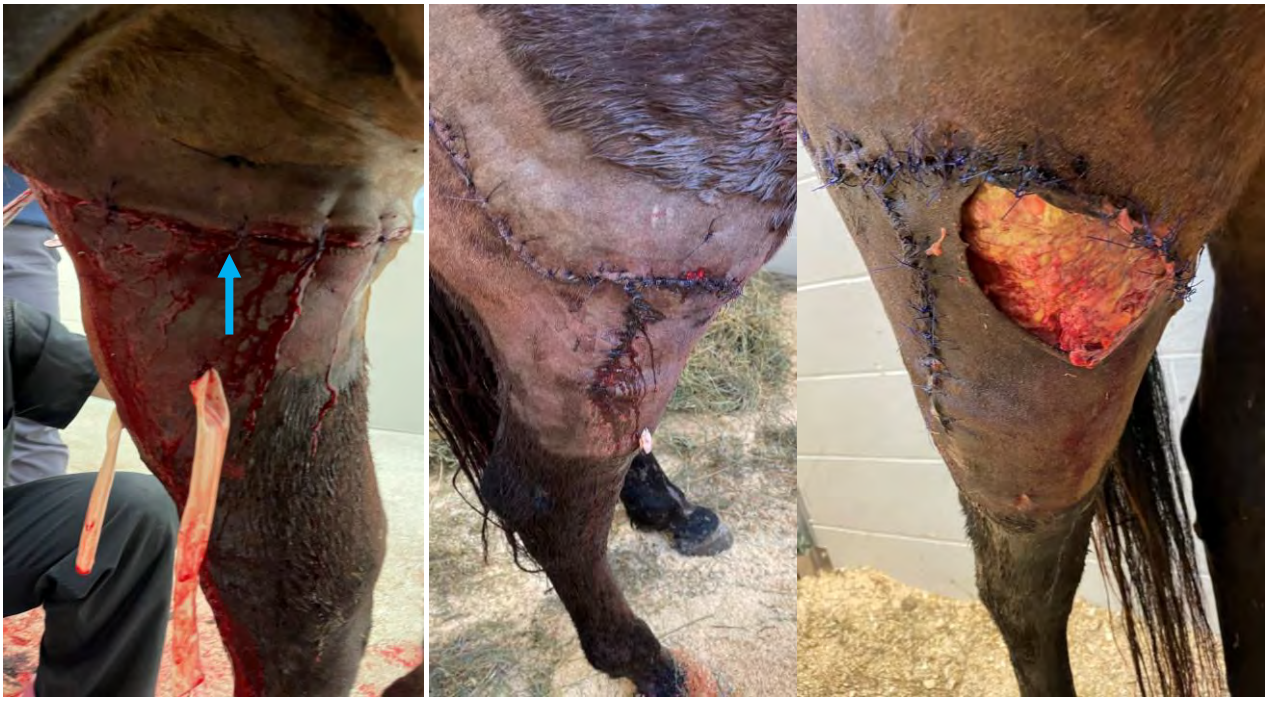

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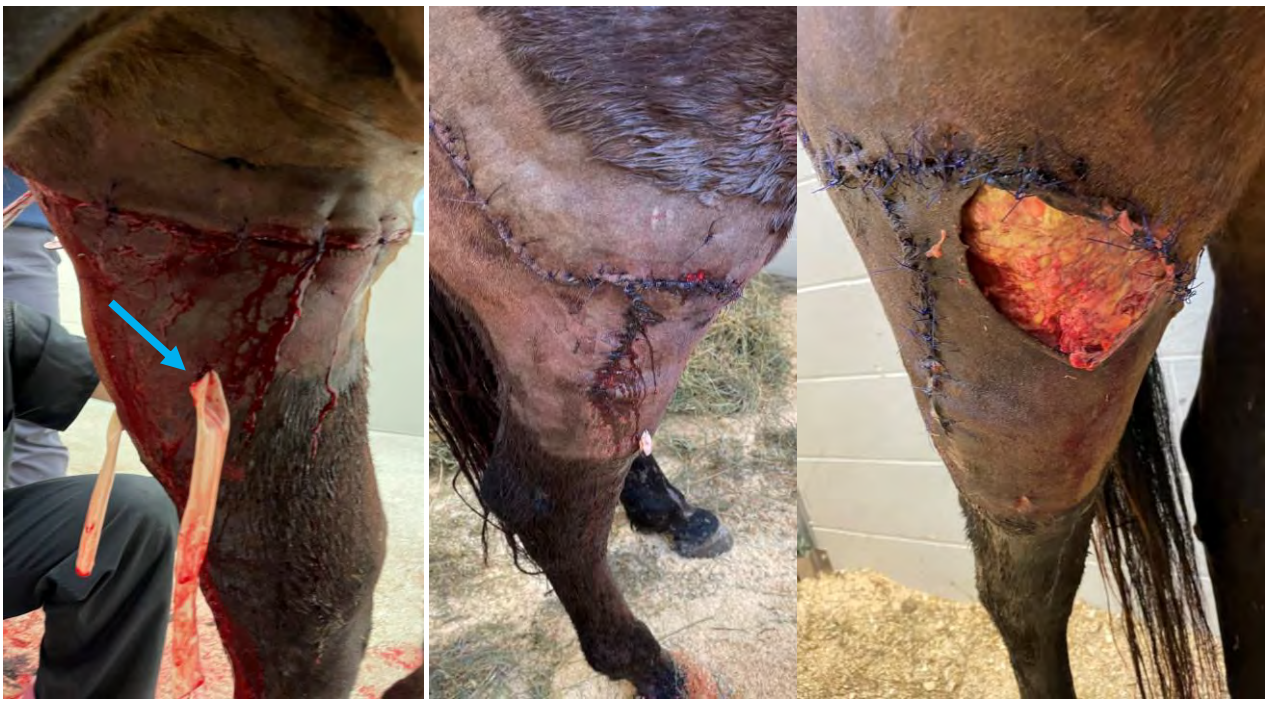

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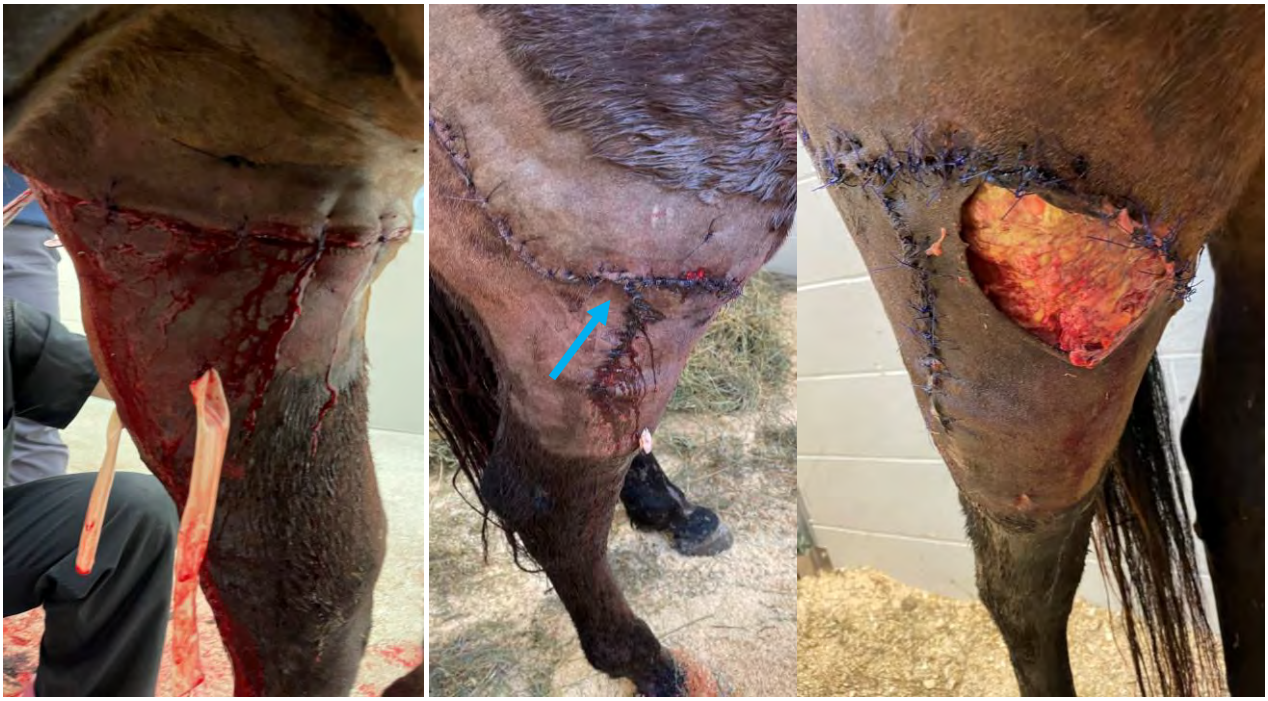

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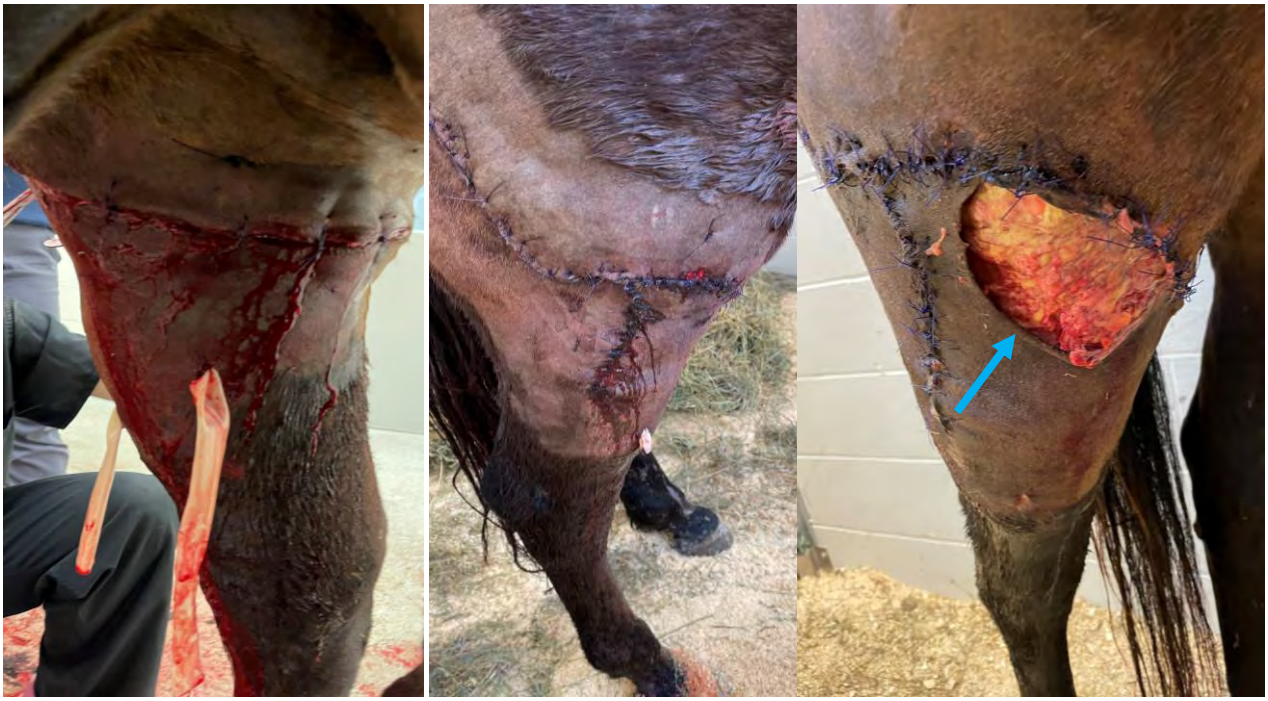

42

Wounds

- Penetrating
- Non-penetrating

43

Outline

- Laceration/wound repair
- Tracheostomy
- Perineal urethrotomy (PU)

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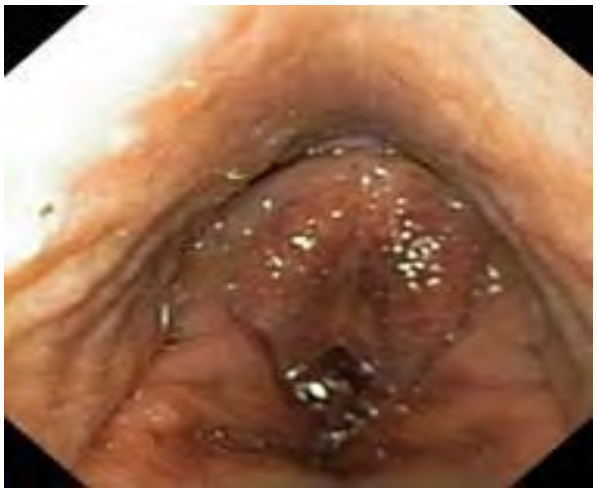
Tracheostomy

- Upper airway distress
- Lower airway distress



45

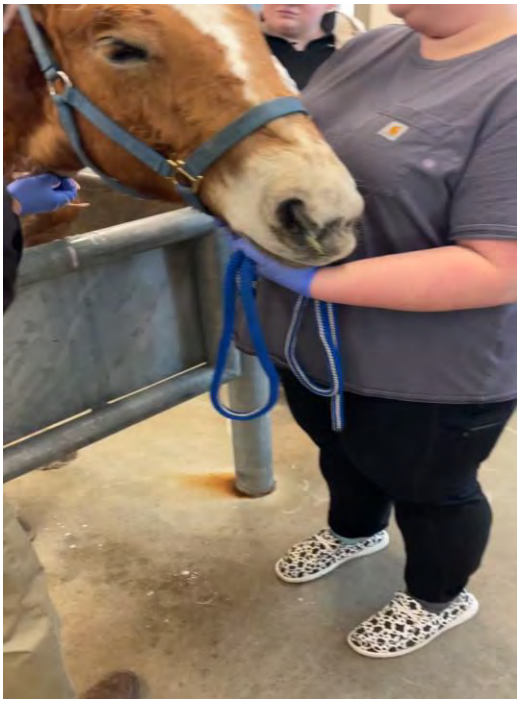
Upper airway distress

- Clinical signs
- Tracheostomy
- Tips & Tricks

46

Clinical signs

- Increased **inspiratory** effort
- Nostril airflow absent or decreased
- Fractious or anxious
- Recumbency – time critical



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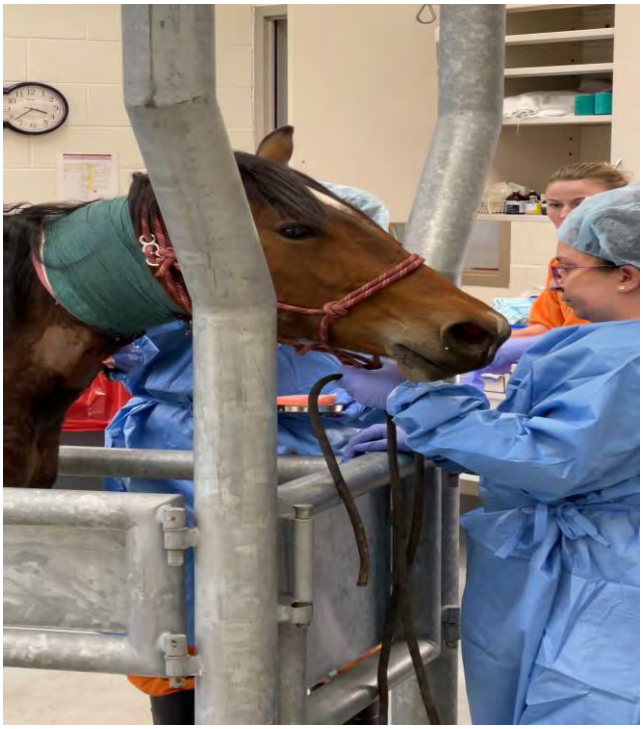


48

Upper airway distress

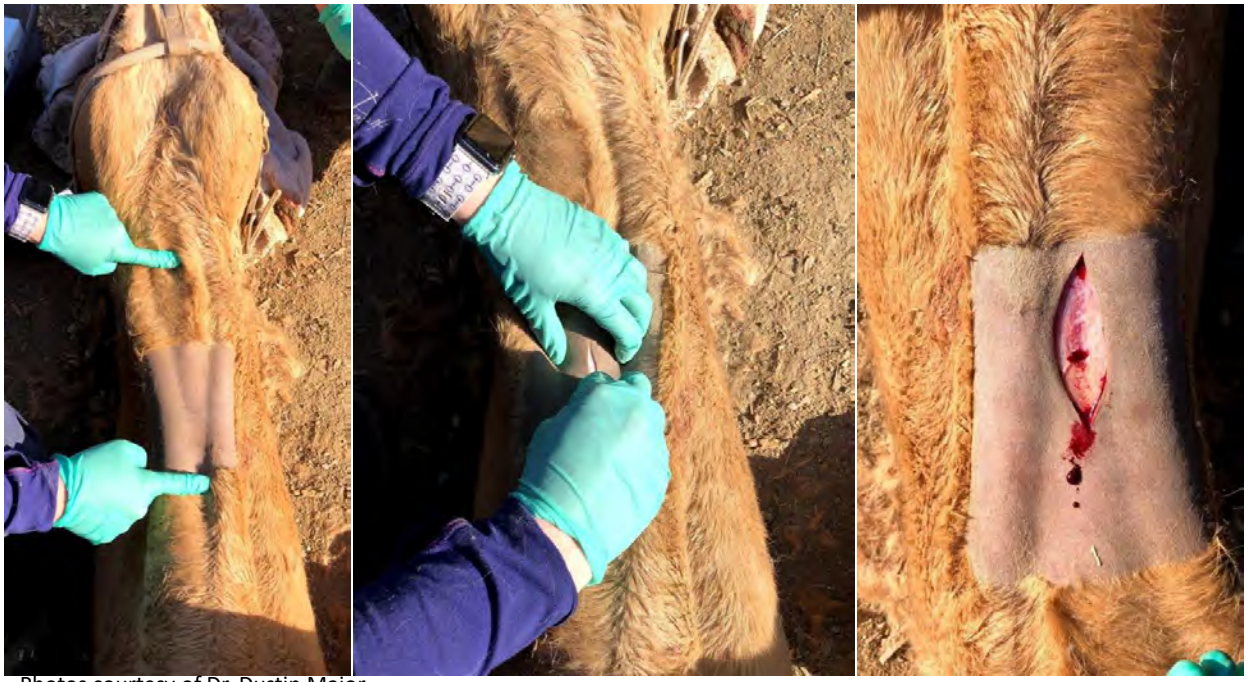
- Clinical signs
- Tracheostomy
- Tips & Tricks

49

Tracheostomy – materials

- Tracheostomy kit
- #10 scalpel blade
- Lidocaine, needles, & syringes
- Tracheostomy tube

50



Photos courtesy of Dr. Dustin Major

51

Photos courtesy of Dr. Dustin Major

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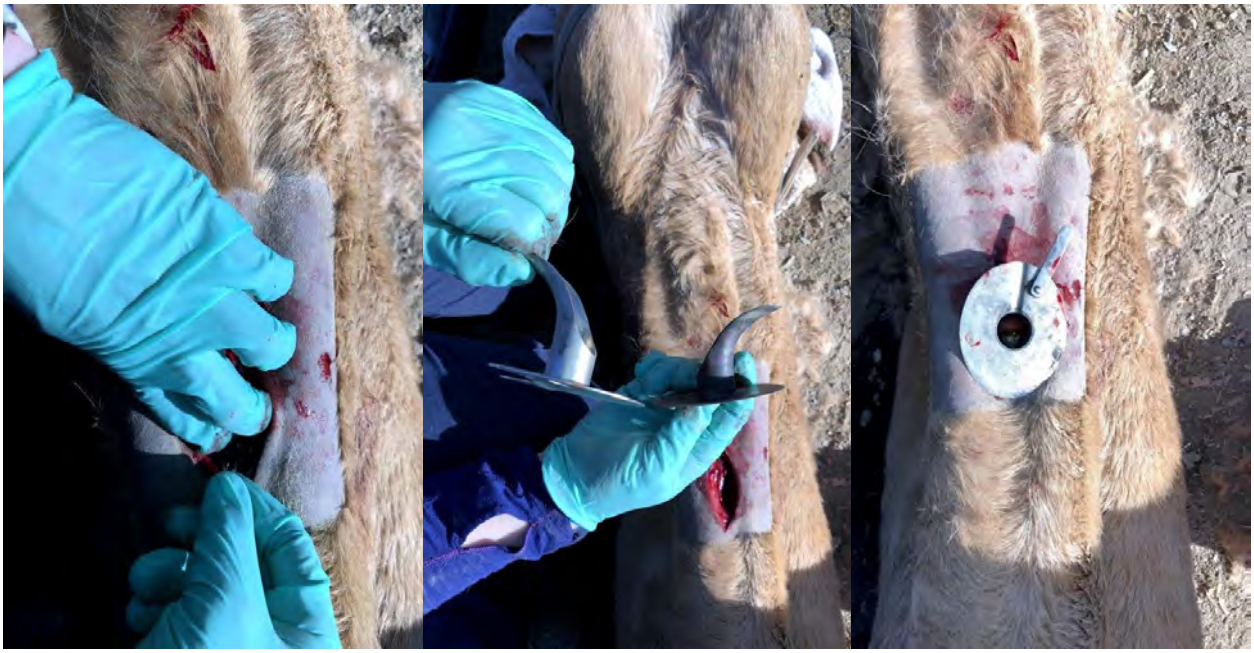

Photos courtesy of Dr. Dustin Major

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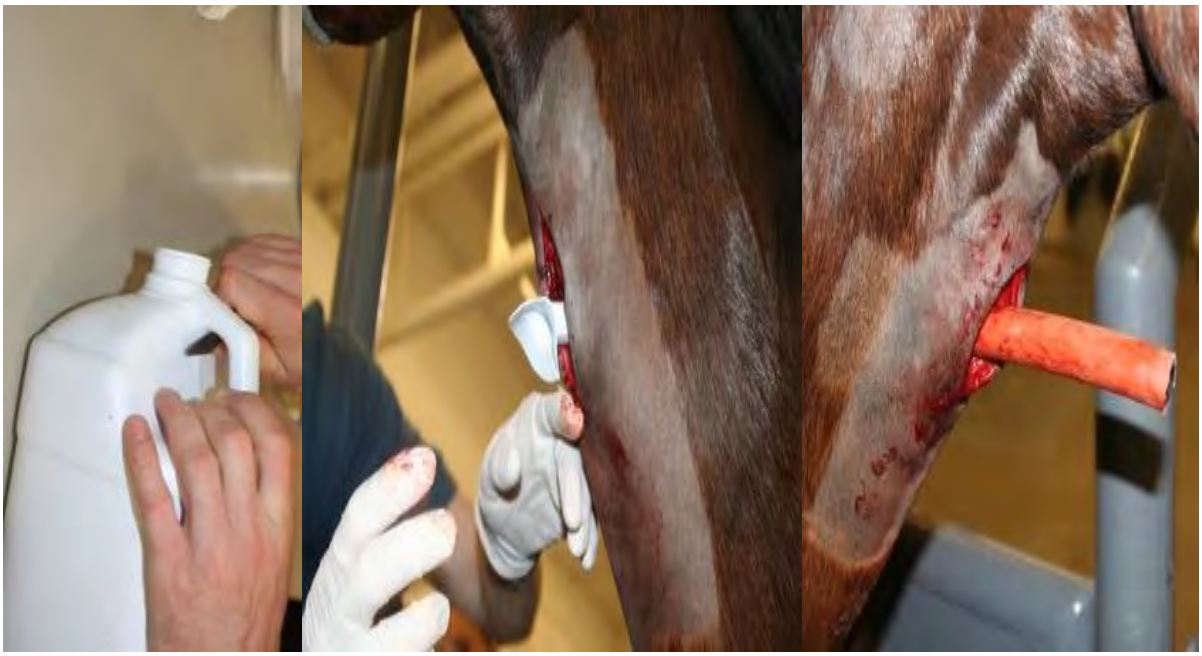

Photos courtesy of Dr. Stephanie Caston

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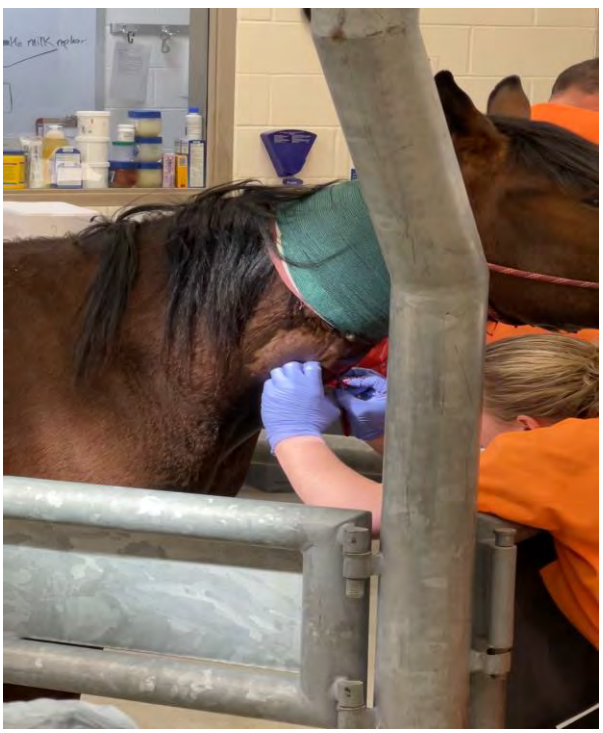
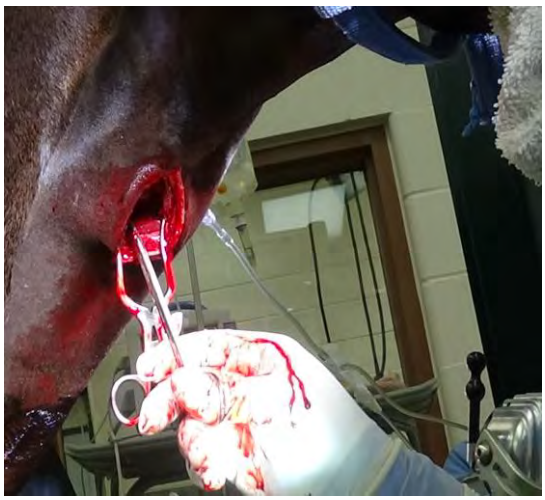


56

Tips & Tricks

- Lidocaine block – large "blebs" make incision more challenging
- Weitlaner retractors
- Occlusion trial prior to removing – should heal in 3-4 weeks



57

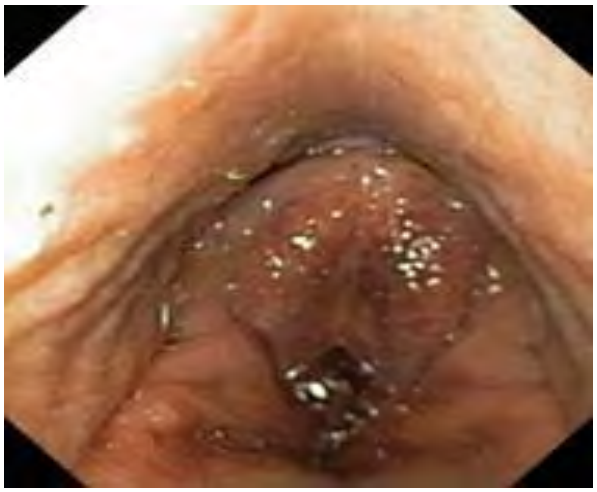
Upper airway distress

- Clinical signs
- Tracheostomy
- Tips & Tricks

58

Tracheostomy

- Upper airway distress
- Lower airway distress



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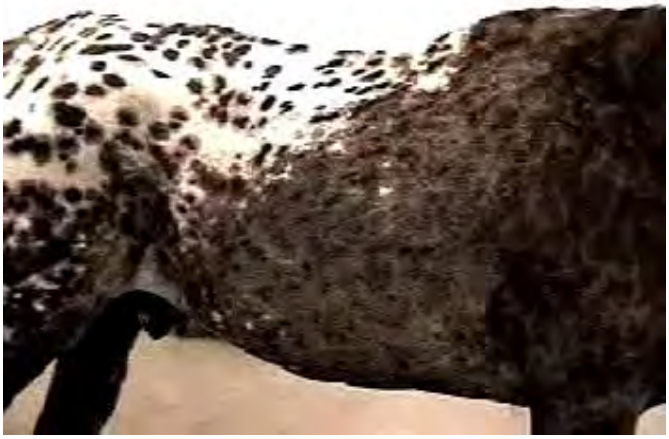
Lower airway distress

- Clinical signs
- Treatment

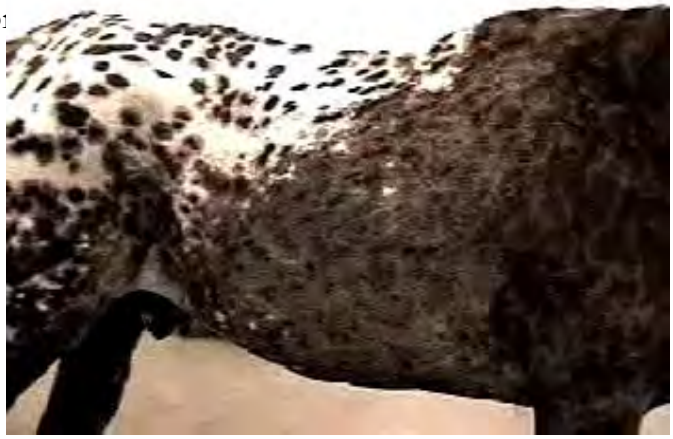


Photos courtesy of Dr. Jamie Kopper

60

Clinical signs

- Increased **EXPIRATORY** effo
- Auscultation for fluid, crackles/wheezes, or decreased lung sounds



Photos courtesy of Dr. Jamie Kopper

61

Clinical signs

- Increased **EXPIRATORY** effort
- Auscultation for fluid, crackles/wheezes, or decreased lung sounds

Photos courtesy of Dr. Jamie Kopper

62

Treatment

- Pleural pneumonia or pneumothorax – thoracocentesis

- Equine asthma
  - N-butyscopolammonium bromide
  - Atropine
  - Systemic steroids
  - Nebulization

Photos courtesy of Dr. Jamie Kopper

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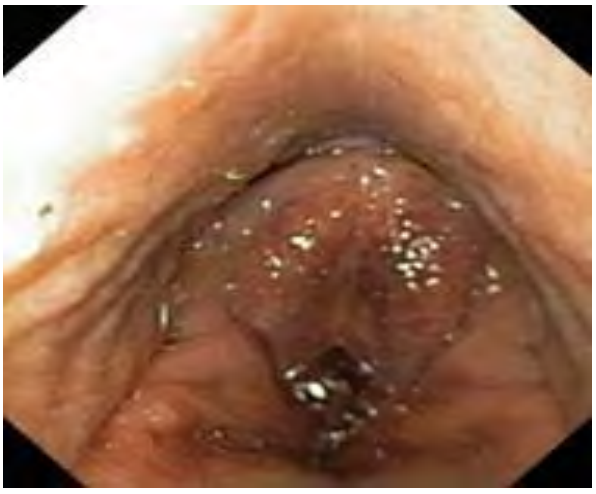
Tracheostomy

- Upper airway distress

- Lower airway distress



64

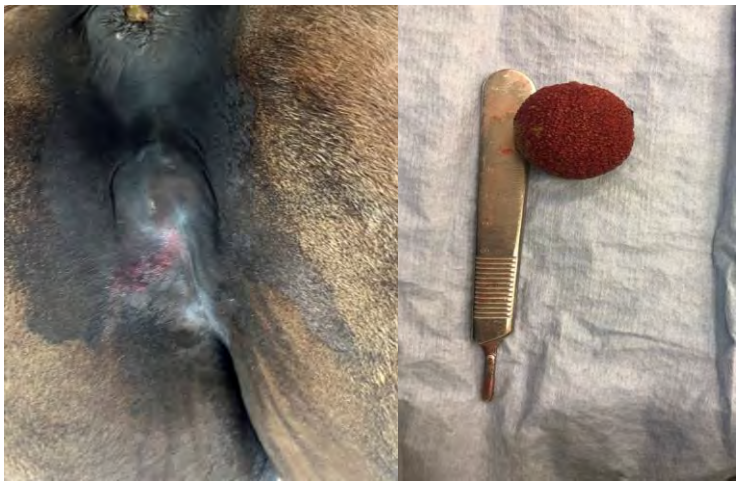
Outline

- Laceration/wound repair
- Tracheostomy
- Perineal urethrotomy (PU)

65

Perineal urethrotomy (PU)

- Urethral obstruction
- Clinical signs
- Surgical procedure



66

Clinical signs

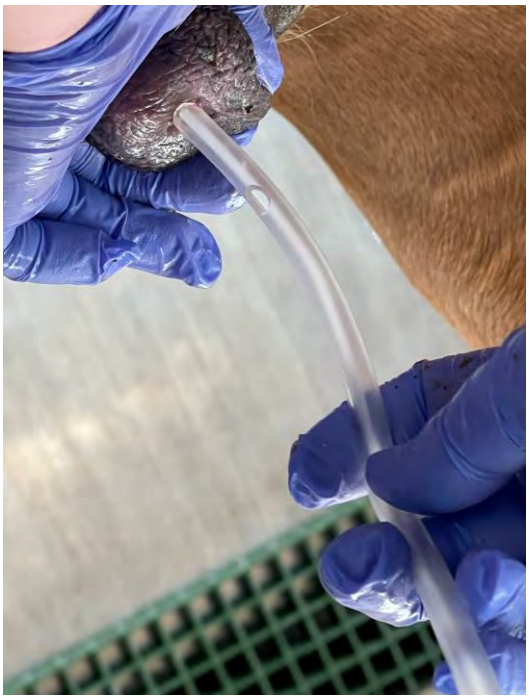
- Straining to urinate
- Colic
- Urethra pulsation
- Urolith palpation

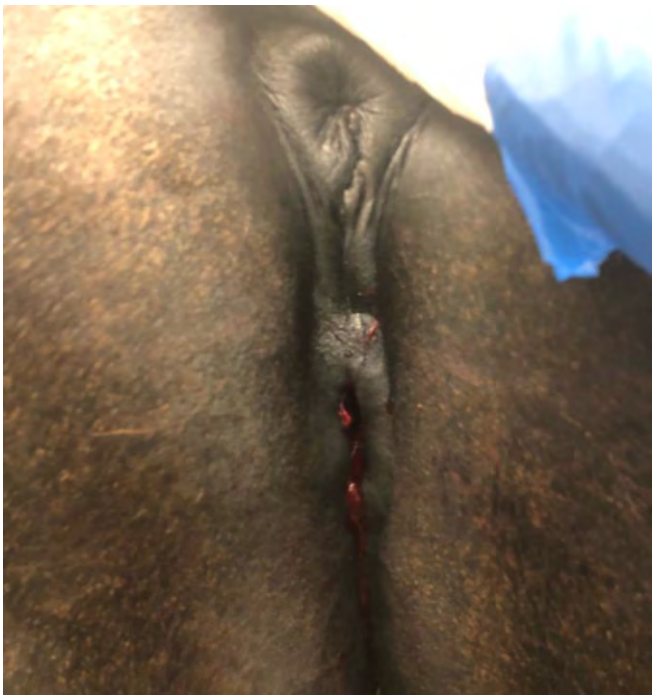
67

Procedure

- Pass urinary catheter to obstruction site
- Epidural or local incision block
- 6-8cm midline incision into urethra starting ~4-6 cm ventral to anus

68

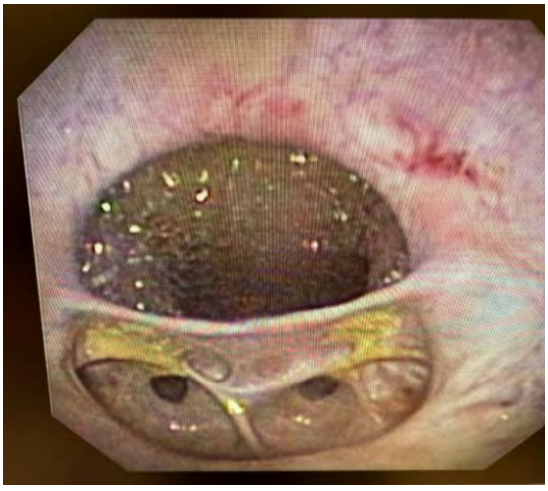




69

PU Tips & Tricks

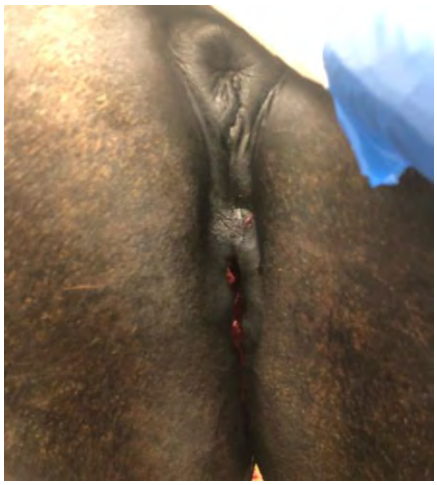
- Watch lidocaine bleb size
- Allis tissue forceps to remove stone
- Endoscopy for urinary bladder damage
- Abdominocentesis if worried about bladder rupture



70

Perineal urethrotomy (PU)

- Hematuria from PU for 24-48 hours
- Should not be profusely hemorrhaging
- Heals in 3-4 weeks – preventatively treat for urine scald



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Outline

- Laceration/wound repair
- Tracheostomy
- Perineal urethrotomy (PU)

72

Summary

- Wound repair, tracheostomy, and perineal urethrotomy are common equine emergencies that can be managed surgically in the field and stabilize horses

73

Questions?

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EQUINE FRACTURE FIRST AID IN THE FIELD

JARROD TROY
DVM, DACVS-LS, CERP

EQUINE

Equine Fracture First Aid & Transportation

Jarrod Troy DVM; DACVS-LA; CERP
Assistant Professor
Iowa State University Veterinary Clinical Sciences

1

Conflict of Interest Disclosure:

I have no financial interest, arrangement, or affiliation with any company or organization.

2

Objectives

- Assess and prepare a horse with a fracture for stabilization
- Utilize different stabilization techniques
- Triage and explain best transport practice for a horse following fracture first aid

3

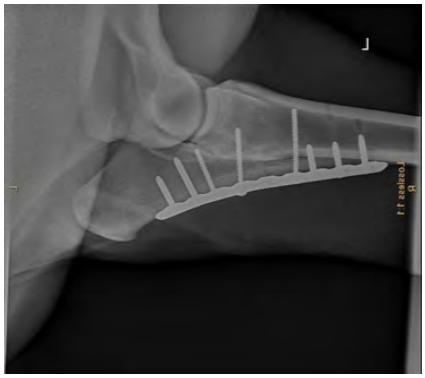
Outline

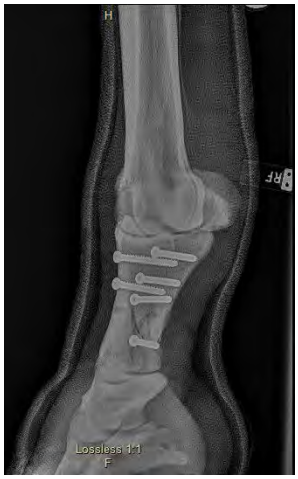
- Fracture first aid
- Fracture stabilization
- Fracture triage
- Transportation

4

Fracture First Aid

- Horse fractures happen
- Many fractures of the limb or skull can be repaired
- Appropriate first aid & transportation

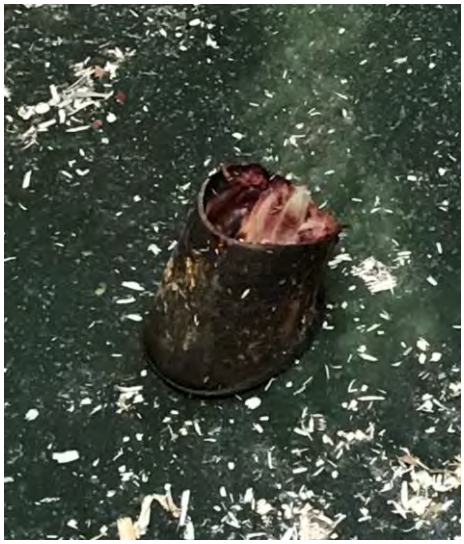




5

Fracture First Aid – Why Important?

- No or **inappropriate** first aid results in…
  - Increased soft tissue trauma → decreased healing
  - Simple fractures → complex fractures
  - Closed fractures → open fractures
  - Intact vasculature → disrupted vasculature → necrosis



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Fracture First Aid – Why Important?

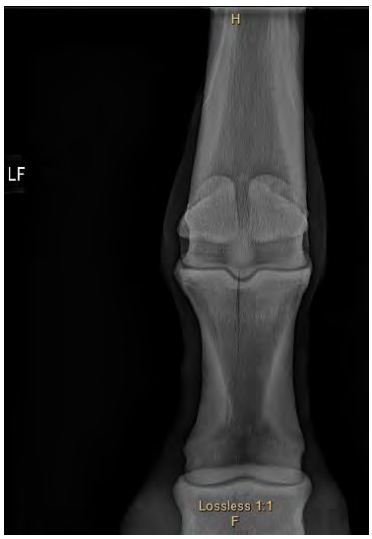
- Appropriate first aid results in…
  - Decreased pain/anxiety
  - Reduced injury and risk of fractures worsening
  - Best chance at a successful outcome

7

Fracture First Aid

- Physical assessment
- Sedation & analgesia
- Wound management
- Radiographs

Smith 2006



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Fracture first aid – Physical assessment

- Anxious horse – sedate if needed
- Physical examination
- Stop severe hemorrhage
- Stabilization may come first

9

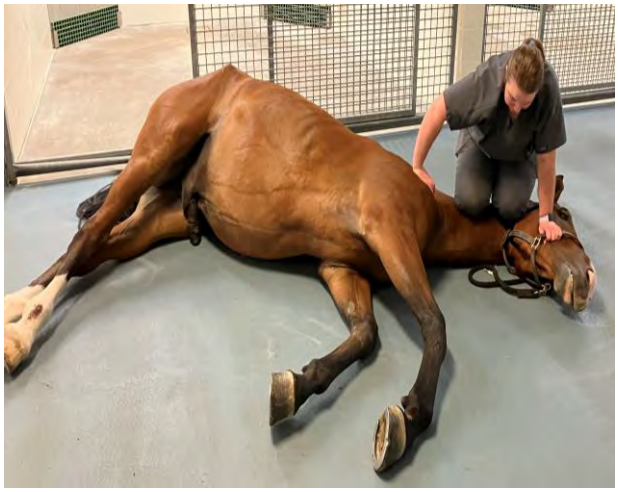
Fracture First Aid – Sedation & Analgesia

- Sedation – "Just enough"
  - **Xylazine** (0.3 – 0.8 mg/kg IV; **α_2-agonist**)
  - **Detomidine** (0.01-0.02 mg/kg IV; **α_2-agonist**)
  - **Butorphanol** (0.01-0.04 mg/kg IV; **opioid**)

10

Fracture First Aid – Sedation & Analgesia

- Sedation – "Just enough"
  - **Xylazine** (0.3 – 0.8 mg/kg IV; **α_2-agonist**)
  - **Detomidine** (0.01-0.02 mg/kg IV; **α_2-agonist**)
  - **Butorphanol** (0.01-0.04 mg/kg IV; **opioid**)
- Avoid Acepromazine



11

Fracture First Aid – Fracture Assessment

- Localized swelling
- Pain on palpation
- Heat
- ± Wounds

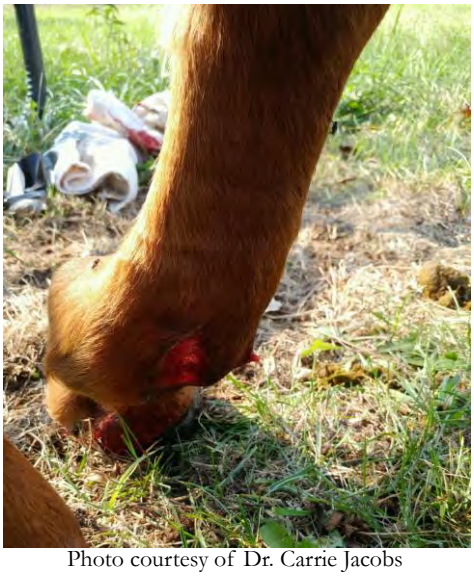
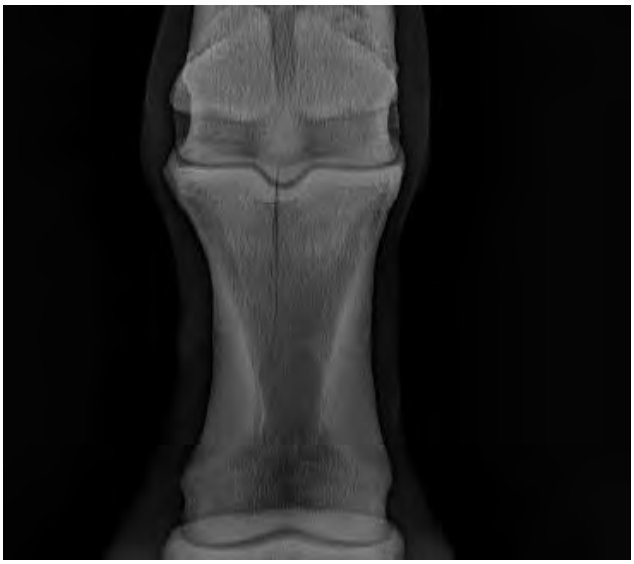


Photo courtesy of Dr. Carrie Jacobs

12

Fracture First Aid – Fracture Assessment

- ± Crepitus or instability
- ± Hemorrhage
- ± Synovial effusion

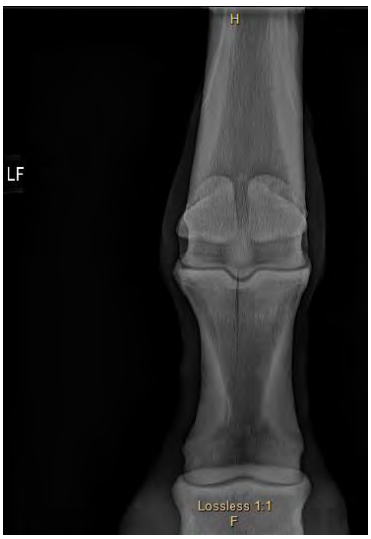


13

Fracture First Aid

- Physical assessment
- Sedation & analgesia
- Wound management
- Radiographs

Smith 2006



14

Fracture First Aid – Wound Management

- Unstable fractures → stabilize fracture → wound management later
- Stable fractures

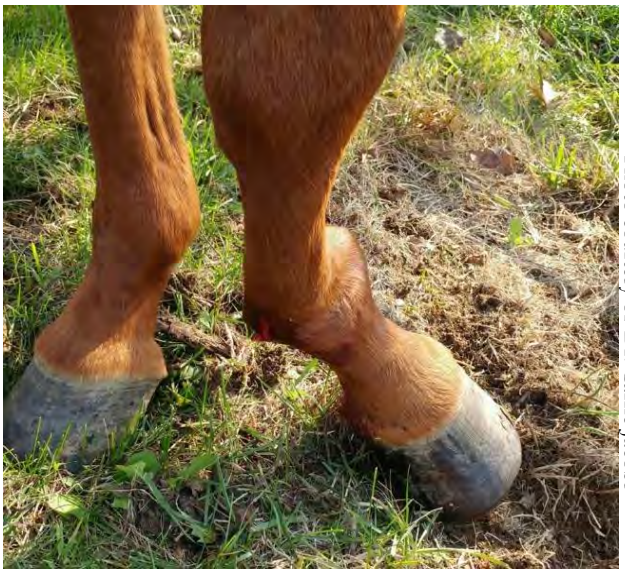
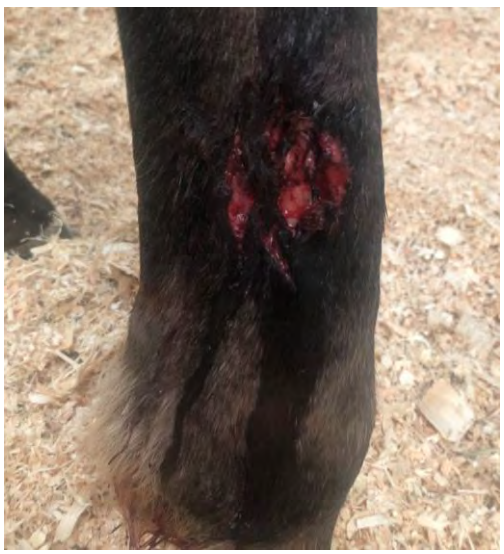


Photo courtesy of Dr. Carrie Jacobs

15

Fracture First Aid – Wound Management

- Stable fractures
  - Clean any gross contamination – isotonic solution
  - Open wounds – water soluble antimicrobial ointment
  - Wound should be included in the stabilization bandage
  - Closed wounds – clean unbroken skin



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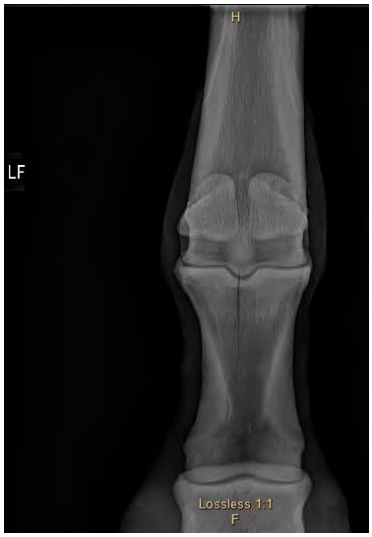
Fracture First Aid

- Physical assessment
- Sedation & analgesia
- Wound management
- Radiographs

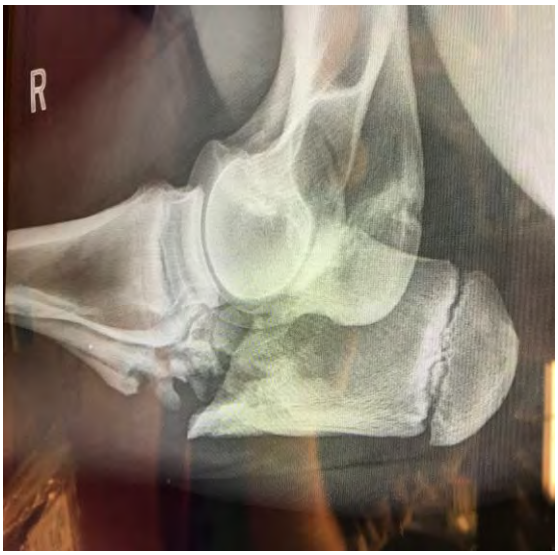
Smith 2006



17

Fracture First Aid - Radiographs

- Unstable fractures → stabilize first
- PVC or Wood splints permit x-ray penetration
- Aluminum Kimzey splint or cast material permits x-ray penetration as well

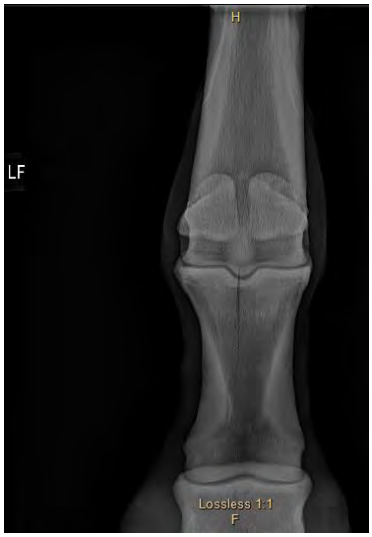


18

Fracture First Aid

- Physical assessment
- Sedation & analgesia
- Wound management
- Radiographs

Smith 2006



19

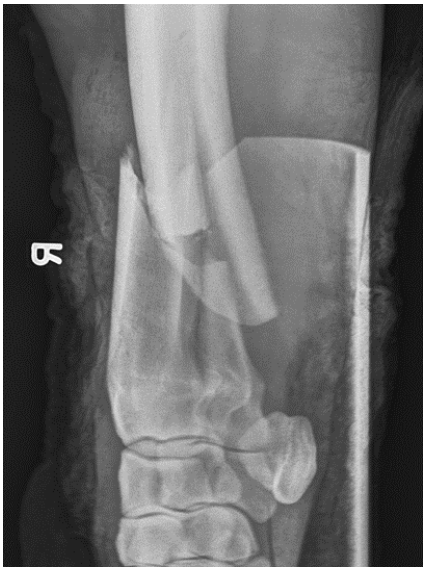
Outline

- Fracture first aid
- Fracture stabilization
- Fracture triage
- Transportation

20

Fracture First Aid – Fracture Stabilization

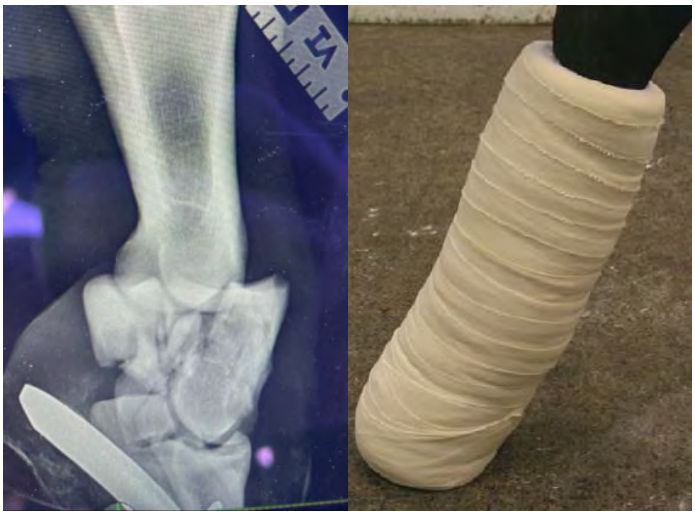
- Stabilization principles
- Stabilization types
- Stabilization methods and location



21

Fracture First Aid – Fracture Principles

- Unstable fractures → **need immediate appropriate stabilization**
- Wound management at hospital

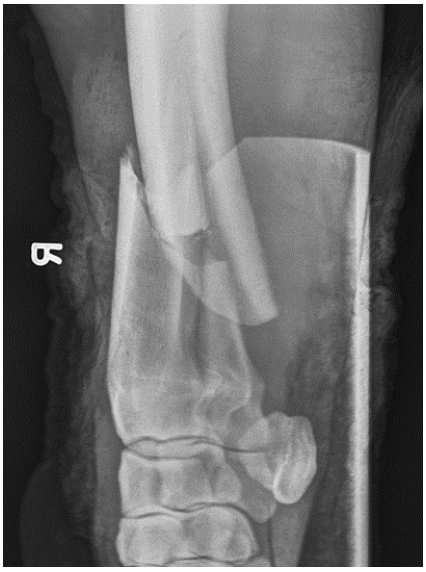


Wright 2016

22

Fracture First Aid – Fracture Principles

- Immobilizes the joint above & below the fracture
- Extends well beyond the fracture line
- Provides intact strut for weight bearing
- Neutralizes the forces on the fracture



23

Fracture First Aid – Fracture Principles

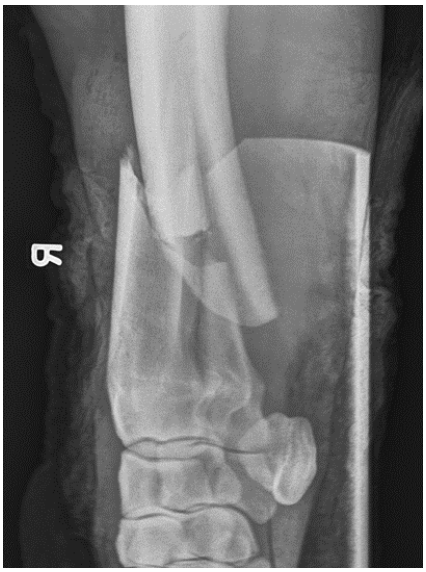
- Prevent further bone or soft tissue injury
- Assist with weight bearing
- Relieve anxiety
- Protect closed fractures from becoming open fractures or displacing

Wright 2016

24

Fracture First Aid – Fracture Stabilization

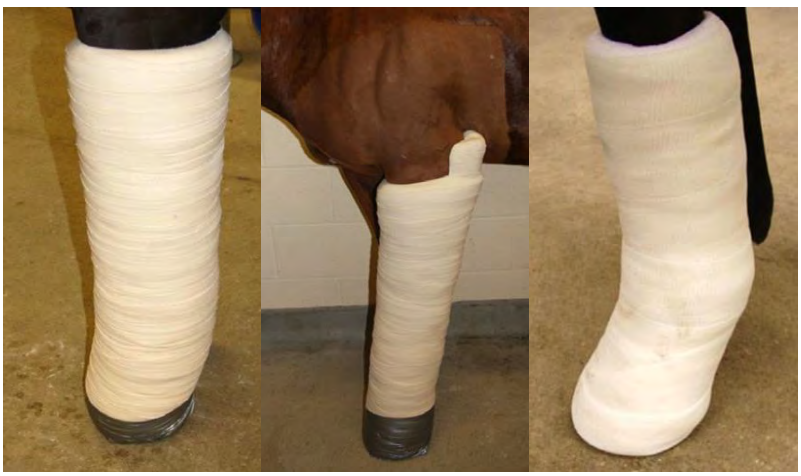
- Stabilization principles
- Stabilization types
- Stabilization methods and location



25

Fracture First Aid – Types of Stabilization

- Robert-Jones bandage
- Splints
- Casts



Wright 2016

26

Fracture First Aid – Robert Jones Bandage

- Multiple layers of cotton
- Elastic gauze compressing each layer
- Bandage diameter = 3x the diameter of the limb
- Short term use – cannot stabilize a fracture long term

Wright 2016

27

Fracture First Aid – Splint

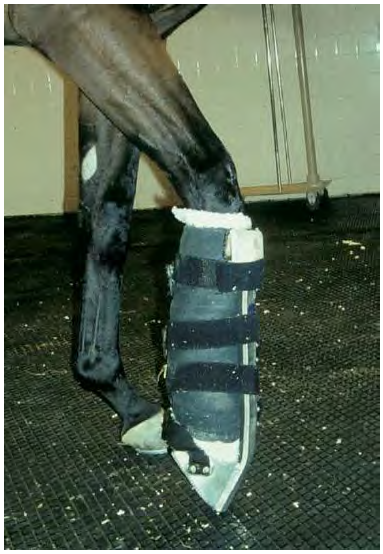
- Rigid & lightweight
- Easily applied under sedation
- Durable – does not break under horse's weight
- Splint must be secured to a bandage
- Splint must not slip out of place

Smith 2006

28

Fracture First Aid – Splint

- PVC (Polyvinyl chloride) pipe
- Wood boards, broomstick handles, etc.
- Leg Saver Splint or Kimzey Splint
  - Ensure top of splint does not end at fracture line
  - No lateral to medial stability
  - Cannot hold large feet

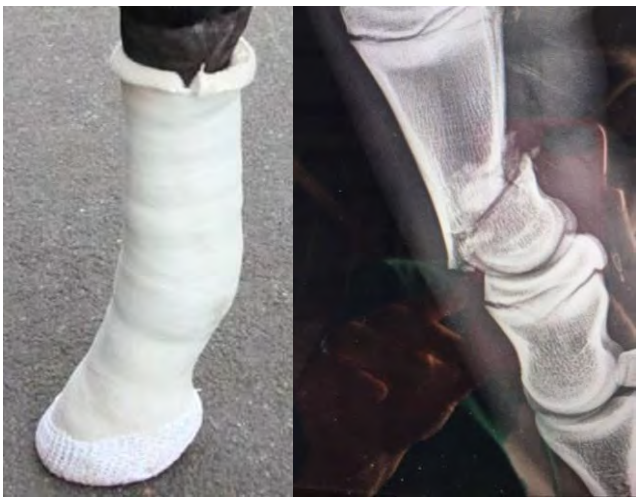


Smith 2006

29

Fracture First Aid - Casts

- Fiberglass casting tape
  - Full limb or half limb
- Cannot be effectively applied if…
  - Too much motion at fracture site
  - Patient is not sufficiently tractable
  - Include the foot when possible
  - Never end a cast at mid-diaphysis
- Bandage cast

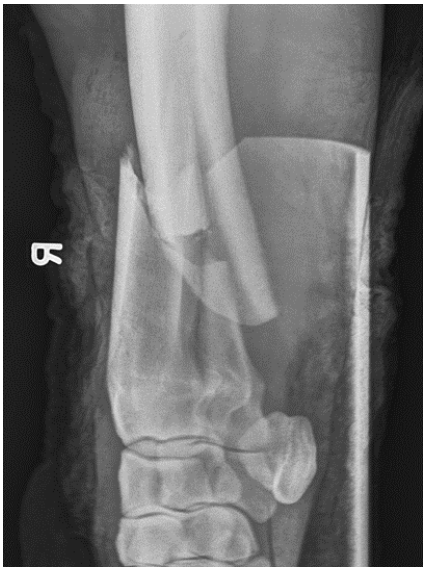


Wright 2016

30

Fracture First Aid – Fracture Stabilization

- Stabilization principles
- Stabilization types
- Stabilization methods and location

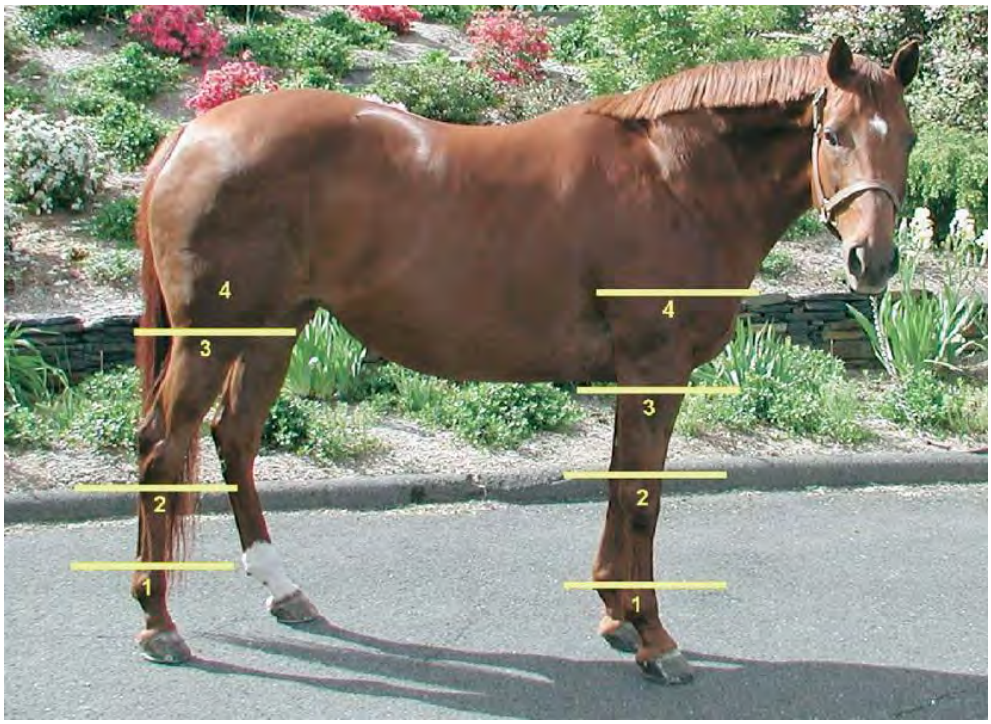


31

Fracture First Aid – Stabilization Methods

- Developed technique based on the forces applied at different fracture locations
- Splinting horse limbs - Divided into 4 regions
- Each region has a method for appropriate fracture stabilization

32



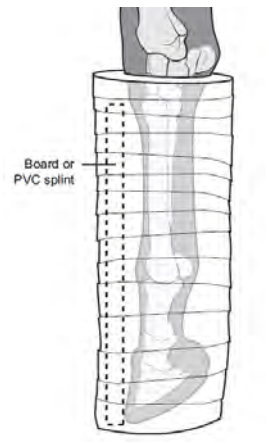
Smith 2006

33

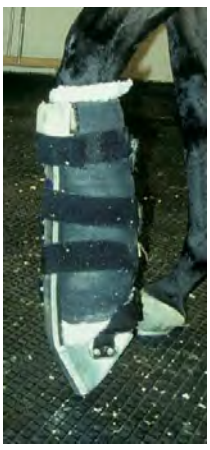
Fracture First Aid – Stabilization Regions

- Region 1 – Front limb
  - Phalanx 1; Phalanx 2
  - Sesamoid bones
  - Distal metacarpal 3

- Stabilization
  - Alignment of the dorsal cortices
    - Phalanges: P1, P2, P3
    - Cannon bone (Metacarpal 3)
    - Toe pointing towards the ground



Mudge & Bramlage 2007

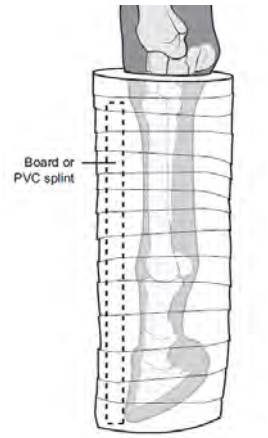


Smith 2006

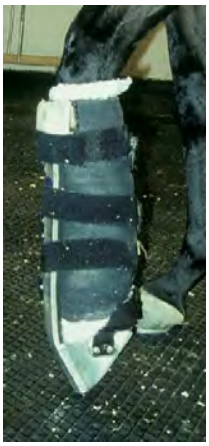
34

Fracture First Aid – Stabilization Regions

- Region 1 – Front limb
- Splint location
  - Dorsal aspect of limb
  - Extends from ground to just below carpus
- "Kimzey" Leg Saver Splint



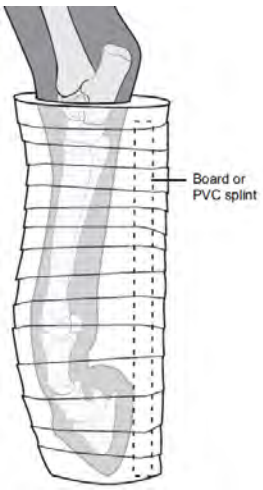
Mudge & Bramlage 2007


Smith 2006

35

Fracture First Aid – Stabilization Regions

- Region 1 – Hind limb
- Splint location
  - Plantar aspect of limb
  - Extends from ground to tarsus



Mudge & Bramlage 2007


Smith 2006

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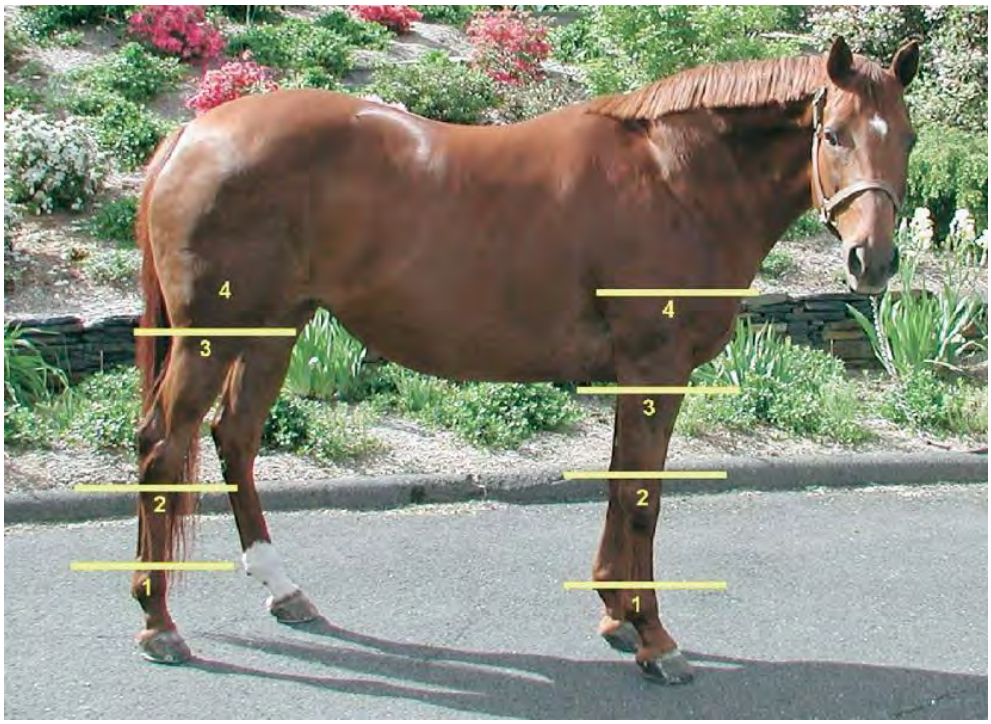


Smith 2006

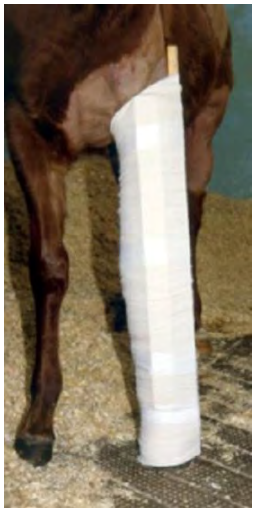
37

Fracture First Aid – Stabilization Regions

- Region 2 – Front limb
  - Mid – proximal metacarpus
  - Carpus
  - Distal radius

- Splint location
  - 2 splints – 90^0 angles from each other
    - 1 splint – caudal aspect
    - 1 splint – lateral aspect
  - Extend from elbow to ground

Smith 2006



Wright 2016

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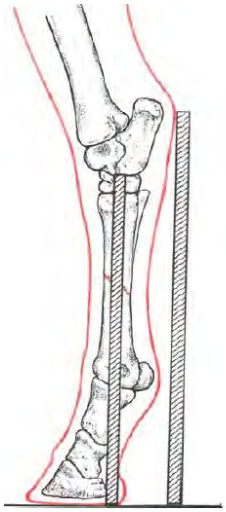
Fracture First Aid – Stabilization Regions

- Region 2 – Hind limb
  - Mid – proximal metatarsus
  - Tarsus

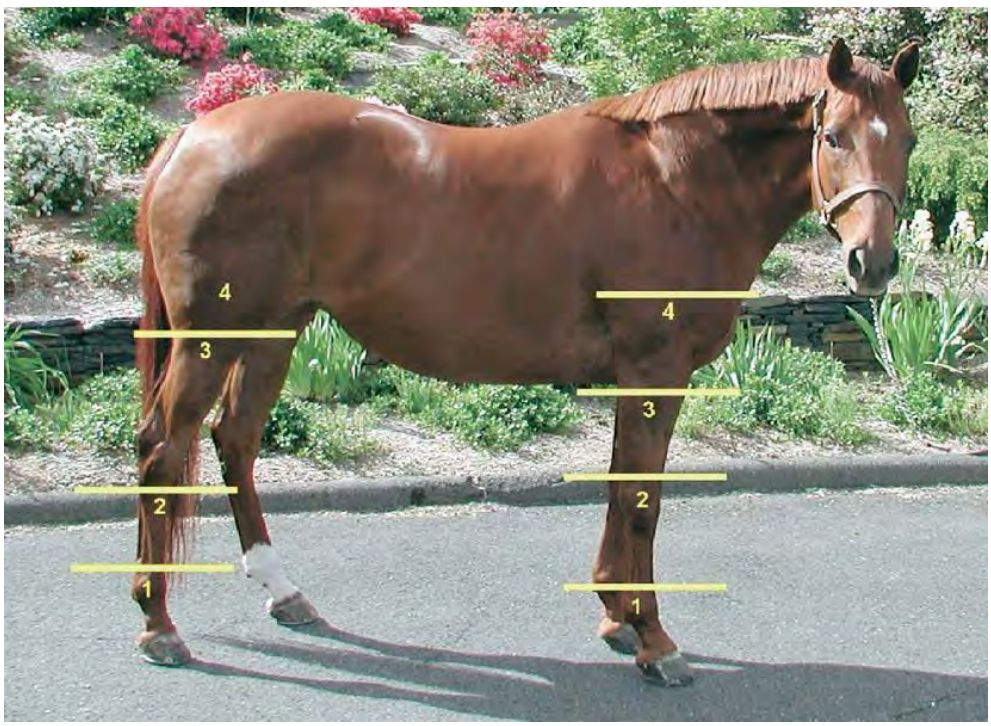
- Splint location
  - 2 splints – 90^0 angles from each other
  - 1 caudal splint – Calcaneus to ground
  - 1 lateral splint –Proximal tarsus to ground
  - Stifle to ground – for proximal metatarsus fractures



Wright 2016

Smith 2006

39

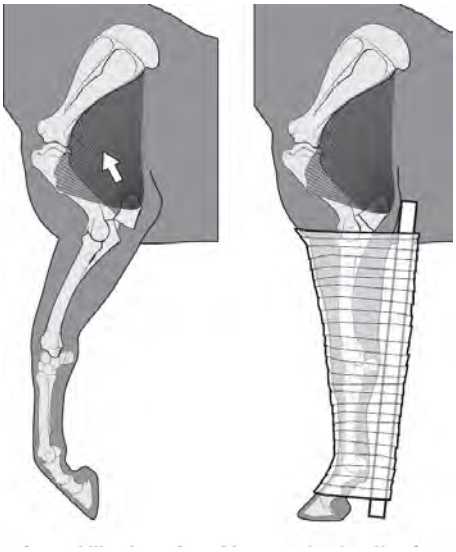


Smith 2006

40

Fracture First Aid – Stabilization Regions

- Region 3 – Front limb
  - Olecranon
- Splint location
  - Caudal splint that keeps the carpus in extension
  - Ground to top of olecranon
- Also useful for horses with radial nerve paralysis or humeral fractures



Mudge & Bramlage 2007

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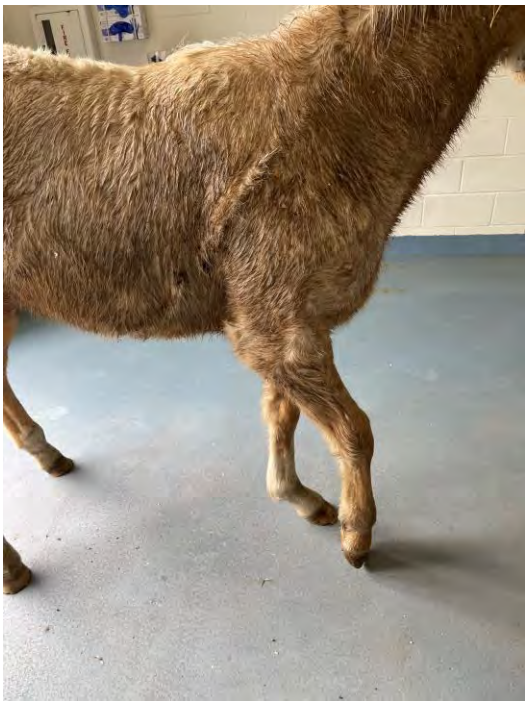
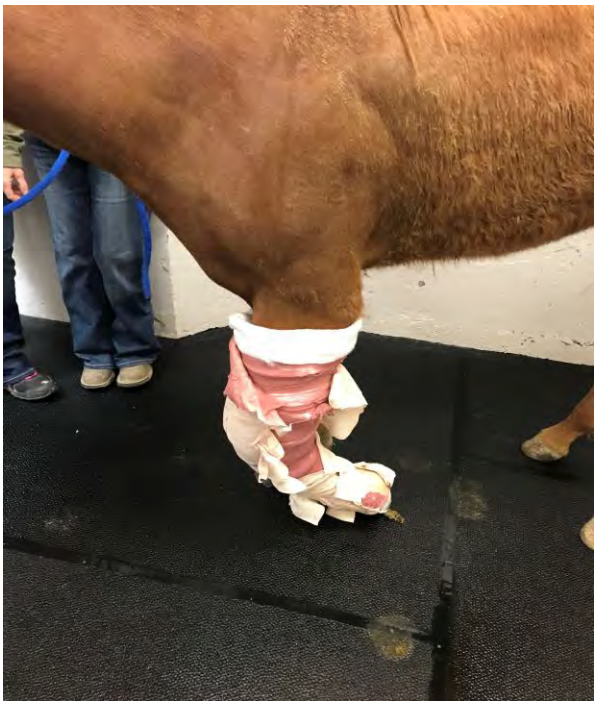
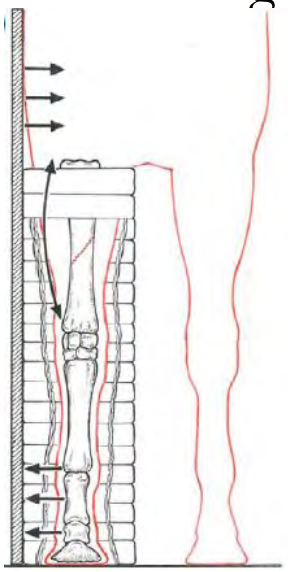




42

Fracture First Aid – Stabilization Regions

- Region 3 – Front limb
  - Mid – proximal radius
- Splint location
  - 2 splints – 90^0 to each other
  - Lateral splint – ground to shoulder
  - Caudal splint – ground to elbow
- Always look for medial wounds with these fractures



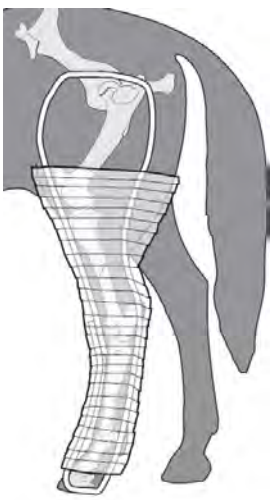
Wright 2016

43

Fracture First Aid – Stabilization Regions

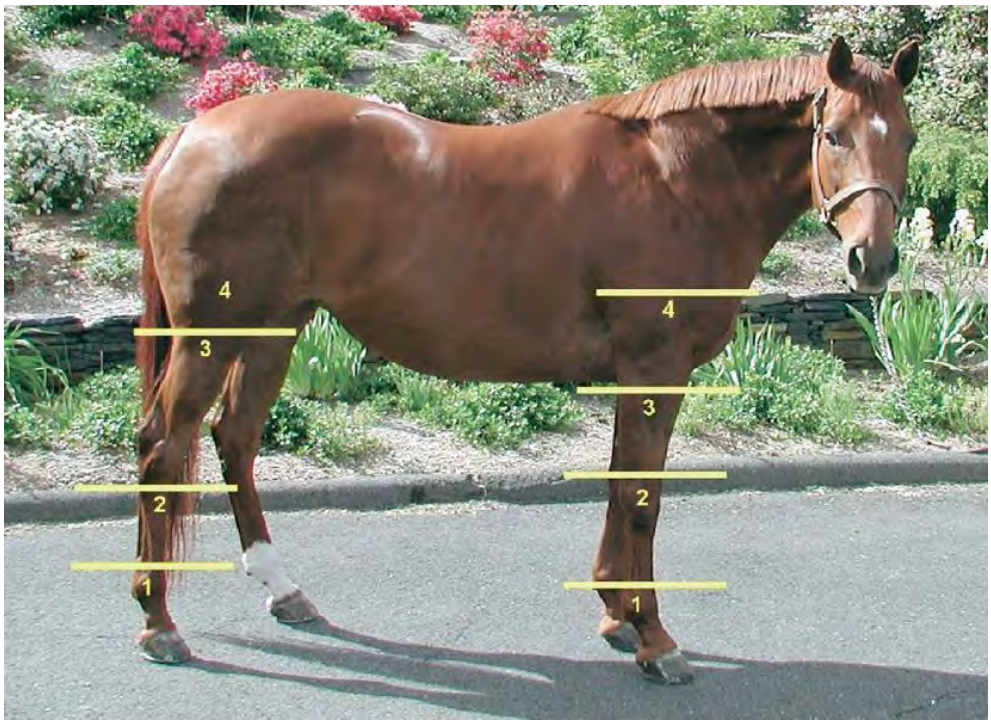
- Region 3 – Hind limb
  - Tibia
- Splint location
  - Lateral splint – spans tarsus & stifle
  - Long and wide splint

Smith 2006



Mudge & Bramlage 2007

44

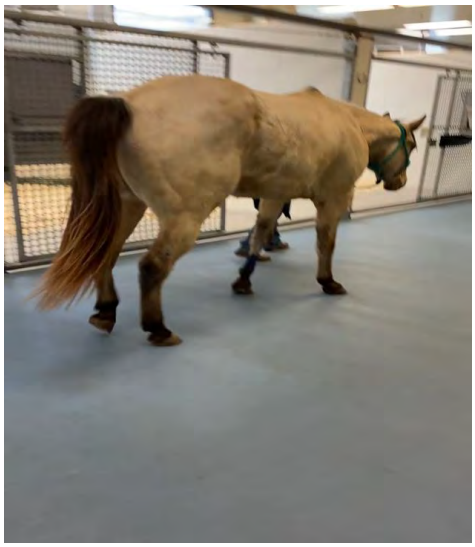


45

Fracture First Aid – Stabilization Regions

- Region 4 – Front & Hind limb
  - Humerus
  - Femur

- Stabilization – Not necessary
  - Humerus fractures with no triceps function → caudal splint to fix carpus in extension



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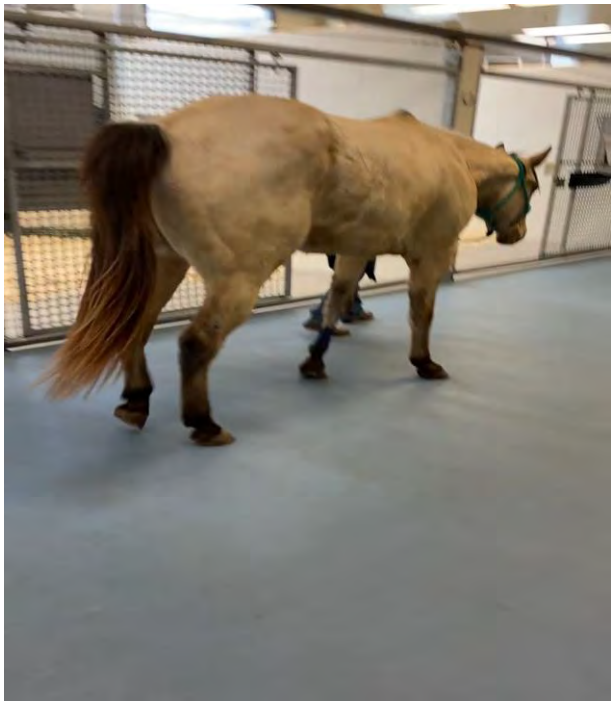
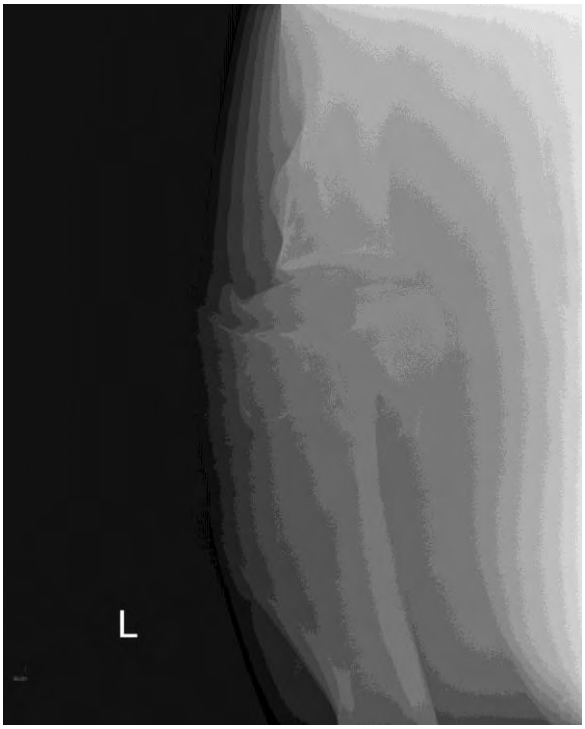




47

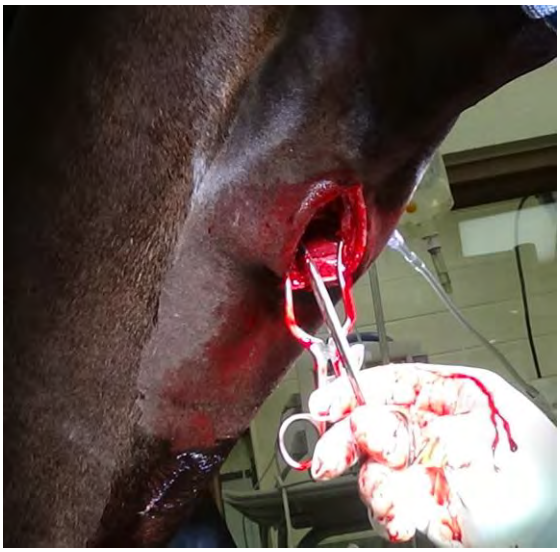
Fracture First Aid – Skull Fractures

- First Aid
- Respiratory compromise
- Significant hemorrhage
- Neurologic deficits
- Ophthalmic evaluation

48

Fracture First Aid – Skull Fractures

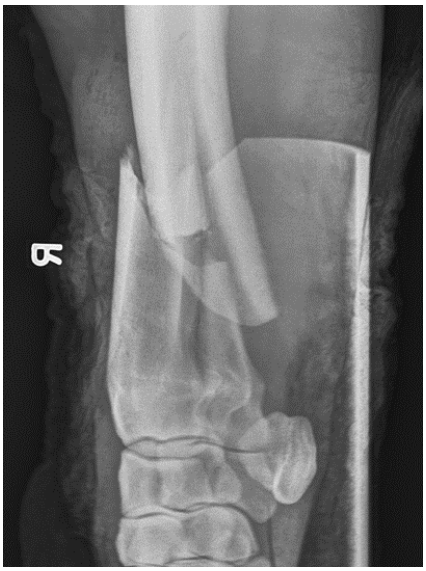
- First Aid
- Respiratory compromise
- Tracheostomy



49

Fracture First Aid – Fracture Stabilization

- Stabilization principles
- Stabilization types
- Stabilization methods and location



50

Outline

- Fracture first aid
- Fracture stabilization
- Fracture triage
- Transportation

51

Fracture triage

- Fluid resuscitation
  - Administration of nephrotoxic drugs (NSAIDs or aminoglycosides)
  - Transportation time – minutes or hours
- Severe hemorrhage → need to control blood loss

52

Foal fluid therapy – Fracture triage

- Foals – limited fluid & energy reserves
  - Rapid dehydration & hypoglycemia
  - Hyperglycemia with potential rebound hypoglycemia
- Initial fluid therapy
  - 10-20 mL/kg bolus over 20 minutes of an isotonic electrolyte solution

53

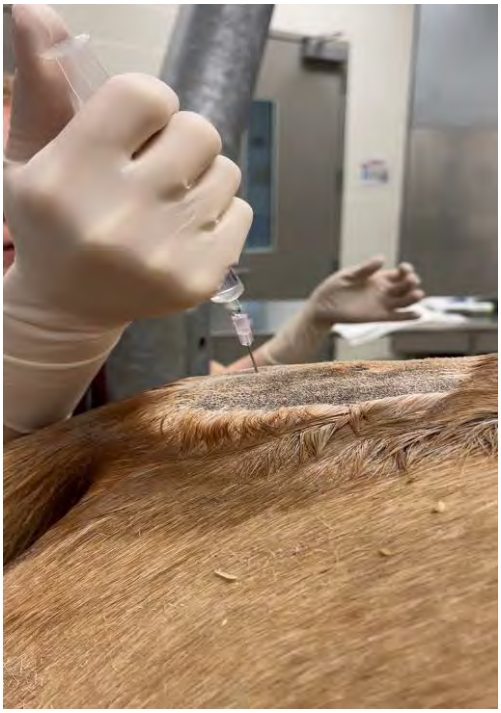
Fracture triage

- Non-steroidal anti-inflammatory drugs (NSAIDs)
- Systemic antibiotics – especially open fractures
- Tetanus toxoid vaccine
- No corticosteroids

54

Fracture triage

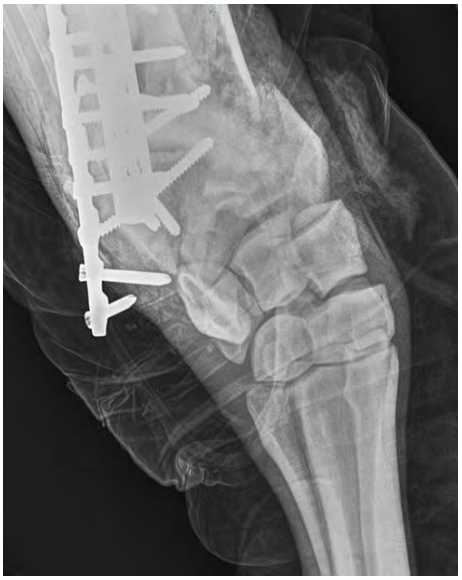
- Opioids – use cautiously
- Epidurals – very rarely
- Avoid sedation or analgesia that causes ataxia



55

Fracture First Aid - Prognosis

- Significant advances in fracture repair
- Prognosis depends on type of fracture and horse
  - Stabilize the fracture and the horse
  - Contact your nearest ACVS large animal surgeon
- Horse temperament and size affect prognosis



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Outline

- Fracture first aid
- Fracture stabilization
- Fracture triage
- Transportation

57

Fracture First Aid - Transportation

- Even with proper stabilization more damage can still occur
- Non-slip floors or extra shavings
- Leave partitions or butt bars in place
- Head free or loose

https://www.scotiscreation.com/New-Inventory-2019-Frontier-Trailers-Unknown-Fast-Track-2-Horse-Straight-Load-w-Side-Ramp-Manchester-6882323

58

Transportation – Horse Position

- Fracture limb towards back of trailer
- Straight load – fractured limb in back
- Slant load – fractured limb side in back
- Important but not worth hours of time

http://www.goretrailers.com/gooseneck19.html

59

Summary

- Decreased pain/anxiety
- Decreased soft tissue & bone damage
- Reduces infection risk
- Best chance at a successful outcome

- Always contact your nearest referral center if any questions

60

Outline

- Fracture first aid
- Fracture stabilization
- Fracture triage
- Transportation

61

References

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- Smith J. Emergency fracture stabilization. *Clin Tech in Equine Pract.* 2006. 5:154-160.
- Wright I.M. Racecourse fracture management. Part 1: Incidence and principles. *Eq Vet Ed.* 2017. 29 (7): 391-400
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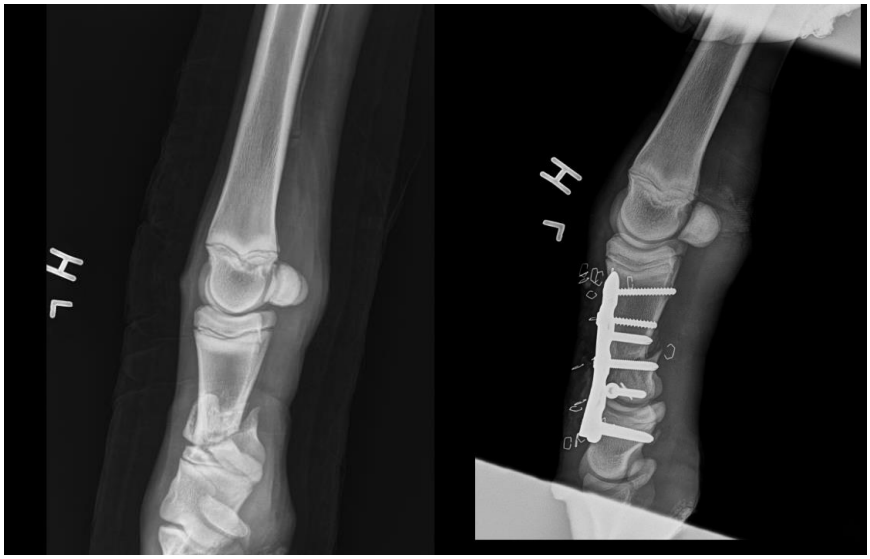
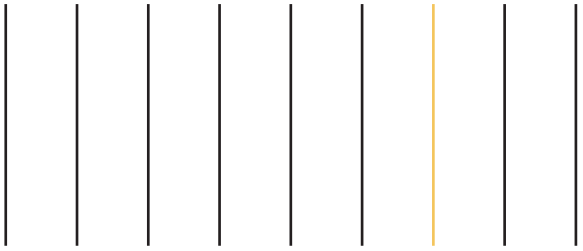
Questions?



63

SUSTAINABILITY IN EQUINE VETERINARY PRACTICE

MAUREEN SUTTER
DVM



EQUINE

Sustainability in Equine Veterinary Practice

and what AAEP is working on

Maureen Sutter DVM
Red Oak Animal Hospital

Maureen Sutter DVM

- 2007 KSU grad
- Ambulatory Internship- RREH
- Kentucky Horse Racing Commission
- Red Oak Animal Hospital
- Kansas Equine Practitioners Group
- AAEP
  - Student Subcommittee of the Commission on Equine Veterinary Sustainability
  - Member Engagement Committee
  - Governance Task Force
  - Practice Owner Task Force
- Decade One Member
- Guiding Wildcats into Future Equine Vets mentor

Why is Change Needed in Equine Practice?

- Decreasing # of equine vets
- Demand > supply
- Large # of vets in retirement age
- Debt to income ratio is not sustainable
- Low compensation compared to SA
- Long hours worked
- Emergency Coverage
- Industry & practice culture

Timeline for Formation of the AAEP Commission on Equine Veterinary Sustainability

TRANSFORMING EQUINE PRACTICE

December 2021 AAEP Convention- Nashville

- Presentation by Dr Carol Clark
  - Chair of the Retention Task Force
- Results of AAEP funded research on why vets are leaving equine practice
- 1 year of qualitative research and interviews with practice owners, recent grads, and vet students

January 2022 AAEP Board Meeting

3 Key Initiatives

- Form a task force to investigate changes to the internship model
- Wanting to support expansion of peer mentorship groups
- Schedule a Practice Owner Summit to determine next steps of improving equine practice business model

May 2022 Practice Owner Summit

Facilitated Practice Owner Summit

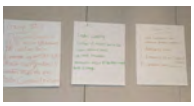
- Rep from each Veterinary Management Group (VMG)
- Rep from each Decade One group
- Several “At Large” Attendees from practices not in a peer mentorship group

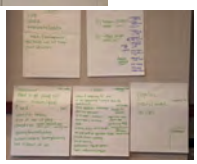
May 2022 Practice Owner Summit

Decision made to focus on:

- Internships
- Emergency Coverage
- Compensation
- Practice Culture
- Student Outreach
- Peer Mentorship groups

“Change The Numbers”





July 2022 AAEP Board Meeting

- Internship Task Force reported progress
- Peer mentorship groups & how to support them with AAEP
- Decision to start the AAEP Commission on Veterinary Sustainability
  - 5 Subcommittees charged with addressing the areas identified at the Practice Owner Summit
- Scholarship support for Decade One and MentorVet

decade one
where equine practitioners learn to thrive

MentorVet

September 2022 AAEP Executive Board Meeting

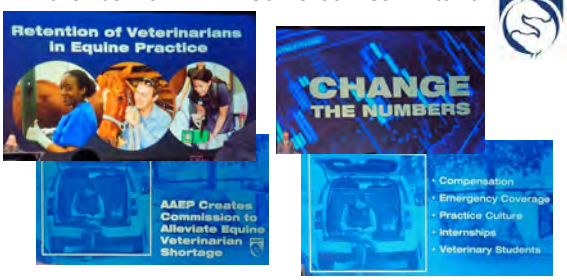
- AAEP Commission on Veterinary Sustainability
  - Co-chairs appointed
  - Committee members assigned from volunteers interested in helping with this initiative

Commission on Equine Veterinary Sustainability

- Internship Subcommittee
- Emergency Coverage
- Compensation Subcommittee
- Practice Culture
- Student Outreach

TRANSFORMING EQUINE PRACTICE

November 2022 AAEP Convention- San Antonio



November 2022 AAEP Convention

Updates

- Dr Jackie Christakos- Internship
- Dr Mike Erskine- Emergency Coverage
- Dr Jim Zeliff- Compensation
- Dr Julianne White- Practice Culture
- Dr Rhonda Rathgeber- Students
- Dr Amy Grice- Peer Mentorship Groups

Internship Subcommittee

- >70% of equine new grads choose to do internships
- Should be mutually beneficial for practice and the intern
- Educational experience
- Preparing Toolkits for prospective interns and for practices
- Chair: Dr Jackie Christakos

Internship Subcommittee- Resources

- Best Practices for AAEP Internship Practices
- Green flags/Red flags
- Core competencies
- Entrustable Professional Activities
- Taking the Reins
- Career Night Feedback Chart

Internship Subcommittee

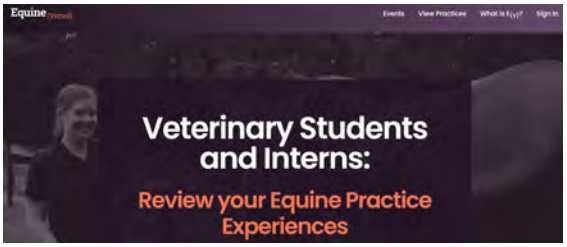
- "Avenues" is being restructured and rebranded with updated AAEP website- Transition to "Internship Hub"
- Standardized and searchable program
  - Salary and benefits
  - Contract basics
  - Average duty hours
  - Caseload
  - NOT a formal match program

Goal is transparency

Internship Subcommittee- Internship Hub

- AAEP Internship Exit Survey
  - Did program match internship description?
  - Would you recommend this internship program?
  - What improvements could this program make in the future?
- Eventually provide a "rating system" for practices as data is collected over years
  - Equinevetted.com is also working on this (website is up and running)

Equinevetted.com



Emergency Coverage Subcommittee

Emergency Coverage Subcommittee

- Common stressor for equine practitioners
- Models identified to show how other practices are providing unique options for emergency coverage
- Subcommittee will establish case studies and toolkits for these models
- Co Chairs: Drs Leann Kuebelbeck and Mike Erskine

Emergency Coverage- Current Models

- Not offering emergency coverage
- Offering part time coverage
- Haul in emergencies
- Utilizing referrals centers- emergencies & tertiary care
- Emergency cooperatives
- Telemedicine
- Utilizing vet techs for triage and treatment
- Utilizing relief vets
- Emergency only practices

Emergency Coverage- Current Models

AAEP Practice Life Podcasts

- "Strategies from the Emergency Coverage Subcommittee"
- "Creating a Shared On Call Network in Your Practice Area"

Compensation Subcommittee

- Typically lower starting salaries compared to small animal
- High student debt load
- Need to gather better data
- Co Chairs: Drs Travis Boston and Jim Zeliff

Compensation Subcommittee

Research findings related to compensation for equine vets

1. Average salaries
2. Emergency fee compensation
3. Compensation satisfaction
4. Average hours worked
5. Employee benefits in equine vet practice

Still to come…..

6. Debt load vs salary
7. # of days worked and revenue impact
8. Revenue as compensation plus production

Compensation Subcommittee

Equine Veterinary Fee Survey Data

- Data from Decade One and VMG 16 members
- Broad cross-section of geographies and practice types
- 12 mo old data
- Periodically repeat survey

Compensation Subcommittee

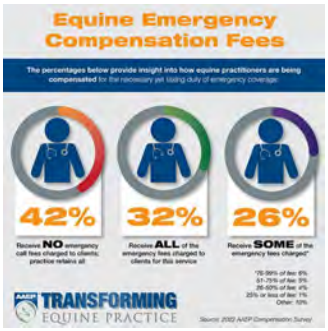
2022 Equine Medicine Salary and Lifestyle Survey

- Last AAEP Salary Survey was in 2007
- Email sent to 6,564 AAEP members
- Responses from 1,378 (21% response rate)
- Average salary of all responses $154,217
- Recent grads (2016-2019) reported average salary of $88,973

All Respondents	2021 Graduates	2020 Graduates	2019 Graduates	2018 Graduates	2017 Graduates	2016 Graduates	2016-2021 Graduates	2016-2019 Graduates (*excluding* 2021 grads & 2020 Interns)
$154,217	$45,115	$62,970	$77,601	$78,805	$91,803	$107,684	$76,581	$88,973

2011-2015 Graduates	2006-2010 Graduates	1996-2005 Graduates	1986-1995 Graduates	1976-1985 Graduates	Graduated prior to 1978	Males	Females
$123,465	$164,398	$187,044	$209,275	$177,307	$188,729	$210,873	$118,637

Table 1: Equine Medicine Salaries Overall and by Various Subgroups



Practice Culture Subcommittee

Co Chairs: Drs Stacey Cordivano & Kelly Zeytoonian

Practice Culture Subcommittee

7 pillars that contribute to a positive workplace culture:

1. Non-Salary Benefits
2. Physical & Mental Safety
3. Connection & Community
4. Mattering at Work
5. Professional & Personal Life
6. Communication
7. Opportunities for Growth

Practice Culture Subcommittee

- Communication Boundaries for the Equine Practice Handbook
- Non Salary Benefits Survey for Employees
- The Stay Interview
- The Key to Successful Teams for the Equine Practice Owner Handbook

Practice Culture Subcommittee

Student Subcommittee

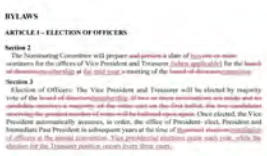
Co Chairs: Drs Rhonda Rathgeber & Scott Toppin

Fall 2023: Speaker's Bureau formed

Student Subcommittee

November 2023 AAEP Convention- San Diego

- AAEP General Membership Meeting
  - Proposed bylaws change up for vote that would allow 2 candidates for vice president and treasurer to be presented to the membership for a member vote



AAEP Governance Task Force

- Formed February 2024
- To review the bylaws and recommend changes to the Board of Directors
- Overall goal to keep the bylaws lean but modernize them to reflect the latest best practices, changes in membership desires, and technology
- Email sent to members May 16th and member comment period is open until June 17th
- Final set of revisions will be available before Annual Convention

Decade One

- Formed by Dr Amy Grice in 2015
- Peer network, career development goals, and business education
- First decade of practice or practice ownership
- Groups of 20-30 members
- Monthly virtual “Check In/ Catch Up” meetings
- Two in person meetings per year
- Meet for 3 years
- AAEP Decade One Scholarships

Decade One Curriculum

Business content modules/workshops

1. Personal & Professional Mission/ Vision/ Values
2. Financial Reports
3. Leadership/ Work Life Balance/ Boundaries
4. Effective Communication/ Negotiation
5. Small Business Primer: Inventory Management/ HR
6. Compensation/ Transition of Ownership/ Valuation

Starting Gate

- “A Winning Beginning” for equine-oriented veterinary students
- Groups of ~ 20-25 form for each graduation year – as many as needed
- New 1st year groups form annually
- Groups stay together for up to four years of veterinary school then can continue in Decade One groups for the early years of their professional careers as equine practitioners

Objectives of Starting Gate

- Minimizing attrition from the equine field before graduation
- Networking with peers from across the country
- Mentorship & Support from experienced equine veterinarian facilitators
- Planning a successful Equine Veterinary Career
- Receiving Business education to increase success
- Developing future leaders of the equine veterinary industry

Program Structure

- Monthly Zoom “Check-in and catch up” meetings with facilitators
- Quarterly Zoom educational meetings with content such as:
  - Managing Your Educational loans
  - Negotiating a Job Offer
  - Understanding Employment Agreements
  - Setting Boundaries
  - Cash flow and how to make a simple budget
  - Managing Stress and Building Resilience
  - Choosing Externships and Internships
  - Imposter Syndrome & Building Confidence

Signing Up

- Go to www.decadeonevet.com, and click on Starting Gate page tab
- Click the sign-up button
- Provide your contact information
- Write a short paragraph about why you want to be an equine practitioner
- AAEP Starting Gate Scholarships

MentorVet

- Founded in 2021 by Dr Addie Reinhard
- Community to support each other towards successful career fulfillment
- Evidence-based practices and novel research
- Online learning
- Financial coaching
- Social connections
- Vet Mentor Partnership
- Share resources
- Mental health coaching
- 10 hrs RACE CE
- AAEP MentorVet Scholarship

Kansas Equine Practitioners Group

- First meeting spring 2016
- Biannual meetings
  - February
  - October
- Lunch, Announcements, Continuing Education
- Sponsorship
  - Patterson, MWI, and Covetrus
  - Zoetis, BI, and Merck
- Currently on Board of Directors

Guiding Wildcats into Future Equine Vets

- Equine focused mentorship program with KSU students and local practitioners
- Engage students into the equine veterinary world
- Practitioners to provide information, support, and guidance
- Partnered with Boehringer Ingelheim
- Kick off event April 2022

Sustainability in Equine Practice Seminar

Opportunities in Equine Practice Seminar

- Initially ran from 2003-2012 with over 4,100 students
- Started up again in 2023
  - 273 students
  - 58 practices involved
- Travel and hotel funding provided for 3rd yr vet students to attend
- Various avenues and disciplines of equine practice, financials, employment, practice ownership, and marketing
- Presentations from practitioners, financial advisors, and practice management consultants
- Practice Exhibit Hall

Coming Spring 2024 – Register Today!

Questions?

CONGENITAL ANGULAR & FLEXURAL LIMB DEFORMITIES

JARROD TROY
DVM, DACVS-LS, CERP

EQUINE

Congenital Angular & Flexural Limb Deformities

Jarrod Troy DVM; DACVS-LA; CERP
Assistant Professor
Iowa State University Veterinary Clinical Sciences

1

Conflict of Interest Disclosure:

I have no financial interest, arrangement, or affiliation with any company or organization.

2

Objectives

- Identify congenital angular limb deformities (ALD)
- Manage/treat congenital angular limb deformities
- Identify congenital flexural limb deformities (FLD)
- Manage/treat congenital flexural limb deformities

3

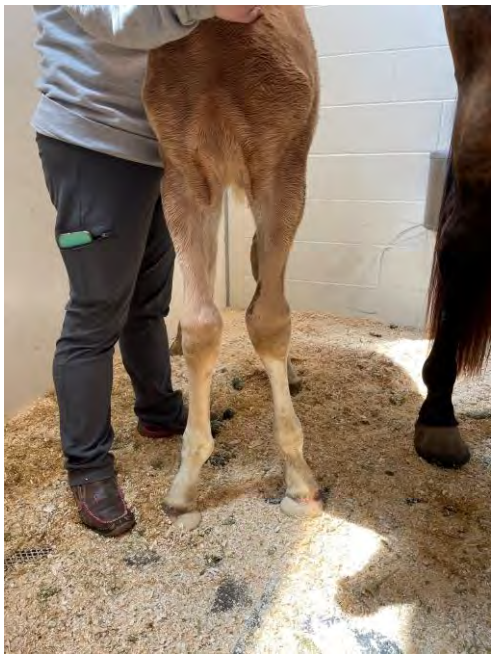
Outline

- Angular limb deformities (ALD)
- Flexural limb deformities (FLD)

4

Angular Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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Angular Limb Deformities Definition

- Lateral or medial deviation of the limb distal to a joint
- Lateral deviation – **Valgus**
- Medial deviation – **Varus**
- Joint must be described (e.g. fetlock varus)

6

Fetlock Valgus

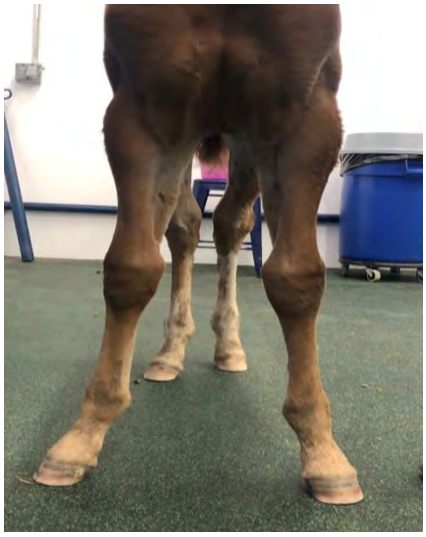
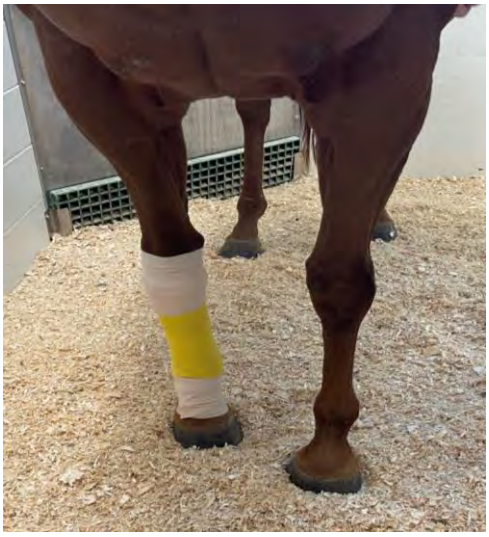


Photo courtesy of Dr. Aubrey Cordrey

Carpal Valgus & Fetlock Varus



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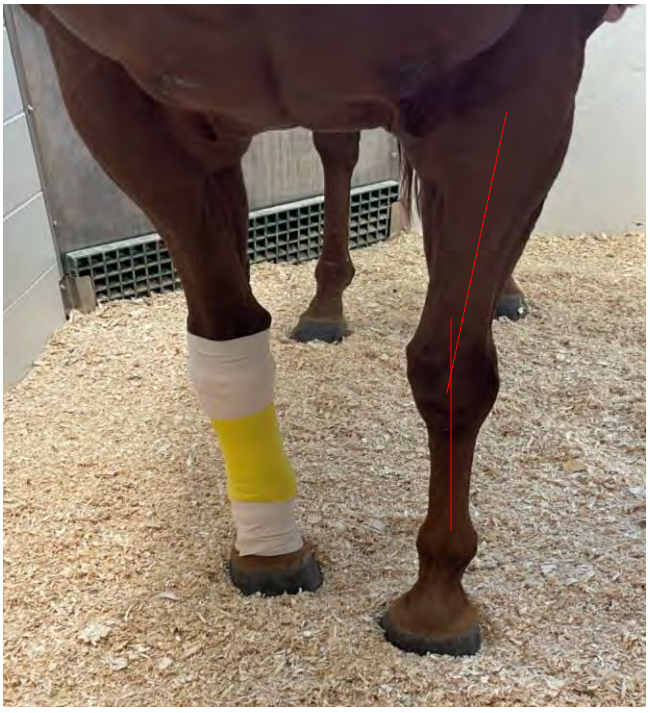

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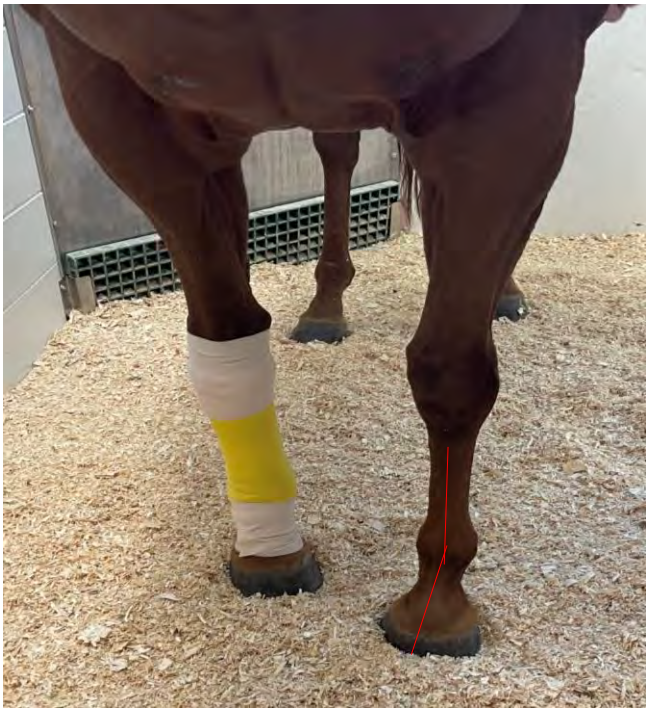

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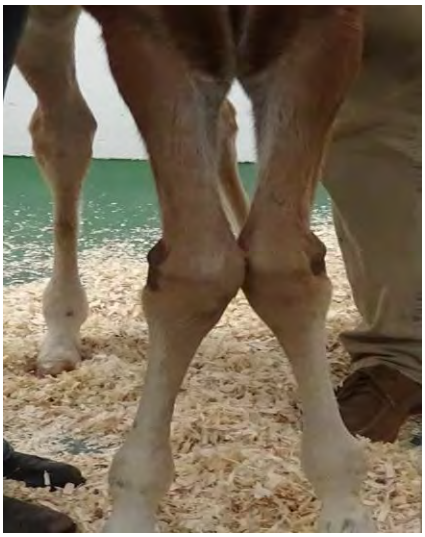
Fetlock Varus

Carpal Valgus (Bilateral)



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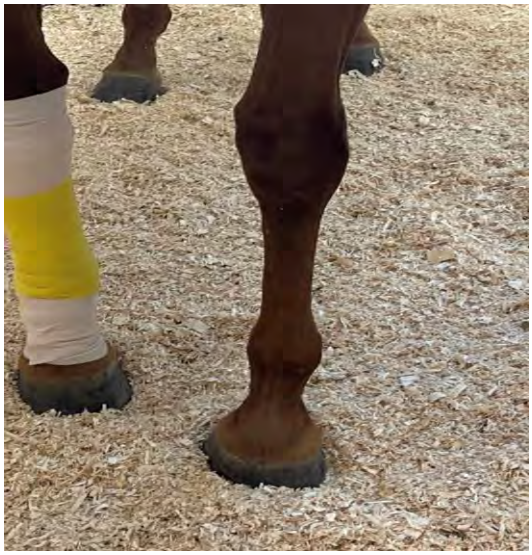
Angular Limb Deformities Lay-Terms

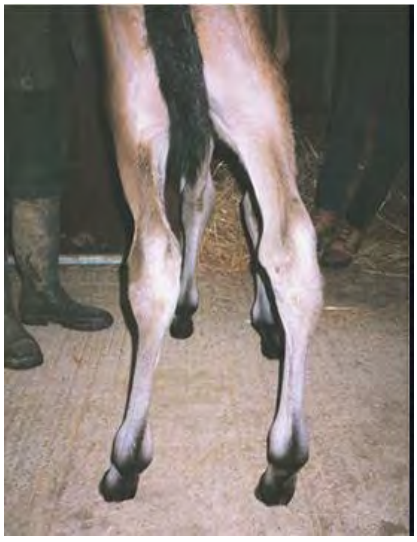
- "Pigeon toed" – inward rotation of foot due to varus deformity



11

Angular Limb Deformities Lay-Terms

- "Pigeon toed" – inward rotation of foot due to varus deformity
- "Windswept" – tarsal valgus & tarsal varus combination



https://thehorsesback.com/crooked-legs-angular-limb-deformities/

12

Angular Limb Deformities Lay-Terms

- "Toed out" – normal in foals. Outward rotation of carpus & fetlock due to lack of chest muscles

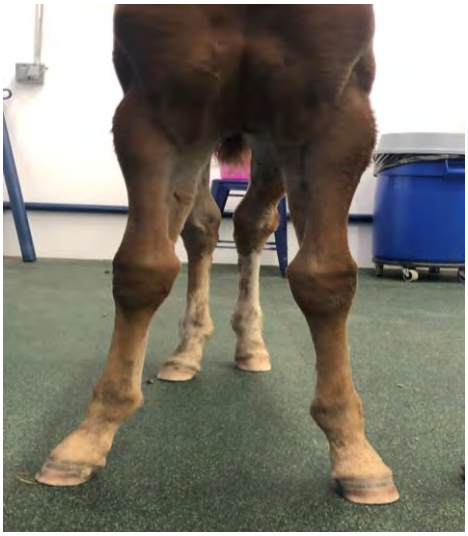


Photo courtesy of Dr. Aubrey Cordrey

13

Angular Limb Deformities Lay-Terms

- "Toed out" – normal in foals. Outward rotation of carpus & fetlock due to lack of chest muscles
- Not normal - If carpus points out but the toes point straight forward → fetlock varus

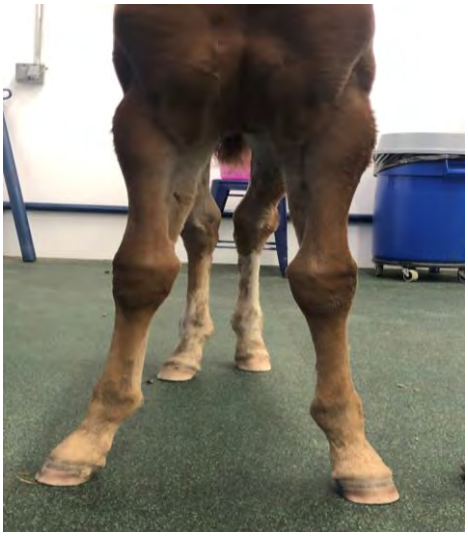
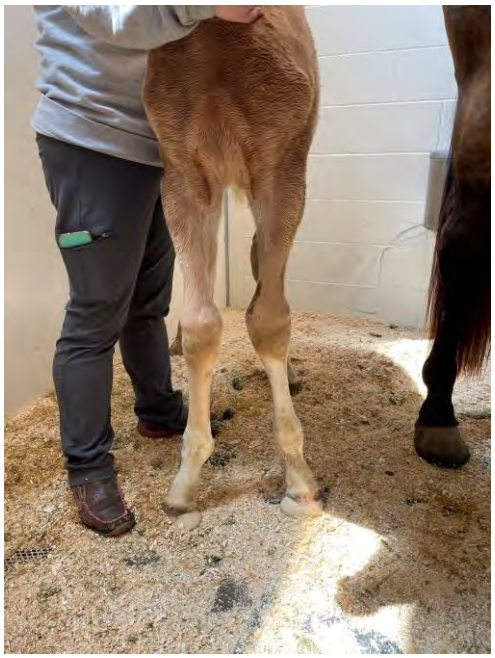


Photo courtesy of Dr. Aubrey Cordrey

14

Angular Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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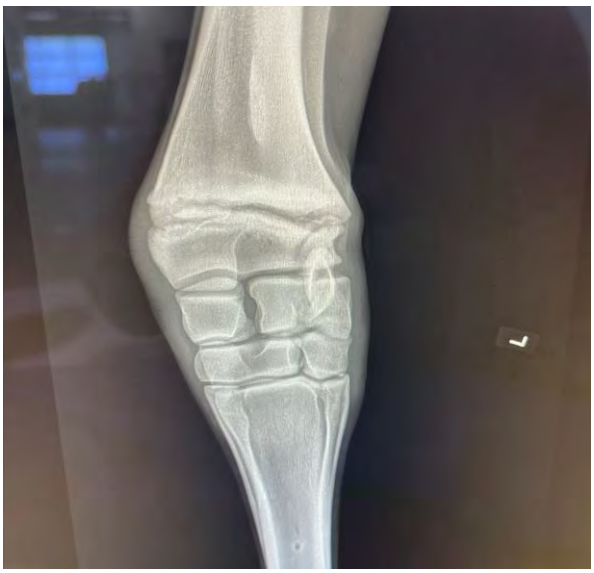
Angular Limb Causes

- Excessive unilateral physeal growth



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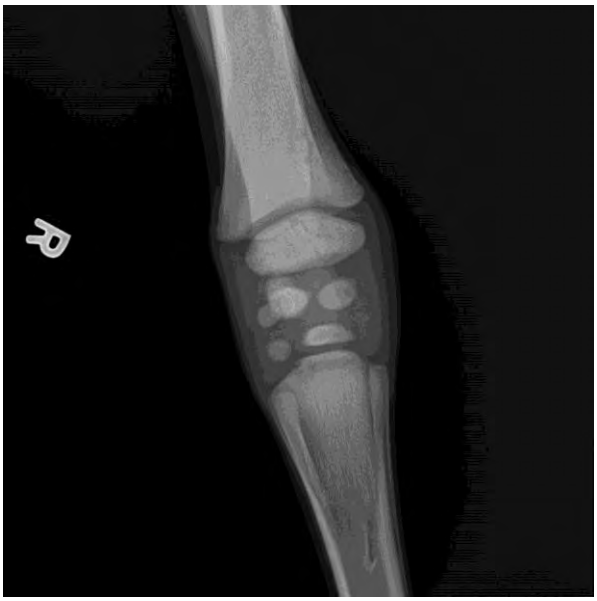
Angular Limb Causes

- Excessive unilateral physeal growth
- Incomplete ossification and crushing of cuboidal bones



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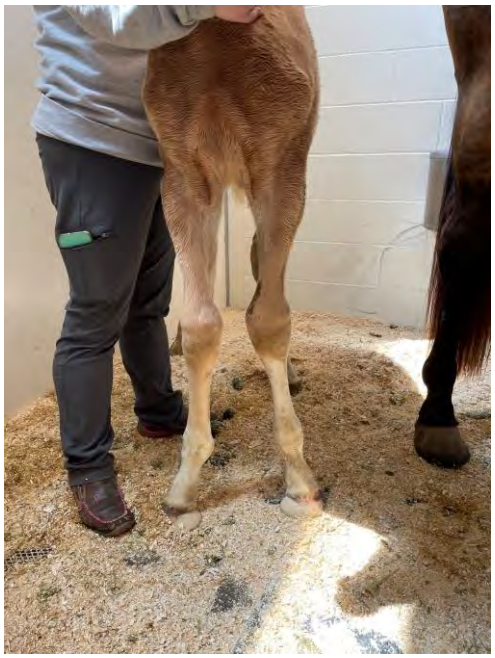
Angular Limb Causes

- Prematurity/dysmaturity
- Placentitis
- Twins
- Soft tissue laxity

18

Angular Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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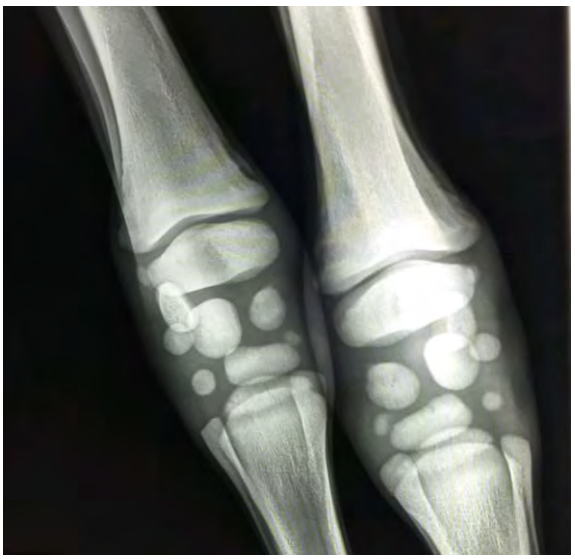
Angular Limb Diagnosis

- Observation
- Palpation
- Radiographs

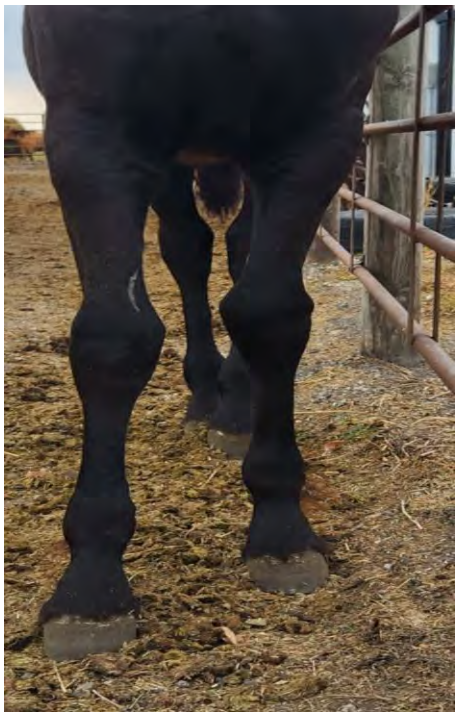


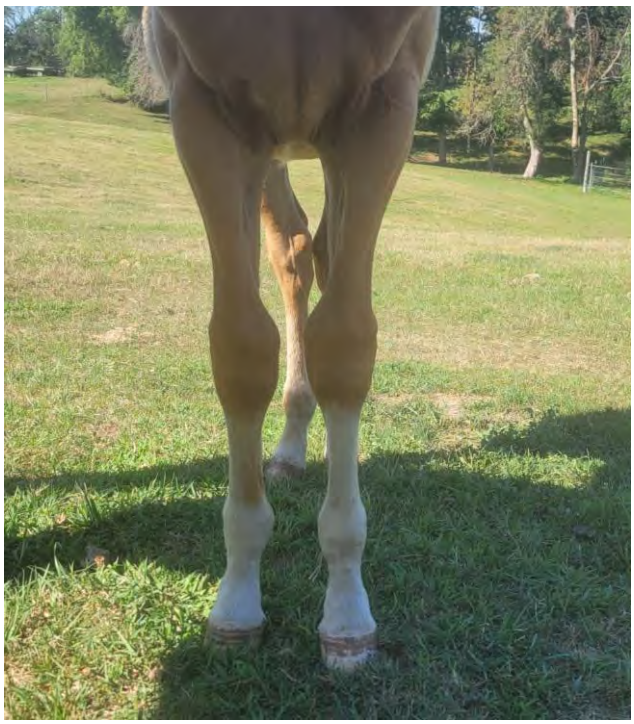
20

Angular Limb Observation

- Begin early in life
- In front of or behind the foal
- Perpendicular to frontal plane of examined limb
- Watch foal walking – may make deformities easier to see

21





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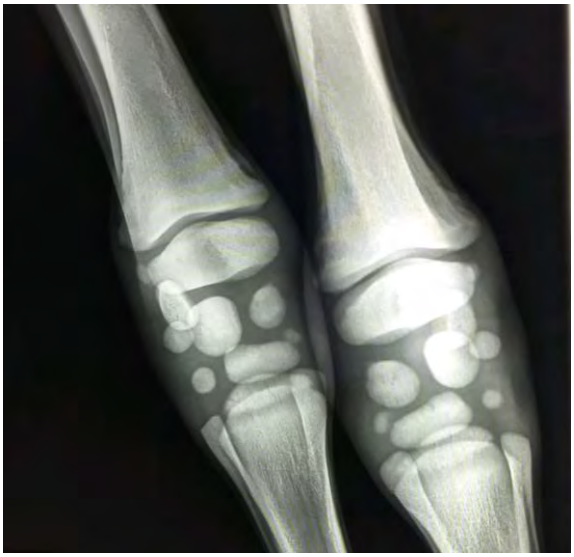
Angular Limb Diagnosis

- Observation
- Palpation
- Radiographs



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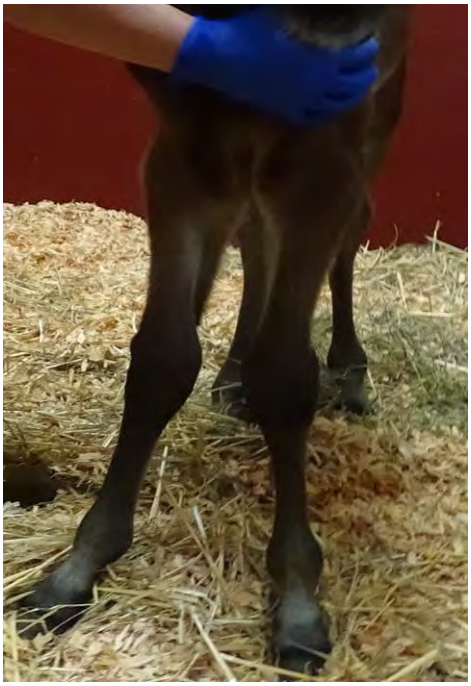
Angular Limb Palpation

- Joint laxity vs. bone change
- Move joint into normal position – laxity
- Cannot move joint – bone change



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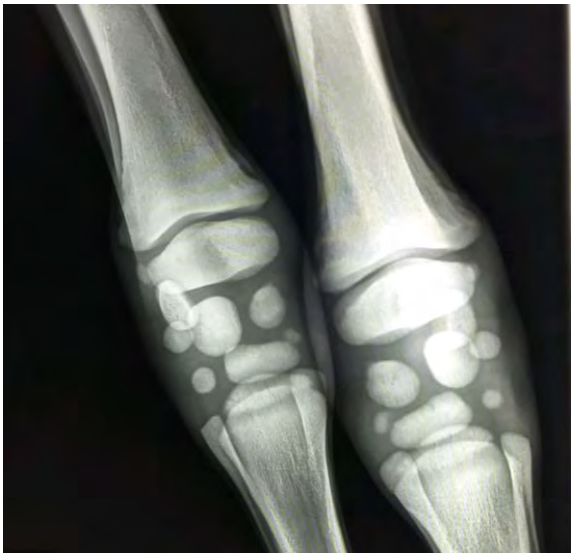
Angular Limb Diagnosis

- Observation
- Palpation
- Radiographs



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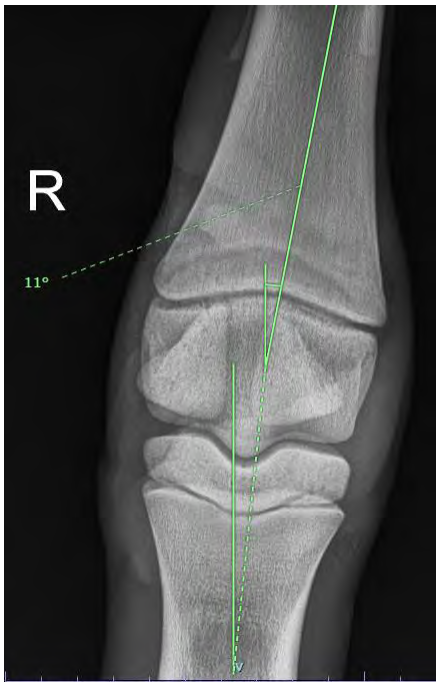
Angular Limb Radiographs

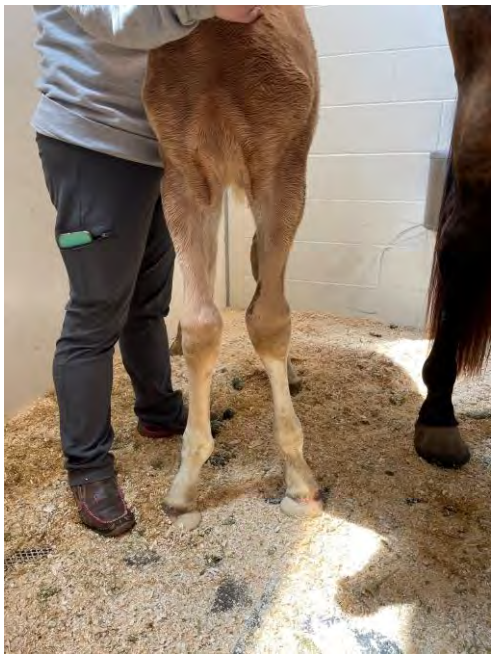
- Dorsal-palmar/plantar views
- Need at least mid-diaphysis of bone above and below affected joint
- Measure angles with diaphyseal lines – visual observation is important



26

Angular Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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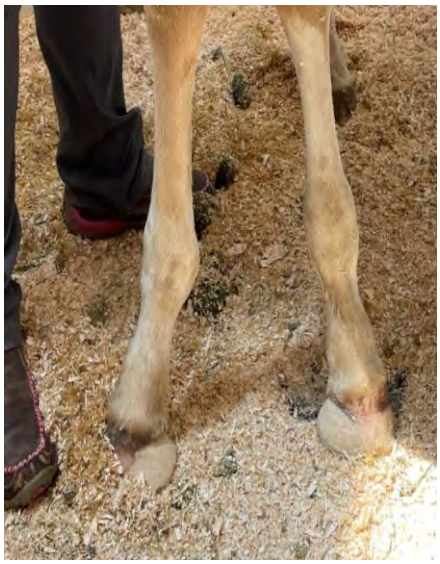
Angular Limb Treatment

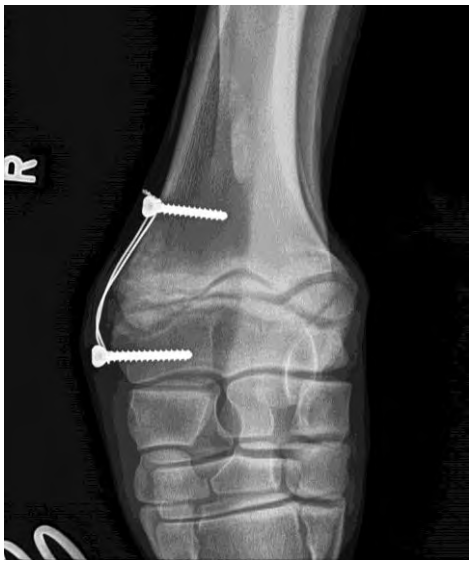
- Joint laxity – controlled exercise & self limiting
- Incomplete ossification – keep bone crushing from occurring
- Excessive physis growth – physeal acceleration or retardation

28

Unilateral Physeal Growth Treatment

- Non-surgical
- Surgical





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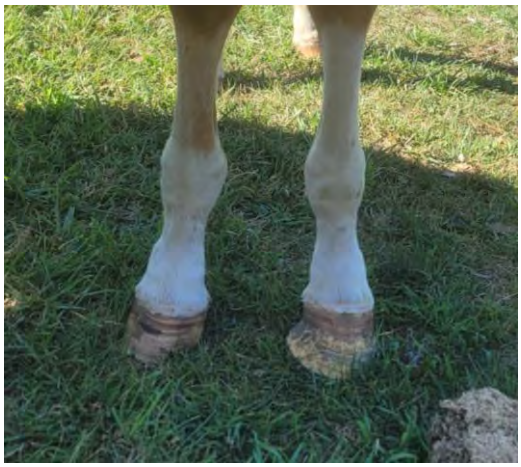
Unilateral Physeal Growth – Non-surgical

- More successful during rapid growth phase of physis
- Fetlock – 2 months
- Tarsus – 4 months
- Carpus – 6 months



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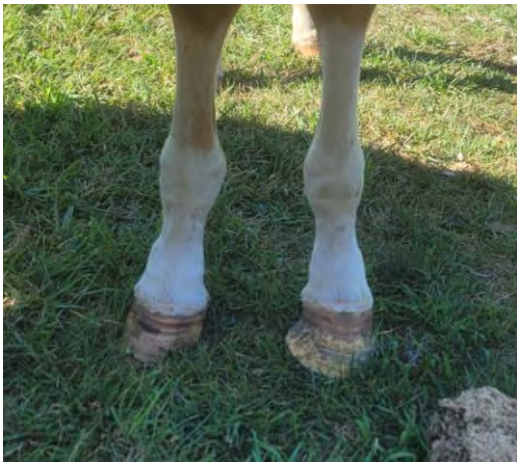
Unilateral Physeal Growth – Non-surgical

- Stall rest and controlled exercise if $>10^0$ angle
- Hoof trimming every 2-4 weeks and create large solar surface
  - Valgus – lower outside hoof wall
  - Varus – lower inside hoof wall
- Hoof extension to slow physis growth



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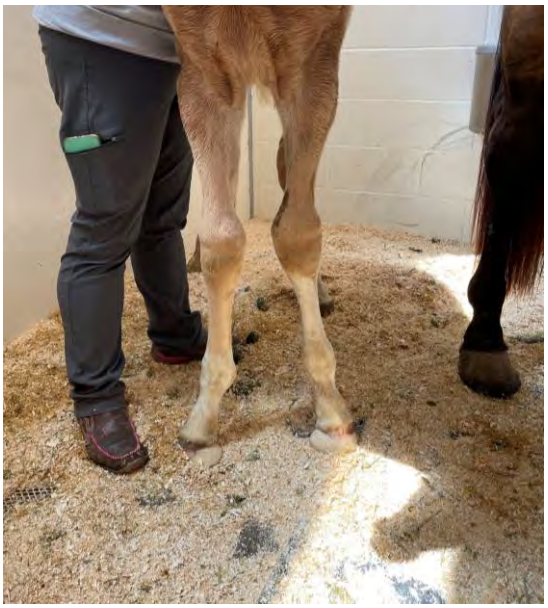

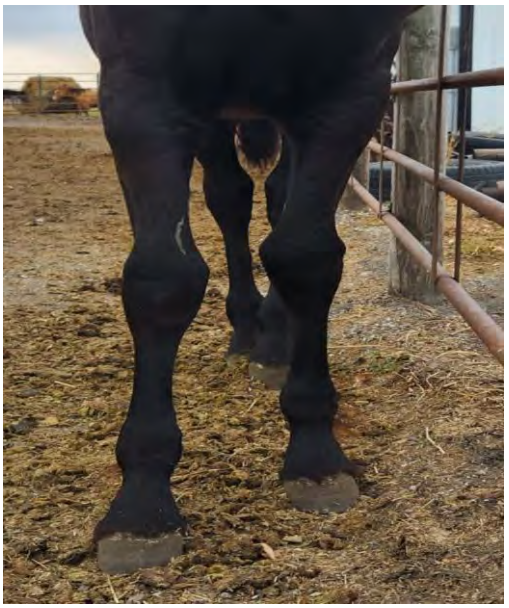

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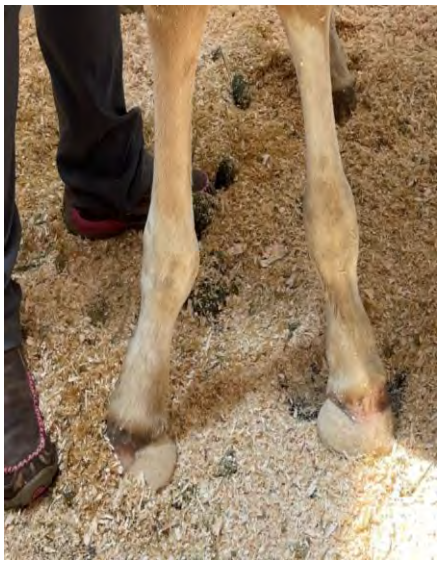
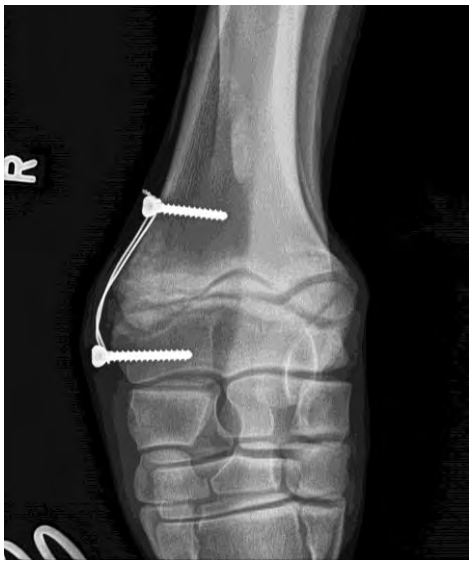
Unilateral Physeal Growth Treatment

- Non-surgical
- Surgical

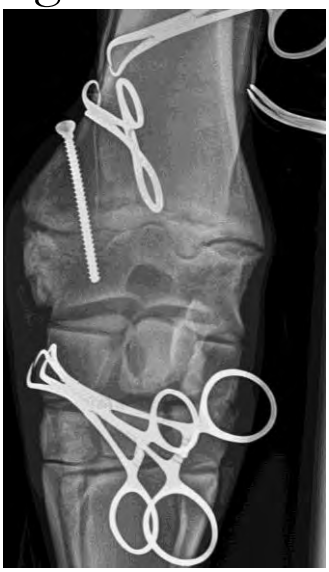




33

Unilateral Physeal Growth – Surgical

- Growth retardation after rapid growth phase or severe ALD (>10^0)
- Transphyseal bridging
- Transphyseal screw
- Implant must be removed – overcorrection for opposite ALD possible



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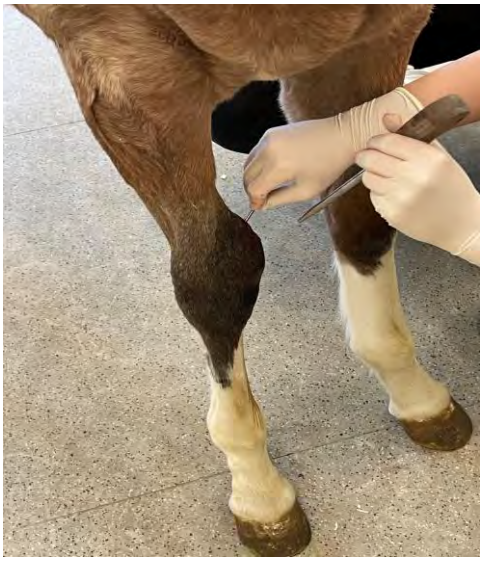
Unilateral Physeal Growth – Surgical

- Implant removal just before the limb is straight to prevent "lag phase" overcorrection
- Weekly images



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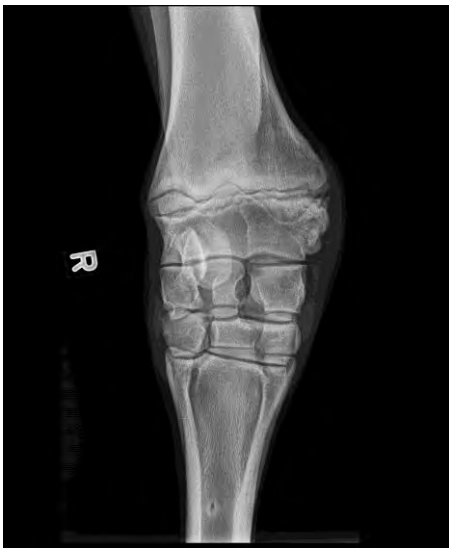
Unilateral Physeal Growth – Surgical

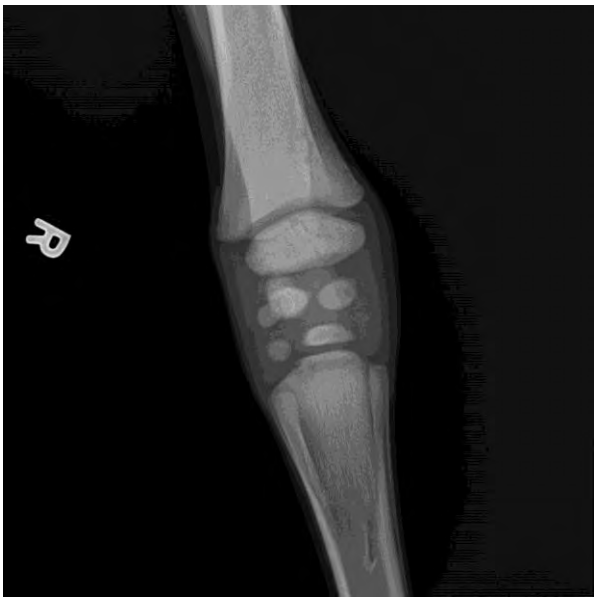
- Periosteal transection (periosteal stripping)
- Growth acceleration of "slow growing side"
- Must occur during rapid growth phase
- Efficacy is controversial



36

Angular Limb Causes

- Excessive unilateral physeal growth
- Incomplete ossification and crushing of cuboidal bones



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Angular Limb Causes

- Excessive unilateral physeal growth
- Incomplete ossification and crushing of cuboidal bones
- Diaphyseal curvature or malunion

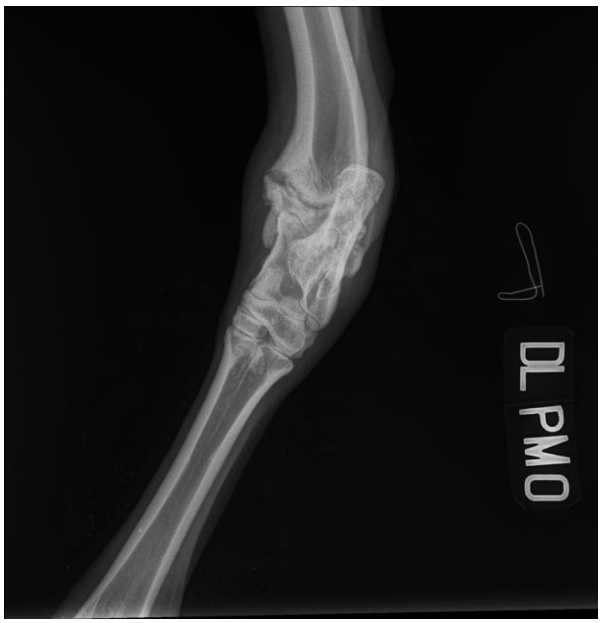

Photo courtesy of Dr. Paul Merkatoris

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Angular Limb Causes

- Wedge ostectomy
- Step ostectomy
- Implant or transfixation pin cast stabilization needed

Photo courtesy of Dr. Paul Merkatoris

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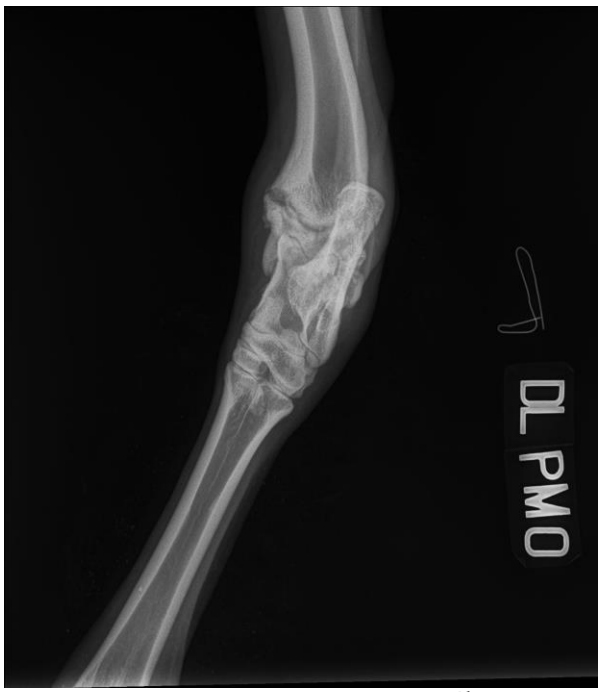
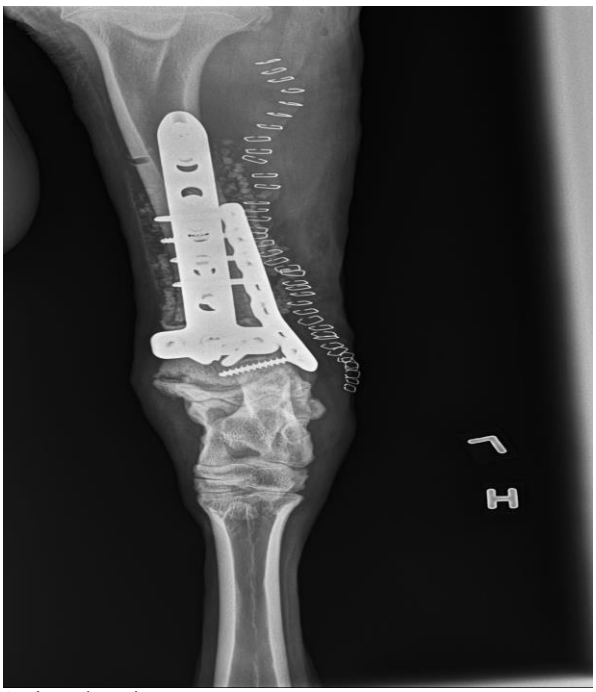


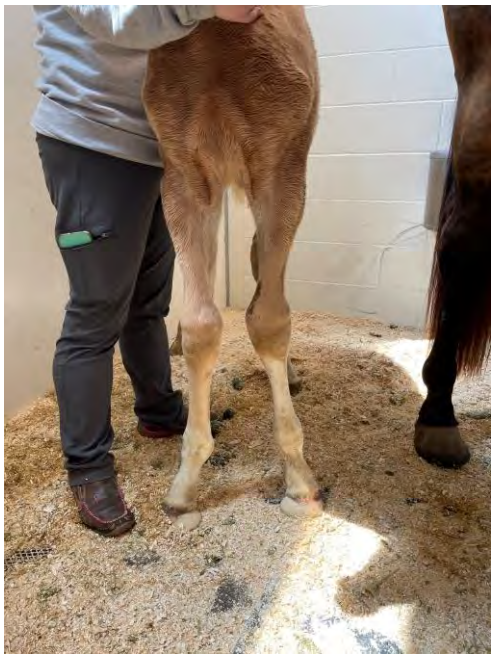


Photos courtesy of Dr. Paul Merkatoris

40

Angular Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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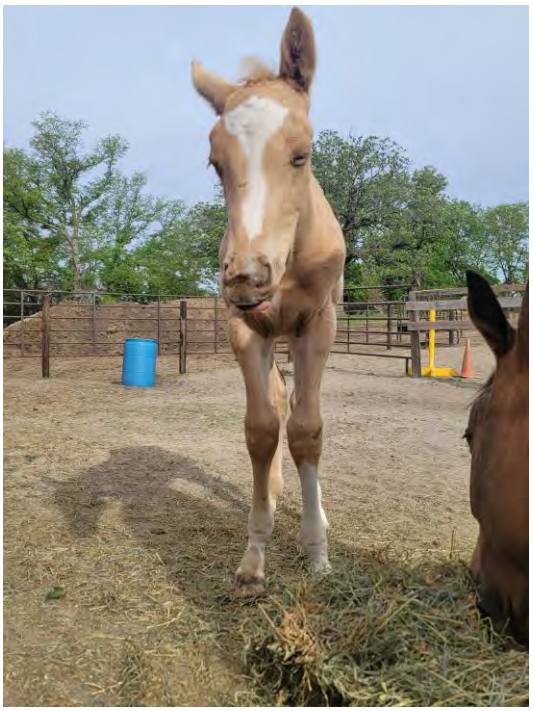
Outline

- Angular limb deformities (ALD)
- Flexural limb deformities (FLD)



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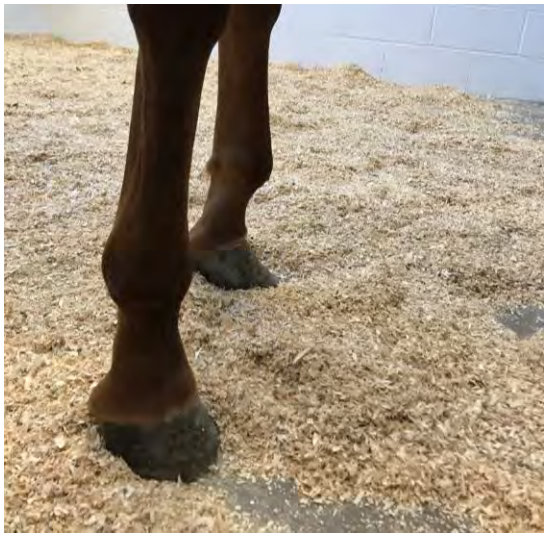
Flexural Limb Deformities

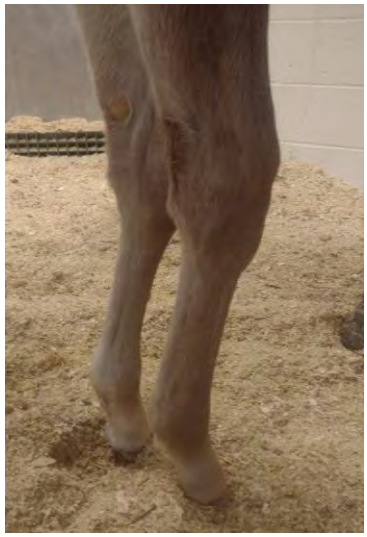
- Definition
- Causes
- Diagnosis
- Treatment



43

Flexural Limb Definition

- "Laxity" – hyperextension of a joint
- "Contracted" – hyperflexion of a joint



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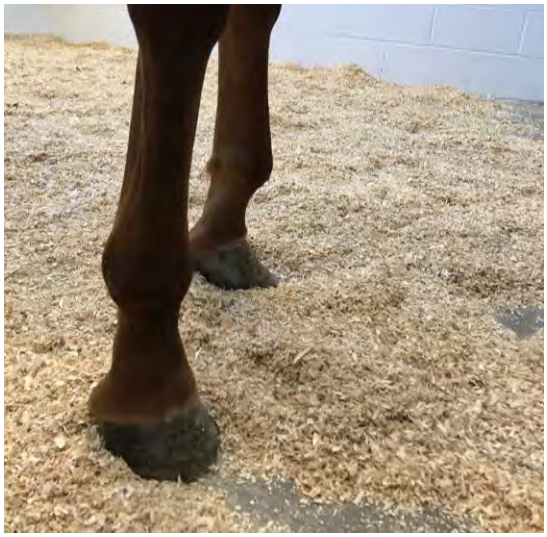
Flexural Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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Flexural Limb Causes

- Intrauterine positioning
- Genetics
- Teratogens

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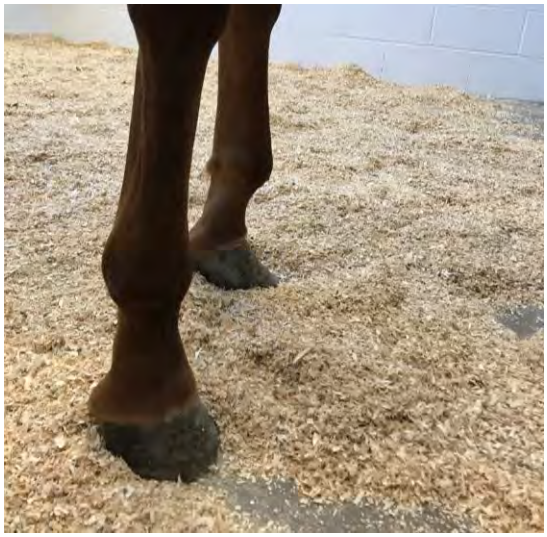
Flexural Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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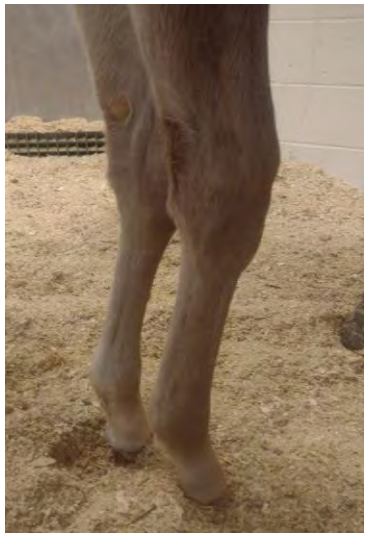
Flexural Limb Diagnosis

- Observation typically only needed
- Palpation to determine if joint can be straightened
- Sometimes radiographs



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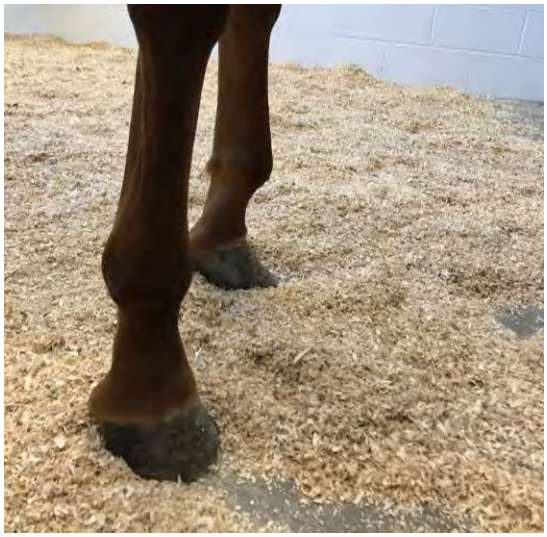
Flexural Limb Deformities

- Definition
- Causes
- Diagnosis
- Treatment



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Flexural Limb Treatment

- Laxity
- Contracted

50

Flexural Limb Treatment – Laxity

- Controlled exercise – no muscle fatigue
- Heel extension if not walking on soles
- Light bandage wraps on skin areas bearing weight (e.g. heels; fetlock)

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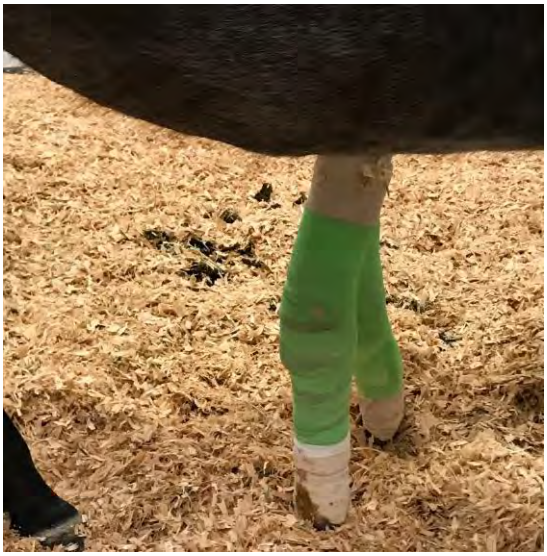
Flexural Limb Treatment

- Laxity
- Contracted

52

Flexural Limb Treatment – Contracted

- Bandages
- Caudal splints – straighten as much as possible without increasing pain
- Toe extensions
- Pain management



53

Flexural Limb Treatment – Contracted

- Splints – PVC pipe or fiberglass cast material
- Cast material molds but breaks easier
- Time with splint on and time with splint off (12 hours on – 12 hours off guideline)
- Splints risk common digital extensor tendon rupture – bandage/splint until heals

54

Flexural Limb Treatment – Contracted

- Splints need to not move out of place
- Must monitor for pressure sores – typically top, bottom, or joint areas

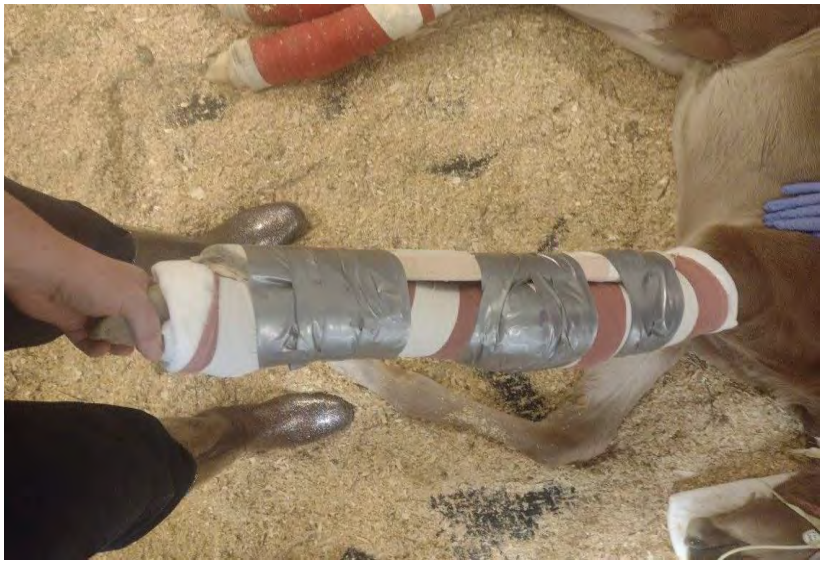


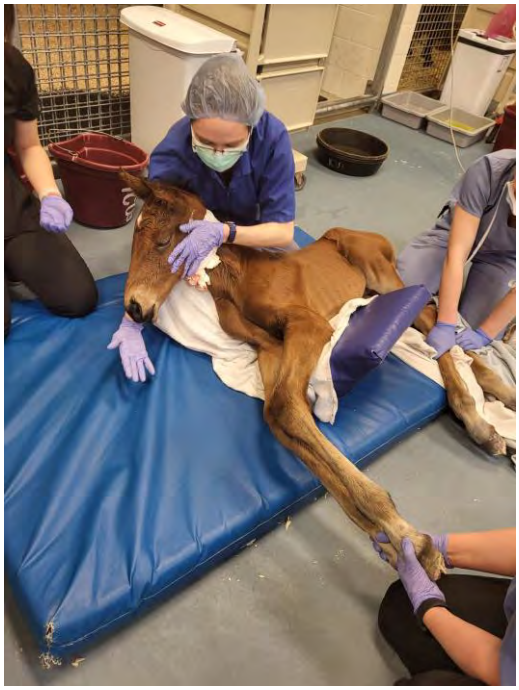
Photo courtesy of Dr. Jackie Willette

55

Flexural Limb Treatment – Contracted

- Foals unable to stand due to contracted tendons need to be managed for failure of passive transfer and sepsis

56



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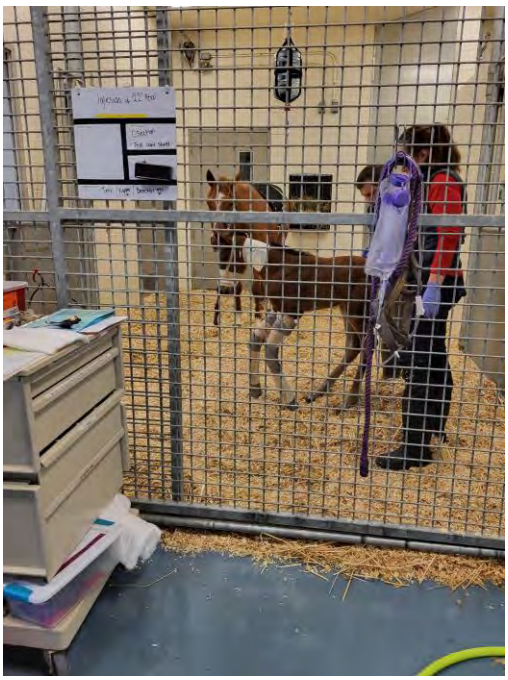

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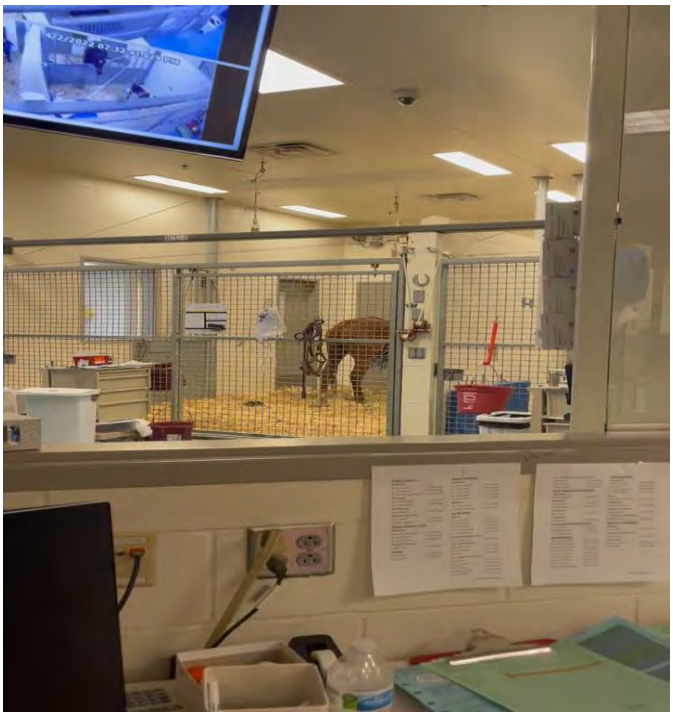

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Flexural Limb Treatment – Contracted

- Surgery if no response to non-surgical management
- Transection of flexor carpi ulnaris & ulnaris lateralis tendons
- Can be successful – concern about athleticism

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Summary

- Congenital angular and flexural limb deformities are common in foals
- Early observation aids many being managed without surgical intervention
- Surgical intervention if non-surgical management is unsuccessful or severe deformity

64

Questions?

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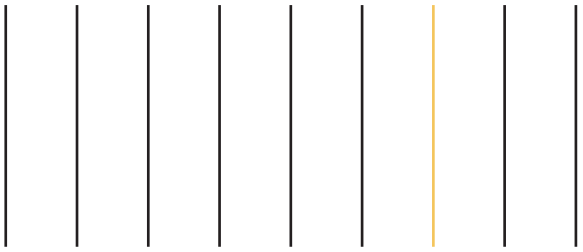
EQUINE COLIC: IMPROVING PATIENT OUTCOMES & PREPARING OWNERS FOR REFERRAL

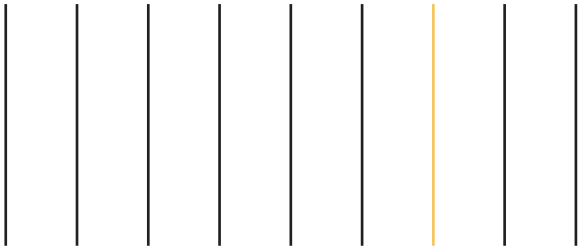
MEGHAN MCCARTHY
DVM, MS



EQUINE

NO HOOF, NO HORSE: FIELD APPROACHES TO COMMON HOOF INJURIES & DISORDERS

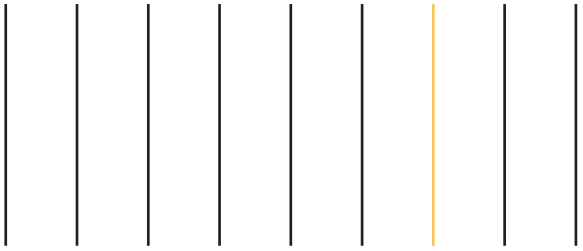
MEGHAN MCCARTHY
DVM, MS



EQUINE

EMERGENCY STABILIZATION OF THE CRITICAL EXOTIC OR ZOO PATIENT

TRENTON SHRADER
DVM



EXOTICS

Kansas State University College of Veterinary Medicine

Emergency Intervention: Exotic Pets

Presented by Dr Trent Shrader, DVM

Kansas State University College of Veterinary Medicine

Overview: Peracute Stabilization

Kansas State University

Introduction

Despite our best efforts, exotic pets commonly present to the attending veterinarian as urgent and emergent patients. A foundation of emergency management skills, accurate clinical interpretation, and interventional techniques will serve the clinician well.

In particular, consideration should be given to the potential risks to human health and safety, as well as unique patient anatomy and physiology.

Challenges of adding exotic and non-traditional pet ER care to your practice

- Specialized equipment
- Frequently, small patient size
- Appropriate staff training
- Training opportunities

Standardized Emergency Kits

6 Separate Kits

Depending on the types of exotic, or “non-traditional pets” your clinic sees, the content of your emergency kits will need to be flexible.

These are the six kits I keep readily available, based on the services we provide. Each contains specific equipment, quick dosing guides, and appropriately sized accessories to manage an emergency

Fish/Aquatics Kit

Mega-vertebrate Kit

Venomous Kit

Hoofstock Kit

Avian Kit

“General” Kit

The ABC’s of Emergency Intervention

A — **Airway**

B — **Breathing**

C — **Circulation**

Airway Assessment

Oral Cavity

Ensure an unobstructed oral cavity

Evaluate for color, jaw tone, and salivary quality (1-2 seconds)

Nasal Passage

Ensure an obstructed nasal aperture(s)

Evaluate for mucus quality, soft tissue or foreign material (1 seconds)

Palpation

For the respiratory elements that are not visually accessible

Evaluate pharynx, trachea, thoracic inlet for obstruction (2 seconds)

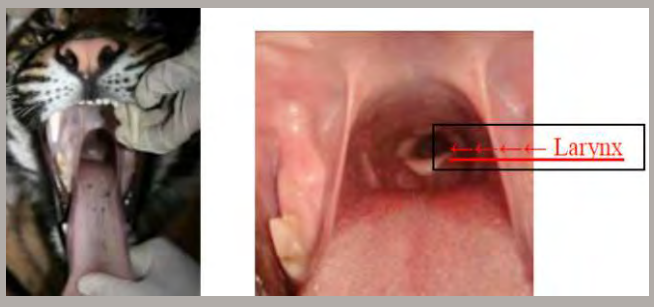
Chest Compliance

Very briefly, assess compliance to consider intrathoracic barriers to appropriate ventilation (1-2 seconds)

Airway Assessment • Oral

Effective airway assessment requires an open oral exam with extension of the tongue and visualization of the arytenoid cartilages

- This may not be possible in some species (rabbits, guinea pigs) due to small oral aperture and pharyngeal anatomy



Barlow, Adam. (2012). Wild tiger capture and immobilisation. 10.13140/RG.2.1.4877.9363.

Airway Assessment • Nasal

Not generally considered an essential component of an airway exam, many non-traditional species are obligate nasal breathers and nasal passage patency should be ensured

- I generally advise a brief (1-2 second) nasal exam even in mouth breathing animals as it may assist in your intervention technique (mouth to snout breathing may not be an option, for example)

Photo credit: Smithsonian's National Zoo and Conservation Biology Institute

Airway Assessment • Palpation

A unique component of the zoological patient airway assessment. An inability to fully visualize the aboral airway due to size, anatomy, or physiology requires palpation of the larynx, trachea, or other respiratory features

- Reminder that tracheal/oral foreign bodies may be secondary - animals that are recumbent without airway control may inhale foreign material

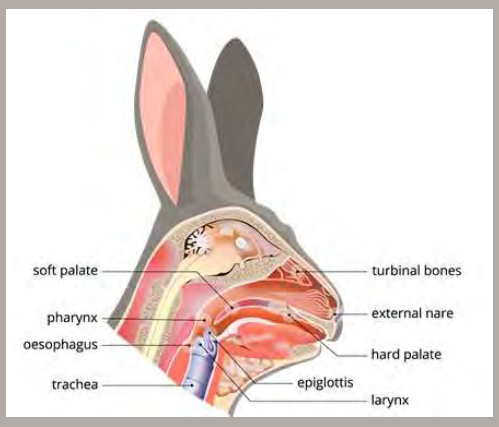


Photo credit: BioScience Media, 2017

Airway Assessment

• Chest Compliance

Another unique component of the zoological or non-traditional pet airway assessment. In some species, significant intrathoracic disease may be the cause of airway obstruction

- Initiation of chest compression in these patients can be associated with higher morbidity and mortality than we see in dogs and cats with unnecessary chest compressions, which are usually relatively benign (i.e. thymoma in rabbits)

Buckley, et al. (2011) Cardiopulmonary resuscitation hospitalized rabbits: 15 cases. 10.1053/j.jepm.2010.11.010

Breathing Assessment

Regular, unstimulated respirations are the norm in every species

Even animals associated with long periods of breath holding should be ventilating regularly during an emergency. Fish may be monitored via opercular movements. Some reptiles may have extreme pauses between breaths. Amphibians may respire through their skin and have minimal coelomic wall excursion.

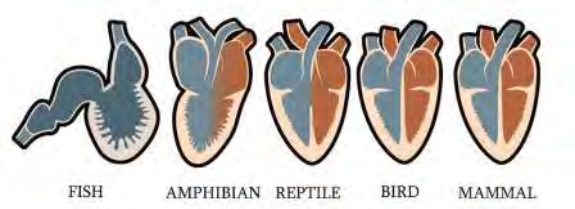
Somewhat controversial in primates

In human CPR, some experts advocate for the removal of rescue breaths from the protocol. In humans, primary cardiac arrest is more common than primary respiratory arrest, which may also be true for primates (capuchins, marmosets, and lemurs represent the most common pets). This is not believed to be the case in most mammals

Use supplemental tools when necessary

Glass slides in front of the nostrils may indicate airflow. Hands are more sensitive but being ungloved carries certain risks as well. Capnography with a nasal cannula or endotracheal tube is essential once obtained (to be discussed in detail in “monitoring”)

Circulation Assessment



Establish pulses and perfusion (CRT)

Familiarize yourself with normal locations for strong superficial pulses in mammals (dorsal pedal, femoral, carotid) and birds (superficial ulnar, direct heart palpation).

Major vessel perfusion does not indicate microvascular perfusion!

Return of spontaneous circulation (ROSC) is the primary goal of all CPR

Circulation may be more challenging to define in a small subset of exotic patients (insects with circulating hemolymph, hibernating reptiles with exceptionally low peripheral vascular perfusion

Heart contraction alone does not suffice

Auscultation of a beating heart is not sufficient evidence alone to establish the presence of vascular perfusion to the tissues

“D” is for Derivatives

Direct airway visualization may be impossible

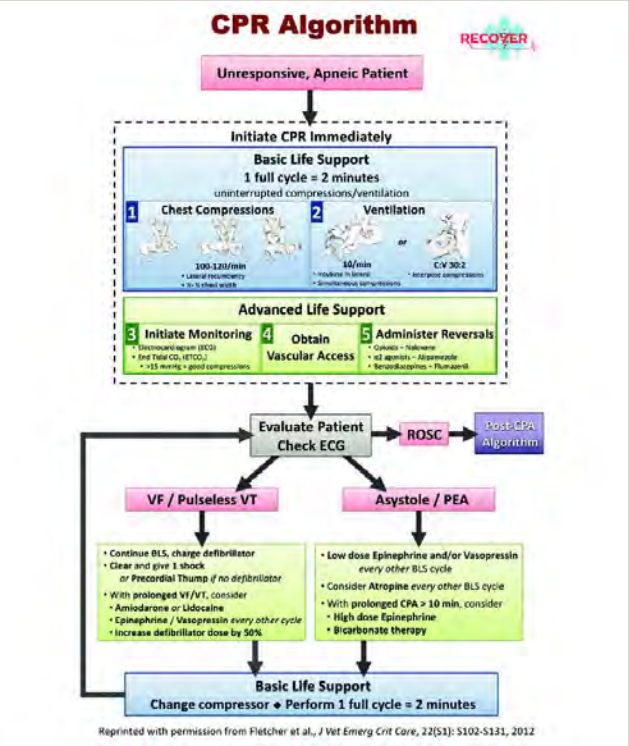
Some of your emergency patients will have anatomically unique airways - Air sacs of birds, gills of fish, dermatologic respiration in amphibians. Spiracles of insects and arachnids. These deeper/less accessible organs may be impossible to visually evaluate but you can evaluate an analogous structure (pelvic respiratory skin in amphibians, air sac auscultation in birds, fanning the gills in a fish, lateral line visualization in tarantulas/roaches/etc)

Breathing

This may be particularly challenging in fish. Is opercular movement happening (opercular respiratory rate: ORR). Agonal breathing is not a functional respiration (and so should prompt CPR) but can be tough to distinguish in birds, reptiles, amphibians.

Circulation

Establishing macrovascular circulation may be challenging in itself. Microvascular circulation is probably impossible to rapidly evaluate in a clinically applicable way for most non-traditional species



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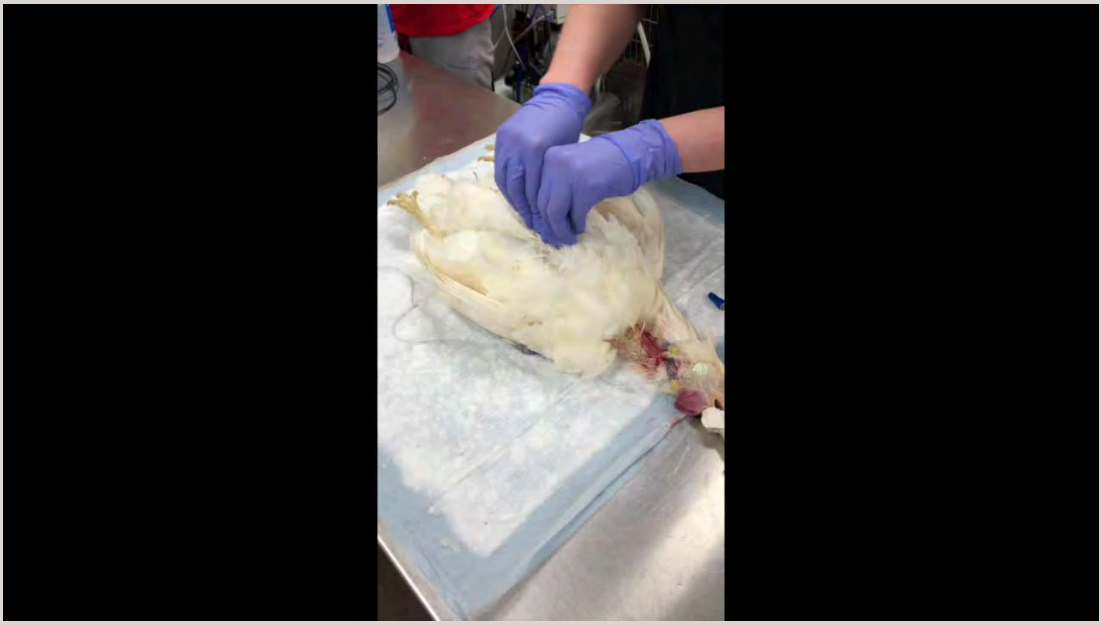
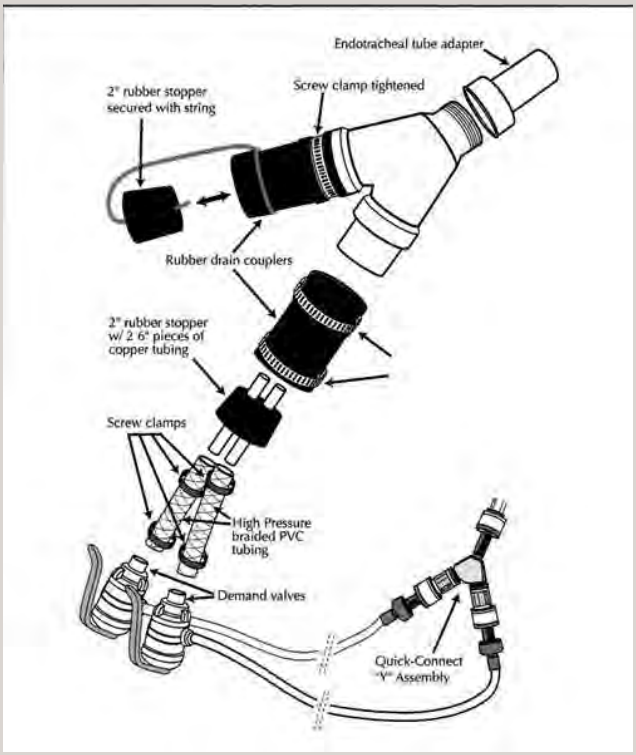
Administer CPR

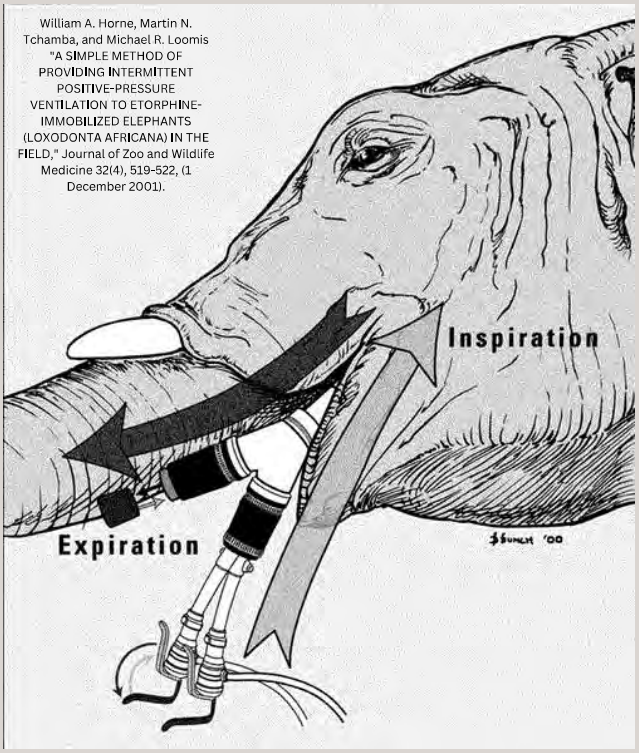
For mammals, follow the standardized protocol for CPR administration as described in the Basic and Advanced Life Support courses through the RECOVER Initiative

But first, a few unique situations:

Avian Compressions







CPR: A brief review

Start compressions as soon as arrest identified

Compressions in a healthy animal are relatively benign

Already delayed in most exotic pets

Compress the chest approx. 33-55% diameter

A rate of 100-120 bpm is appropriate for all mammals, regardless of normal heartrate. 150-170 in birds.

Intubation should occur concurrently with compressions

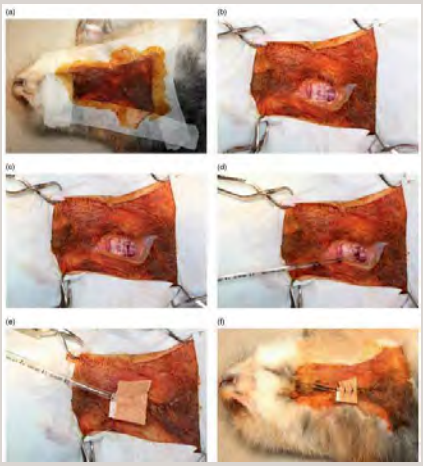
Don't stop compressions to intubate, continue while in lateral

One cycle of CPR is 2 minutes

Swap compressor to prevent fatigue

Administer epinephrine/ glycopyrrolate/ atropine every other cycle

CPR Pearls



Atropine works in rabbits:
Due to atropine esterase activity, the dose is increased and the duration of activity is reduced, but it remains a vital and effective resucitation drug

Tight fitting face masks work:
In a review of 15 rabbits, successful ROSC was achieved in over half of patients. Due to the challenge of intubating urgently, tight fitting face mask ventilation is advised in small herbivores

ROSC won't happen in a hypothermic patient:
We probably under-prioritize the urgency that thermal support should be provided to exotic patients presenting in an emergency setting. Forced air or circulating water blankets are preferred

In CPR, it's better to be close than slow:
You may not remember doses precisely or calculate volumes with exact precision but it's better to administer a slightly low or high dose during the critical seconds of an arrest

Don't let perfection be the enemy of good

Facemask ventilation or nasal intubation can be effective

In some species, emergency intubation is challenging and time consuming. Tight facemask ventilation has been shown to be very effective in rabbits for emergency resuscitation

Backup options to vascular access

Vascular access is challenging in debilitated and shock-affected animals, making some challenging species borderline impossible. Consider administration of Epi/Atropine via endotracheal tube if IV isn't available. But don't forget about oral veins! (sublingual esp.)

You aren't awarded beauty points

If your best vascular access is an intraosseous catheter, scrub and place it. Draping and sterile gloving is best but those are precious seconds. Air sac cannulation in a bird delivers oxygen just as effectively as an endotracheal tube. Duct tape is a strong and effective muzzle to secure an oral cavity around a bite block (a PVC pipe, for example)

Anesthesia of the Emergency Exotic Patient

Fundamentals and Essentials

Standardized protocols are rarely the right solution

Many clinics will have “sick cat” or “sick dog” anesthesia protocols that are mistakenly perceived as “emergency event” protocols.

Usually this means:

- Very low doses that are inadequate to sustain a sedation
- Sedation doses are designed for either
  - Fractious animals that are in extreme pain or
  - Patients too reactive to place a catheter

Think quickly, but still THINK. 30 seconds to consider comorbidities can save a life

Very ill birds and small mammals often benefit from sedation and/or anesthesia to prevent the compounding effects of stress on their disease.

Emergency Hazardous Animal Anesthesia

1. In some states and clinics, you may be asked to attend an emergency for a potentially dangerous animal
2. You will probably need to dart. Practice darting seriously and frequently, prior to accepting a call to do home visits for hazardous species
3. Multimodal anesthesia is still the preference. Mitigating the maximum dose of any one drug is desirable, unless you can’t fit the entire volume in your remote drug delivery device.

General Considerations for Emergency Hazardous Animal Anesthesia cont.

1. Ketamine - Butorphanol - Midazolam - Dexmedetomidine is usually well tolerated and allows for rapid induction while generally preserving cardiac output and spontaneous respirations in critically ill predators
    a. Again, standard protocols are generally poor plans: for example, if you have an elderly cat with known renal dysfunction, there's no need to add poor anesthetic plan and event to the other health crisis it is experiencing
2. In some large hoof stock, you may need super potent opioids
    a. These require special licensing as they can be potentially fatal to humans
3. Prepare for the anesthesia to go poorly
    a. Prepare your staff and equipment for hypotension, respiratory depression, cardiac arrest, hyper/hypothermia, etc

Emergency Non-Traditional Pet Anesthesia Cont.

Other non-traditional pets may require immobilization to allow safe access. Having a pole syringe, darting equipment, or other remote capture equipment is VERY useful. Some circumstances you may need them include:

- Extremely high stress individuals prone to capture myopathy with restraint
- Severely injured animals liable to cause further/life threatening injury to themselves
- Animals that may need to be transported substantial distances for appropriate medical intervention
- Animals that have escaped their farms/fenced areas or that have wandered into hazardous areas

Monitoring

Pulse Oximetry

Lingual is most reliable for the majority of animals

Consider the vulva, prepuce, ear, toe pad, propatagium, or other site if necessary

Non-invasive Blood Pressure, +/- IBP

NIBP is dramatically faster to acquire - forelimb, tail, pelvic limb, and tongue are all acceptable

IBP may be added once underway

Capnography

Essential tool in every intubated patient.

Can be fitted to a the back of a tight fitting face mask in non-intubated patients but accuracy is questionable - trends

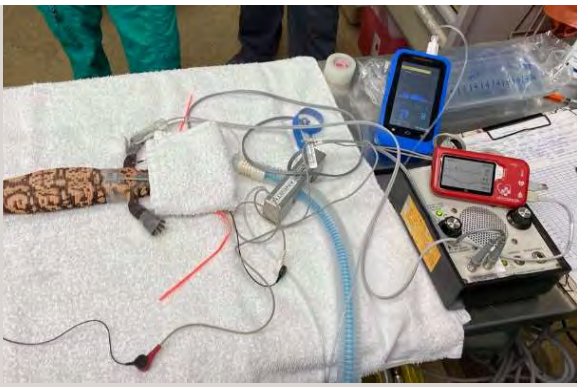
Electrocardiography

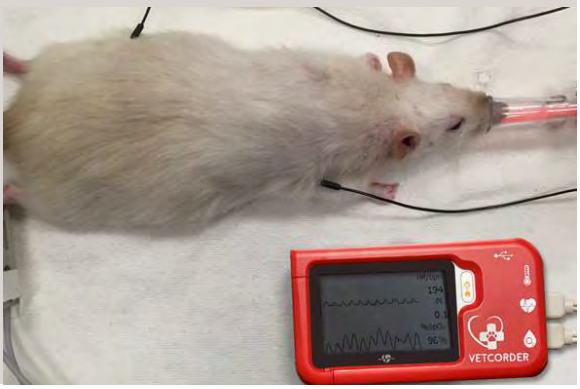
Heart rate, rhythm, and waveform with be a first indicator of many biochemical abnormalities as well

Place these four monitoring tools should be placed early and monitored continuously while the animal is still critical

There are published normals for dozens of species for normal monitor placement and expected values under anesthesia or awake

e 1. Electrode position for *Amazona ochrocephala* parrot. Red and yellow cables in superior members in the dorsal fold of the wing, black and green cable on inferior members on the knee joint.





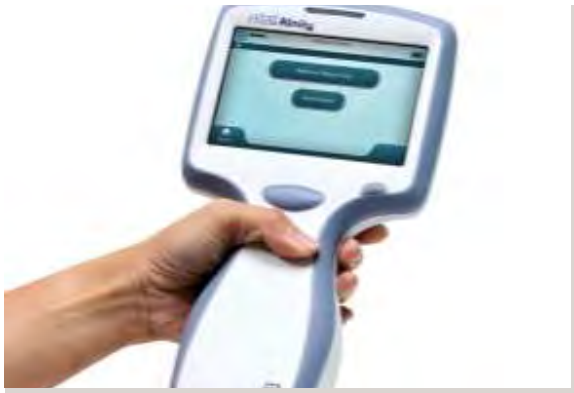
Electrocardiography in Birds

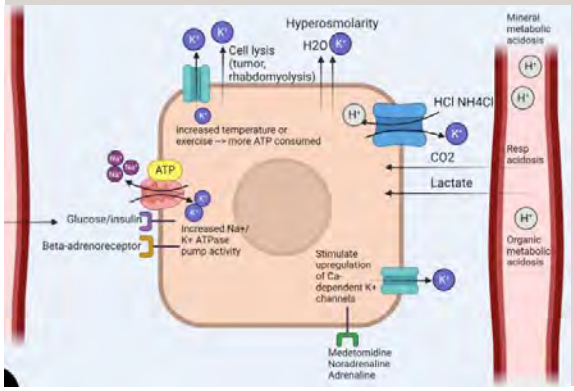
Echocardiography of small mammals readily translates from dogs and cats

- No significant differences between echocardiography and electrocardiography between breeds or sexes of rabbits

Avian ECG is best obtained as a 6-lead echo with paper speed of 100 mm/sec due to the rapid avian heart rate

- Heart rate, wave amplitude, intervals, and wave durations have all been published for a variety of avian species
- Cardiac disease is a common presenting complaint in psittacine birds and electrocardiography is an important triage diagnostic test in the acutely emergent avian patient





Continuous Blood Monitoring

Some species-specific anesthetic complications require supplemental monitoring:

- Medetomidine induced hyperkalemia (noted in big cats but seems to affect an unknown number of exotic species)
- Malignant hyperthermia in pot bellied pigs with isoflurane
- Passive regurgitation in guinea pigs
- Hyperthermia in chinchillas
- Regurgitation associated with narcotics in hoof stock
- Capture myopathy and subsequent pigmenturia with cardiac ischemia

Generally, most critical patients should have intra-procedural blood gas values collected every 90 minutes at a minimum

Oxygenation

Effective oxygenation in the emergent patient is a combination of oxygen delivery, oxygen absorption, delivery to tissue, and depletion of oxygen from the red blood cell into tissue cells

- Many, if not most, zoological animals presenting in an emergency will be experiencing some degree of hypoxia
  - Three primary interventions to reduce hypoxia
    - Increase inhaled oxygen concentration / PaO2
    - Resolve underlying acid/base imbalances impairing oxygen absorption and delivery (especially from acidosis)
    - Increase minute volume and ventilatory rate
  - Preexisting misconceptions or knowledge gaps have prevented exotic vets from addressing hypoxia to the fullest extent of our abilities

Oxygenation

Misconceptions and Updates in Exotic Oxygenation

- Birds and many small mammals must be intubated with uncuffed endotracheal tubes - False
  - Due to their complete tracheal rings, use caution with cuffed tubes in birds. However, using a syringe with a pressure gauge, they can be safely intubated
    - Maintain pressure in the cuff balloon at approx. 12 mmHg
- Reptiles should be anesthetized on room air because 100% oxygen anesthesia will make them apneic - False to Misleading
  - In a study with bearded dragons, return to spontaneous respirations after anesthesia with 100% oxygen was no different than using room air. However, this is a single species and may not represent reptiles as a whole

Oxygenation Cont.

Concepts in Oxygen support for the emergency zoo patient

- Provide oxygen early and at high volume
  - Flow-by as early as possible, then intubate and ventilate
- In species that are challenging to support, utilize specialized equipment
  - Oxygen “leaf blower” to ventilate large hoof stock in the field (Zubinator)
  - Oxygen bubbler for fish, amphibians, aquatic environments
  - Chamber oxygen prior to handling for all high stress patients (small primates, small carnivores and herbivores, et)
- Using humidified oxygen, nasal cannulas are easy and can be used for field procedures, transport, especially hospitalization
  - Staple in place, most patients tolerate extremely well

Intravenous Access

Cephalic

Preferred site for most mammals, not readily available in non-mammalian species

Ventral Coccygeal

Preferred site in reptiles, but can be an alternative catheter site in large hoof stock or a site for IV injections off the needle

Basilic Vein

Preferred site in birds for IV catheter placement and allows for bandaging the wing in place to maintain.

Alternatively, may utilize the medial metatarsal

Intra-Osseous

Catheterization of the bone is best done in a sterile field with appropriate aseptic prep. However, for patients in decompensatory shock, it an be done in a exhibit/field setting

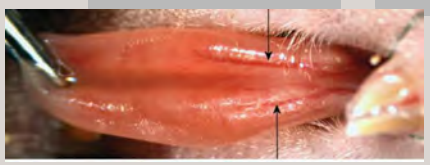
Always place some sort of venous access prior to any patient transport

Venous Access - Cont.

For urgent sampling or challenging patients, some alternative sites

Sublingual

I use this site commonly for urgent sampling in large species that have a thick fur coat. Significantly easier access compared to peripheral limbs



Medial Metatarsal

Commonly used sampling site in birds, can be easily obtained with minimal alcohol - Beneficial in hypothermic patients

Jugular vein

Preferred site for sample collection in almost every species, although can be a challenging stick in many small mammals and reptiles. Some birds (pigeons) have a venous plexus

Sub-carapacial

In chelonians, may represent an easier access site for the emergency trauma patient. Risk for ventral vertebral trauma and lymph contamination.

Fluid Therapy in the Peracute Emergency

Too large of a subject to even scratch the surface, but a few pearls from recent developments

Fluid resuscitation should be in small boluses

As a general rule, large shock boluses without time for assessment are not indicated due to the damage they may cause to the endothelial glycocalyx. This results in leakier vessels, hindering the response to treatment. 10 ml/kg then reevaluate briefly is a good rule

Use hypertonic saline over colloids

Rapidly administered colloids in the face of a septic patient or severely debilitated patient can commonly lead to movement of synthetic proteins into the interstitial fluid, counteracting the benefit of the increased oncotic pull.

Also, in large animals the necessary volume of crystalloids may be prohibitively slow to administer. Hypertonic saline will pull water from the interstitial space more quickly to return normal pressure

Stabilization of the acid/base balance is paramount

Appropriate response of the NO2 receptors in the vascular endothelium relies on a pH of 7.3-7.5 in most species. Oxygen carrying capacity of hemoglobin is diminished at lower pH, as well as vasodilation due to smooth muscle response to the acidosis

Thermal Support

Always provide thermal support prior to transport. Hypothermia and/or hyperthermia are life threatening homeostasis deviations:

- Understand the appropriate core temperature for the species you are working with
  - Marsupials (kangaroos, wallabies, opossum) are somewhat common companions that have a lower core temp than other placental mammals
  - Many small mammals have significantly higher core temperature targets than dogs and cats
- Foil blankets are extremely effective
- Forced air warmers are also effective but will need a generator/electricity or portable unit

Summary

Control the situation

You can't treat an animal you can't touch. Anesthesia of the critical patient is concerning but necessary. Time is of the essence and it's best to be assertive in controlling the patient

Monitor Monitor Monitor

Appropriate intervention is dictated by testing, not guessing. Test and respond frequently and consistently until the patient is fully recovered and awake.

Stabilization isn't about style

It's great to have a plan but the reality is that outcomes are the only thing that matters. Use personal clothing as blankets, draw blood from odd places, make educated guesses with doses but you don't have time for a lit review. Always review your cases afterward to see if there are ways to bolster your preparedness.

Questions?

BOVINE LEUKOSIS VIRUS CONTROL, FARMERS PERCEPTIONS, NEW STRATEGIES & OLD REMEDIES

FRANK VAN DER MEER
DVM, PHD

LARGE ANIMAL

Bovine Leukosis Virus control, farmers perceptions, new strategies, and old remedies.

Frank van der Meer, Sulav Shrestha, Alessa Kuczewski

In North America, almost 90% of the dairy and beef herds are infected with BLV with the within-herd prevalence of approximately 40% and 55%, respectively. These numbers are very similar in Canada.
Investigation of within-herd BLV prevalence rates among Canadian dairy herds with the convenience samples revealed a median within-herd BLV prevalence of 40-50%.
The natural hosts of BLV includes cattle (Bos taurus, Bos indicus) and its closely related species water buffalo (Bubalus bubalis), and yak (Bos grunniens). However, experimental infection is possible in diverse hosts including sheep (Ovis aries), goats (Capra aegagrus hircus), and rabbits (Oryctolagus cuniculus). The broad host range of BLV can be attributed to the expression of cationic amino acid transporter 1 (CAT1)/solute carrier family 7 member 1 (SLC7A1) in these hosts' cells which functions as the receptor for BLV.

The transmission of BLV virus can occur horizontally or vertically. A free BLV virus is unstable in the environment, therefore natural infection with BLV occurs primarily by exchange of BLV-infected cells present in the bodily fluids such as milk, blood, and colostrum.

Horizontal transmission
In dairy farms, iatrogenic procedures such as using blood infected needles provide ample opportunity for transfer of BLV-infected cells. Reuse of needles have been associated with increased BLV herd prevalence, indicating the risk of transferring BLV infection being high when injecting a BLV-infected animal followed by a non-infected one with the same needle. Rectal palpation experiment conducted with reuse of palpation sleeves that had been used in BLV-infected animals demonstrated a high risk of seroconversion in BLV-negative animals, as opposed to using new sleeves for every animal. However, single use of needles or rectal palpation gloves failed to reduce BLV incidence in a separate study. This suggests that the invasiveness of the procedure and the extent of infected blood exchange opportunity may contribute to the risk of BLV transfer. Additional potential routes include herd management procedures such as dehorning and tattooing. Use of gouge dehorners without sterilization has been associated with increased BLV prevalence in epidemiological studies. Electric dehorning or sterilizing dehorners after use might minimize the BLV transmission risk.
Hematophagous arthropods may pose BLV transmission risk dependent on the geography and season, which contributes to the insect population and biting incidence. Experimental infection by inoculating mouth parts of hematophagous flies that fed on blood from a BLV-positive cow was able to cause seroconversion in BLV-negative cattle. However, the role of these flies in transmitting BLV under natural grazing conditions remains to be elucidated. Direct close contact between animals is indicated as a risk, however, the exact mechanism involved is not clear. Detection of proviral DNA in saliva and nasal secretions of BLV-

infected cattle indicates that close contact between animals may pose a risk, but this remains to be validated.
Use of semen from BLV-seropositive bulls is not regarded as a substantial risk as artificial insemination with ejaculates from BLV-seropositive bulls failed to induce infection in BLV-seronegative herd. Breeding heifers with BLV-seropositive bulls failed to demonstrate the role of semen in BLV transmission. However, BLV proviral DNA has been detected in the vaginal secretions and smegma of bulls, thus breeding routes cannot be completely ruled out as a risk for BLV transmission.

Vertical transmission
Perinatal transmission of BLV can occur from a BLV-infected dam to its calf and the risk is greater if the maternal BLV proviral load is high. Evidence of identical BLV genomic sequences in the dam and its infected calf highlights the possibility of intrauterine BLV transmission.
The frequency of milk and colostrum-borne BLV transmission was reported to be much lower than other direct contact routes. Intraperitoneal inoculation of leukocytes harvested from the colostrum of a BLV-infected Holstein was able to establish infection in sheep, suggesting the infectious potential of BLV-infected colostrum/milk. However, milk and colostrum from BLV-infected dam also impose a preventive role as these anti-BLV maternal antibodies are detected for 3 to 9 months in calves. This can be confirmed by the results from an in vitro experiment that demonstrated colostrum containing significantly higher antibody titer than serum but lower proviral load than blood. In order to acquire this passive immunity while minimizing the transmission risk, a simple treatment of freeze-thawing of colostrum can be recommended.

Pathogenesis
Bovine leukemia virus causes enzootic bovine leukosis (EBL), and primarily targets CD5+ IgM+ B-lymphocytes, wherein it integrates its reverse-transcribed genetic material into the host's genome, forming a provirus and inducing a lifelong, persistent infection. Additionally, BLV provirus integration in other cells such as T-lymphocytes, monocytes, granulocytes, and mammary epithelial cells have also been reported, however, the tumor cells are only specific to the CD5+ IgM+ B-cells.
Bovine leukemia virus and HTLV-1 are closely related, and often these two models are studied to understand the initial phases following infection with both viruses. In the HTLV-1 model, the viral spread occurs through cell-to-cell contact following entry. After primary infection, the virus replicates either by an infectious cycle or clonal expansion. The infectious cycle involves new target cell infection through cell-to-cell transfer of viral particles, reverse transcription of the viral RNA, integration of the DNA copy of virus into the host chromosome forming a provirus, viral protein expression, and virion budding. The clonal expansion mechanism involves mitotic division of the cells harboring the integrated provirus.
Early BLV infection is characterized by opposing forces: i) BLV favoring proviral integration into genes or promoters leading to clonal expansions, and ii) a massive depletion of the proviruses integrated next to the transcribed regions as a result of increased viral

expression and increased exposure to the host immune response. The interplay of these opposing forces drives the BLV proviral load establishment in the host.

Progression of BLV infection

Classically, the progression of BLV infection was categorized into different stages: aleukemic stage, persistent lymphocytosis (PL) stage, and lymphoma stage. This framework implied that the persistent lymphocytosis and lymphoma stage resulted after a gradual progression of BLV infection and the expansion of blood lymphocytes. However, this theory has been challenged by recent findings which indicate that the persistent lymphocytosis stage can manifest shortly after infection and does not necessarily require a slow, gradual progression of BLV infection. Considering the importance of BLV proviral load in the current BLV diagnostics, it is necessary to understand how quickly the BLV provirus establishes itself following infection and whether the proviral load remains consistent or fluctuates over time. This information is useful for monitoring in BLV control programs. Longitudinal experimental studies have indicated that the proviral load is established shortly after infection and remains relatively stable over time. However, experimental studies may not accurately represent a natural infection due to the variation in the size of the inoculum. A natural BLV infection longitudinal study has suggested that the fluctuations in lymphocyte count over time may not necessarily be a consequence of gradual disease progression, and proviral load does not demonstrate significant increments with time.

Impact of BLV infection

Following a BLV infection, the host's immune system is activated, engaging both humoral and cell-mediated immune responses. This results in persistent antibody production throughout the host's lifetime. However, a gradual reduction in helper T-cells (CD4+) and cytotoxic T-cells (CD8+), along with disruptions in the proliferation and apoptosis of blood lymphocytes, adversely impacts the immune and vaccination responses in the host. The suppressed immune system renders BLV-infected animals more vulnerable to secondary infections. Cattle infected with BLV, exhibiting elevated white blood cells (WBC) and lymphocytes, have a higher incidence of subclinical mastitis compared to BLV-seronegative cows or BLV-seropositive cows with normal WBCs and lymphocytes. The severity of mastitis is also higher among BLV-seropositive cows with high proviral loads. Additionally, BLV infections results in a 30% incidence of persistent lymphocytosis and 5-10% of these lead to cases of lymphoma among infected animals, severely impacting animal welfare.

The assessment of BLV's impact on the milk production of individual animals and at herd level has varied results. Apart from milk production, BLV infection influences cow longevity, with BLV-infected cattle reportedly having a higher likelihood of leaving the herd earlier than their non-infected counterparts.

Diagnosis

A significant proportion of BLV-infected animals (70%) do not exhibit visible clinical signs. In such circumstances, BLV detection becomes challenging without specific clinical tests.

Historically, age-dependent normal reference intervals for lymphocyte counts were established in Danish cattle, to screen for leukemic cattle in 1963. Although this method was successful in eradicating EBL from Danish herds, the application of this method in the current North American dairy herds may be complicated because of the breed, genetic changes, increased production, and environmental differences. Additionally, with only 30% of BLV-infected cattle demonstrating lymphocytosis, relying entirely on lymphocyte monitoring will not detect all infected animals.

A more reliable BLV diagnostic strategy includes detecting the host's immune response against the virus through serological tests and detecting the proviral genome using polymerase chain reaction (PCR) tests. Serological assays, such as radioimmunoassay (RIA), agar-gel immunodiffusion (AGID), and enzyme-linked immunosorbent assays (ELISA), can be used to detect the antibodies against BLV, commonly anti-gp51 and anti-p24, targeting envelope glycoprotein and viral capsid protein, respectively. These antibodies are expressed throughout the host's lifetime following BLV infection. ELISA is reliable and flexible as it can be used to screen various sample types including serum, milk, and colostrum. Commercially available BLV ELISA kits have demonstrated a relative sensitivity of 100% and relative specificity of 95-100%, making ELISA a readily available BLV diagnostic test.

Another BLV detection method involves detection of a segment of the proviral DNA. Various PCR methods such as conventional PCR, nested PCR, real-time quantitative PCR (qPCR), and direct blood-based PCR, have been applied to amplify targeted BLV proviral sites. Experimental studies have indicated that BLV proviruses and antibodies can be detected as early as 24- and 36-days post-infection, respectively. This implies proviral detecting methods enables the identification of BLV infection earlier than antibody detection. However, PCR methods require a complicated sample processing and stringent protocols to avoid cross contamination, which increases the testing cost and cannot be performed without proper laboratory facilities.

The host genome can get integrated with multiple copies of BLV proviruses. Quantitative PCR (qPCR) methods enables quantification of BLV proviral load, which is expressed as the number of BLV proviruses per denominator such as quantity of DNA or endogenous genes. Multiple approaches to quantifying BLV proviral load are implemented, with differences existing in the choice of target BLV gene for amplification, qPCR assays employed, and methods used in proviral load calculation. Categorization of BLV-infected animals into high (HPL) or low (LPL) proviral loads is rendered to be crucial as HPL cows are considered a higher risk of transmitting the virus than LPL cows. Additionally, quantifying BLV proviral load serves as a method to monitor infection status and infectivity in BLV infected animals.

BLV control

Over the years, various control strategies were tried, sometimes organized, but most of those failed due to difficulties in maintaining biosecurity, encountering practical challenges, or just plain 'control fatigue' which comes down to losing interest. None of these programs were mandatory, and generally small scale. It is not easy to maintain a set of best management practices 24/7, 365 days/year, especially when the only perceived benefit is to see a set of numbers (=infected animals) on a sheet of paper (=laboratory

results) go down. Only in highly infected cow herds, observable results could motivate farmers and their personnel, as the number of cows with leukosis will decline (slowly) over time when the prevalence declines as well. This is an important contributing factor to the limited success for BLV control, apart from the fact that it has been shown multiple times (especially for BVDV control) that voluntary control of a livestock virus has a low chance of success.

Which factors could motivate the farmer to actively work on BLV control? Economic incentives are most important. Clarifying to the farmers and the farmer community what a BLV infection level of on average 40% of the herd would mean in lost revenue (decreased milk production, reduced longevity and slaughter value) would be helpful. On the other hand, making clear what the interventions (increased labour, purchase of material, or lower efficiency) would cost paints a more realistic picture in which the pros and cons of BLV control can be weighed. In our economic study, which focused on the 'average farm' in Alberta, Canada, we collected all the economic data and included the potential benefit of BLV control, and the costs associated with interventions in our analysis. Different control strategies were compared, and in all cases BLV control led to a net positive financial result. Apart from the financial motivators, concerns for public health and animal welfare, striving for improvement of milk quality, peer pressure and/or higher levels of education and good realistic information will motivate farmers to increase their efforts for control. Veterinarians and other stakeholders could assist in this process by taking away barriers that could hinder control, assist in design of farm specific intervention or through the provision of incentives for delivering BLV negative milk or meat.
It should be noted however, that identification of the best management practices for BLV control is not always straight forward. Many of the 'logical' transmission routes are still scientifically debated or unproven. Routes such as mixed colostrum provision, reusing rectal palpation sleeves, or using needles for multiple cows are the first that come to mind as a transmission risk, however, it is difficult to quantify their contribution to the spread of this virus.

UPDATES ON BOVINE VIRAL DIARRHEA VIRUS INFECTIONS & CONTROL, A CANADIAN PERSPECTIVE

FRANK VAN DER MEER
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LARGE ANIMAL

Updates on bovine viral diarrhea virus infections and control, a Canadian perspective.

Frank van der Meer and Adam Chernick

The virus

Bovine viral diarrhea viruses are enveloped, single-stranded RNA viruses of the genus Pestivirus within the Family Flaviviridae. The genome of BVDV is about 12.3kb. The virus contains both 5' and 3' untranslated regions (UTRs) that flank a single, large open reading frame (ORF) which encodes the viral proteins. The 5'UTR is a highly conserved, non-protein coding region that has an important secondary structure, it is an important target for diagnostic use, most PCRs will detect this region of the genome. It functions mainly as a ribosomal entry site and is essential for infectivity. Similarly, the 3'UTR is highly structured and conserved and plays a vital role in viral RNA replication. The first protein encoded by the ORF is Npro, a viral protease that, along with a variety of host proteases, co- and post-translationally cleaves viral proteins apart and alters the host type I interferon antiviral response. The structural proteins follow and include the capsid protein (Cap) and three envelope-embedded surface glycoproteins (Erns, E1 and E2). The capsid forms a structure around the viral RNA in a mature virion. Erns lacks a transmembrane region and is secreted from infected cells, binds to host cell surface proteins and has an RNase activity. E1 is a surface glycoprotein involved in host cell binding and entry in conjunction with the E2 glycoprotein. Both E1 and E2 contain antigenic sites recognized by the host immune response, however E2 appears to be more dominant in this role. Although Erns and E1 can both induce antibodies, the majority of neutralizing adaptive immune responses target E2. p7, which encodes a protein required for infectivity and produces an ion channel in other *Flaviviruses*, sits between the structural and non-structural genes. The non-structural genes include NS2, NS3, NS4A, NS4B, NS5A and NS5B. NS2 and NS3 perform multiple functions as a single polypeptide (serine protease and helicase) and are essential for viral replication, but their most notable property in the context of persistent infection is how they act as the genetic basis for differentiating cpBVDV and ncpBVDV strains. A wide range of mutations have been shown to result in this biotypic conversion including deletions, duplications and rearrangements of the viral genome, single point mutations and recombination with other BVDV genomes or with host RNAs. It is ultimately the independent expression of NS2 from NS3 that is the hallmark of a cpBVDV strain and therefore to the development of mucosal disease. The spontaneous generation or exogenous introduction of a cpBVDV strain that is antigenically similar to a persistent, ncpBVDV strain in a PI animal will eventually be fatal.

The main host cell receptor for these surface proteins is CD46. Upon host cell binding, the viral envelope fuses with the host cell membrane and ejects its contents into the host cell cytoplasm. The viral RNA is uncoated, and the host cell machinery begins to translate the viral proteins. New virions are produced on the endoplasmic reticulum, transported through the trans-Golgi network, and released from the host cell by exocytosis.

Genetic variability and phylogenetics of BVDV

BVDV is divided into two main genotypes, BVDV1 and BVDV2 with each being further divided into sub-genotypes. Originally the naming of pestiviruses was based on the area or animal species the virus species was discovered in, however, the increase in new discovered viruses of this group made it necessary to come up with a new nomenclature: *Pestivirus* A, *Pestivirus* B (BVDV type 1 and 2), *Pestivirus* C etcetera. It should be noted that 21 *Pestivirus* A subtypes (BVDV1a-u) and 4 *Pestivirus* B subtypes (BVDV2a-2d) are discovered thus far. There is considerable genetic variation both within and between sub-genotypes. Furthermore, while numerous sub-genotypes of BVDV1 exist there are generally only a few found in any given geographic region. This genetic variation has implications for the phenotypic differences between viral isolates with antigenic differences being of particular importance with respect to vaccine development. In North America, BVDV1a, BVDV1b and BVDV2a circulate widely with BVDV1b likely being the most prevalent.
PI animals are integral to the ongoing transmission of BVDV but their role in driving genetic diversity is not clear. Although they are known to generate and maintain herd specific strains it has also been found that the population of viral genomes within a single, PI animal is highly diverse. The interaction between the refining selection of the PI animal's immune system and this diversity is not well understood but it may play a role in the ongoing evolution of BVDV.

Transmission and clinical implications

Animal production systems face many challenges with respect to raising and maintaining economically viable animal populations. One of the chief concerns of these operations are diseases which can significantly impact the production potential of animals and, as a result, the bottom line of the operation. Diseases leading to morbidity in a population can be challenging to address, particularly when infections remain subclinical and difficult to identify without laboratory diagnostic testing. BVDV is a viral infection of cattle found worldwide in both dairy and beef cattle operations where BVDV is a major production limiting pathogen. Although the precise behaviour of this pathogen will vary due to the differing nature of dairy and beef farms, BVDV has a notable and negative impact in both situations.

Although there have been cases of BVDV outbreaks associated with high mortality, fortunately this is uncommon. Most infections are subclinical and can circulate relatively unnoticed on a farm for years. Most infections are transient in nature with less than 1% being persistent. Transient infections result from the transmission of the virus from an infected host to a susceptible host. These mostly occur horizontally but may also result from vertical transmission *in utero*. These infections result in a viremia of approximately two to three weeks followed by the development of a robust, neutralizing immune response that clears the virus and produces a long-lasting immunity against the infecting strain. While viremic and during recovery afterwards the animal will experience the production limiting effects that make this such an important pathogen. These may include reduced performance metrics such as milk production and daily weight gain. Immunosuppression

is particularly noteworthy since it can lead to a variety of secondary infections. The most notable is probably bovine respiratory disease (BRD) which has a significant production limiting effect as well as mortality, particularly in feedlots. Although both biotypes have immunosuppressive capabilities, non-cytopathogenic BVDV (ncpBVDV) appears to be more potent than cytopathogenic BVDV (cpBVDV) in this regard due to the lack of type I interferon synthesis during infection. This immunomodulation of the host is proposed to play a key role in establishing persistence by supressing both the innate and adaptive immune systems. It may also be partially due to differential host cell tropism of the biotypes. Transient infections are responsible for the majority of economic losses on a farm since they represent the bulk of infection. However, on their own they would not be able to perpetuate BVDV infections for years. The virus would infect all susceptible animals and the resulting adaptive immunity would protect the herd against reinfection with that strain. PI is necessary for the long-term maintenance of BVDV in a herd.

Persistent infections

PI is the result of an *in-utero* infection with a ncpBVDV strain during the first ~125 days of gestation. During development of the fetal immune system, the viral antigen is recognized as a self-antigen. The resulting calf is immunotolerant to the infecting strain of virus and will not produce an immune response capable of clearing the infection. While other outcomes are possible from *in utero* transmission of BVDV (transient infection, abortion, and mummification), PI is the most notable and epidemiologically important. Immunotolerance of PI animals is the hallmark of such infections. These animals have very similar immune cell populations (except during mucosal disease (MD)) and have functional antigen presenting cells but seem to have a strong BVDV tolerance in their CD4-positive cells. Although they may produce adaptive immune responses to BVDV strains other than the initial one they are generally very permissive to BVDV infection. As such, the calf will develop a blood serum viremia of between 10^6 and 10^7 $TCID_{50}$/mL that can vary throughout their life. This viremia fuels high levels of viral shedding (10^4 $TCID_{50}$/g of feces and 10^6 $TCID_{50}$/mL of mucosal secretions) which continuously challenges the rest of the herd with BVDV and drives ongoing transient infections. Although the PI animal's immune system can respond against BVDV strains that are antigenically distinct from the infecting strain and therefore refining the population of viruses in the host, these animals also seem to act as a source of novel viral variants that may contribute to evading the rest of the herds adaptive immune responses and re-infecting them. In this way, a very small number of PI animals (often <1% of a herd) can maintain BVDV within a herd indefinitely.

PI animals are not easily identified in a herd but generally do not perform as well as their immunocompetent peers. As with transient infections, they have poorer performance metrics and are more susceptible to secondary infections that can lead to premature mortality. They are also capable of spontaneously developing fatal MD. MD results from the introduction of a cpBVDV strain that is antigenically similar to the persistent, ncpBVDV strain. The cpBVDV strain could be exogenous (from a vaccine for example) or due to spontaneous mutation of the ncpBVDV strain. MD is characterized by the development of lesions along mucosal surfaces and the digestive tract, diarrhea, and weight loss. It is

typically fatal within about two weeks of the appearance of clinical signs. PI animals do not always develop MD and can live to reproductive age. PI dams will produce PI calves themselves, resulting in multiple generations of related PI animals. PI bulls may also have BVDV in their semen which can induce PI in calves following breeding or artificial insemination. In summary, PI is essential to maintaining BVDV infections in a herd and plays an integral role in spreading the virus.

Vaccines

The main aspects of successful BVDV control programs include biosecurity, virus elimination and ongoing monitoring. Specific measures to control and eradicate BVDV revolve around first eliminating sources of infection in a herd and then preventing BVDV from re-infecting the herd. Clearing BVDV from a herd in regions with high infection rates relies on vaccination and identification and removal of PI animals. Most vaccines in use today are modified live, multivalent vaccines. In addition to a variety of other pathogens, the vaccines commonly used in North America contain both BVDV1a and BVDV2a strains. The primary goal of vaccination is to prevent a PI from emerging. To avoid the accidental induction of PI through the use of vaccines if a pregnant dam is vaccinated, and to elicit better antigen presentation, cpBVDV strains are usually used in vaccine production. There have also been several ncpBVDV vaccines that are protective as well, although they do not seem to be widely used. The differential immune responses resulting from Th1/Th2-like regulatory mechanisms to different biotypes also have important implications for the choice of biotype in a vaccine. Most of these vaccines result in a robust adaptive immune response against the target strain and heterologous strains to varying extents. They also yield a net positive economic benefit to the vaccinating farm although this will vary significantly from region to region.

The use of cpBVDV strains in vaccines to eliminate PIs from a group of animals (for example in feed yards) has thus far always been unsuccessful. It is not possible to induce MD using vaccines in all PIs that are present in a group of calves.

Larger scale, phylogenetic studies utilizing isolates collected over years and from across Canada demonstrate a marked diversity of viral isolates. This is true both with respect to the genotypes and sub-genotypes in circulation as well as the variation observed within these genetic groupings. The identification of BVDV1a, BVDV1b and BVDV2a in Canada emphasizes the need for vaccines to address all three sub-genotypes. While multivalent BVDV1a/BVDV2a vaccines are common in Canada, they rely on potentially suboptimal cross-protection against BVDV1b. Given the number of BVDV1b isolates identified through convenience sampling in our studies and the high prevalence of BVDV1b found using more robust sampling methods there is a pressing need to design vaccines that more explicitly protect against the diversity of viruses currently in circulation.

Other control methods

While vaccination is an effective tool for reducing economic losses at the herd level and can be useful if properly implemented, it must be used in combination with other tools as it is not capable of eradicating BVDV alone. This is largely because vaccines do not

always produce a sufficient immune response towards BVDV to entirely prevent vertical transmission of the virus and the genesis of new PI calves. Although the herd will experience a reduced burden from the resulting PI calves thanks to the vaccine-induced immunity, there is a high probability that the virus will persist in the population. To fully eradicate BVDV on a farm, animals must be tested for viremia and positive animals re-tested at least two weeks later to confirm PI. These animals must be removed from the herd and biocontainment barriers put in place. Biocontainment measures are also integral to successful eradication campaigns. A combination of tools over long periods of time is required to declare a region or farm BVDV-free.

BVDV in heterologous hosts

Bovine Viral Diarrhea Virus infections were discovered in sheep, swine, goat, many wild herbivores (deer, moose etc), camelids, but also rabbit and hare for example. The epidemiological contribution of these animals to the virus maintenance in populations is unclear. It can be expected that BVDV PIs in any wildlife species will have a difficult time surviving long enough to contribute to the circulation of the virus in the wildlife population. Any domesticated animal that can be infected and excrete the virus have a higher probability infecting the bovine herds, but good data on these 'spill back' infections is lacking. Many species of wildlife have pestivirus antibodies, however, most of these are derived of one of the 8 Border Disease Virus species. It should be noted that in the past the circulation of BVDV in swine has provided challenges to correctly diagnose Classical Swine Fever Virus infections during outbreaks, and several herds were eliminated due to the cross reactivity of BVDV and CSFV induced antibodies. Currently more specific tests should be able to avoid those situations.

IMPROVEMENT OPTIONS & DEVELOPMENTS IN BOVINE VACCINES & VACCINATION STRATEGIES

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Improvement options and developments in bovine vaccines and vaccination strategies

This text is not meant to discourage the use of vaccines, but to discuss the best strategies of vaccine use in bovines and provide realistic expectations about their contribution to infectious disease management in beef and dairy herds.
It should be noted that vaccination is not the same as immunisation. The administration of a vaccine doesn't mean that the animal can immunologically respond, will be able to resist an infection with a pathogen, or even that the disease associated with that pathogen will be milder or absent when it gets infected. Therefore, the choice of vaccines, the optimization of the circumstances for the animal to respond to a vaccine, the timing of vaccination(s), and the reduction of the risk of getting infected, amongst other things, need to be considered to ensure the best outcome possible. The best outcome could be 'prevention of disease' whereby infection is still possible, but the animal is not getting a disease, or is less affected, or 'prevention of infection' which would be ideal.

As probably every veterinarian knows, the AVMA and other organisations have identified a set of 'core' and 'non-core' vaccines.

The core vaccines are

- Infectious Bovine Rhinotracheitis virus (IBRV) (Bovine herpesvirus 1)
- Bovine Viral Diarrhea Virus (BVDV)
- Parainfluenza Virus (PI3)
- Bovine Respiratory Syncytial Virus (BRSV)
- Clostridial Vaccines (*C. hemolyticum* and *tetani* are not considered core, but are considered risk-based)

These vaccines are our best defensive tools we currently have in our toolbox. However, there is significant room for improvement, and specifically to improve the knowledge of the diseases and the pathogens. Further studies on the role of these pathogens and the interaction with their hosts are necessary to better understand the way interventions could be implemented and improved.

The BHV1, PI3V and BRSV viruses all infect the respiratory tract at different levels and with various severity. While BHV1 can also cause a systemic infection leading to for example abortions or mastitis, it is not uncommon to see reproductive tract pathology depending on the tropism of the infecting strain. Vaccinating against BHV1 will have a positive effect in the prevention of reproductive tract ailments, but the respiratory tract is not sufficiently protected. Studies have clearly indicated that BHV1 vaccines will not prevent outbreaks but could aid in the prevention or mitigation of clinical disease. PI3V and BRSV are almost exclusively infecting the lung tissue. The contribution of PI3V to the development of the bovine respiratory disease complex is far from clear. Therefore, the level of protection derived from PI3V vaccines is also a matter of debate. Most cows will be antibody positive

for this virus, without having displayed any type of disease that can be associated with this virus. The interaction of this virus with bacterial pathogens are also poorly studied. BRSV however, can cause calf mortality and severe clinical outcomes. Its role in BRDC pathogenesis is again not very clear.

As a rule of thumb, vaccines for respiratory tract pathogens are not necessary the most effective, probably the induction of a systemic antibody (IgG) or T-cell responses through vaccination doesn't always prevent damage to the cells and we should focus on other components of the immune system to reach a higher level of protection. There is a good reason that intranasal application of respiratory vaccines is explored, you would like the immunity to be effective at the port of entry, the first place where virus replication will take place and damage will happen.

Clostridial vaccines are in many ways different, they contain the toxoids that induce the pathology, these vaccines are very effective, and immunity is long lasting, in contrast to the 'old' bacterin vaccines. Longitudinal studies on how long this immunity last exactly are lacking, but if we compare those to the human or equine tetanus vaccines, we can expect many years' protection after the initial completed series of vaccines and boosters (these are killed adjuvated vaccines, they require a booster). How many the 'X-way' clostridium vaccine should be required in the vaccination schedule depends on the specific situation of the farm, where the farm situated, history of disease, which animal group/age needs to be protected etc. When there are indications that a certain Clostridial species is causing clinical problems, that species need to be included. Boosting these vaccines yearly doesn't harm but is probably not always needed.

Provision of any 'non-core' vaccine is depending on farm-specific situations. Location, time of year, age of animal, immune status of those animals, availability of labour and funds, production goals or believes of farmer and many other factors should be considered. Some of those factors are easy to understand and incorporated in a vaccination strategy, others are less well understood or simply cannot be changed.

One of the most applied, non-core vaccines are the vaccines against scours. The same limited vaccine protection that was indicated for respiratory pathogens can be expected when GI tract pathogen vaccines (such as rota-, coronavirus) are used. Scours vaccines provide protection in a different way. Vaccinating the dam, to prevent diarrhea in the calf is complicated. Using this strategy variation can be expected, for example in the response of the vaccinated cow, the type and quantity of antibody that will be transferred to the colostrum, the uptake of that 'enriched' colostrum by the calf, the transfer to and circulation in the blood of those antibodies and lastly the amount of antibodies that ends up in the GI tract of that calf. Currently, we are performing a study that will evaluate all aspects of this vaccination strategy, identify what goes well, what needs improvement, and what is a reasonable expectation when animals (beef or dairy) are vaccinated. Timing in these cases is of the essence and not always easy to organize or predict. Many factors can influence the outcome: the 'booster' is sometimes forgotten or badly timed (it takes time to

make an antibody), the amount of colostrum ingested by the calf is insufficient or the pathogen level in the environment of the calf is too high etcetera. These are non-vaccine related factors, apart from the fact that most vaccines do not contain the most recent circulating virus strains.

The emerging epidemiological situation will determine if dairy farmers need to start vaccinating against for example leptospirosis. *Leptospira canicola, L. grippotyphosa, L. hardjo, L. icterohaemorrhagiae,* and *L. pomona* are incorporated in these vaccines. These strains are associated with abortion and infertility, but we haven't noticed a wide spread of these pathogens in the western Canadian cattle populations at this moment. They seem to slowly move northwards and are noticed sometimes when causing zoonotic infections. Especially with imports of animals from the south the risk of establishing these pathogens in the Canadian cattle herds is real. Generally, the immunity is relatively short lived, so frequent boosters are necessary, whereby vaccinations in the spring will provide the highest level of infection in the period of expected challenge (summer/autumn).

Despite all the opportunities and advances in vaccinology, we must always keep in mind that the success of a vaccine is dependent on 1. the quality of the vaccine, 2. the ability of the host to respond to the vaccination, 3. the willingness of the veterinarian and the farmer to apply the vaccine and 4. to do this in the correct way.
For 1 and 4 protocols and SOPs will be available to assist us, the producer of vaccines needs to prove that the product is what he/she promised, and the way the vaccine is delivered can be described in detail. The ability of the host to mount that needed immune response that turns a vaccination into an immunisation is surrounded with many variables. Sometimes due to controllable (stress, age, deworming, hygiene) or uncontrollable (genetics, weather) circumstances the immune response following vaccination can vary enormously. Another big known-unknown is the willingness of the farmers and veterinarians to use a certain vaccine. The human factor in the willingness to use a vaccine cannot be underestimated.

New Developments in Vaccines and Vaccination Strategies, what can be Expected in the Next 5-10 Years

Every intervention will have limitations, vaccination is no exception. Therefore, new strategies are being developed and different targets explored. Up till now following isolation of the pathogen, either killing, attenuation or utilizing a component of the pathogen was used to develop vaccines. Some of the pathogens are difficult to culture, others are very variable and therefore may require different vaccination approaches that are more adaptable. The high variability of certain pathogens, or the limited availability of vaccines drove the need for 'farm-specific' vaccines, derived from a pathogen that is known to circulate in a region or farm. Although a very attractive option, culture of these pathogens is required and only killed vaccines can be produced this way. An adjuvant is therefore required which can lead to side effects, and boosting with the same vaccine will

be needed for a robust, lasting immune response. Efficacy of this strategy is regularly questioned, and not without reason.

Outlook into the not-so-distant future:

A new trend is the so called 'platform' vaccines which are making an entrance in the veterinary world, adaptable backbones that can express a piece of the pathogen (the piece that induce an immune response) could be a new viable solution to the limitations of conventional vaccines and may be able to provide a more predictable immune response compared to the farm-specific vaccines. In human vaccinology this strategy is extensively used to provide quick updates for seasonal influenza vaccines. There is no reason to only restrict its use to these pathogens.

One of these platforms that is approved by the USDA is a baculovirus (=silkworm infecting virus) expression system which is used to produce adaptable vaccines (about 12 weeks from genome sequencing to vaccine). This system can produce many different pathogen proteins, and once a baculovirus+ foreign gene construct is created (and approved), it can be easily adapted to allow for a strain specific vaccine development. The result is a subunit vaccine which needs an adjuvant and requires a booster.

A versatile approach is the use of viral vectors, pox-, herpes-, and adenoviruses (these are all large DNA viruses) which are extensively explored whereby canarypox and fowlpox vectors are already used in veterinary vaccinology. Basically, a weakened large DNA virus that can accommodate foreign DNA can be used to express a gene of interest from another pathogen. Multiple foreign genes could be integrated in such a vector, so a multivalent vaccine may not be necessary anymore. Although it is a modified virus, it may be able to replicate, depending on the targeted host. For example, a canarypox vector doesn't replicate well in a mammalian host, but an adenovirus from a mammal might have that ability. Also, immune responses against the vector could have consequences for the possibility to boost with this same vector.

An example of a target that could make its entry soon in the cattle industry is the use of 'immunocastration' vaccines, based on gonadotropin-releasing hormone (GnRH). The release of this small protein that regulates the production of FSH and LH is the initial step in the hypothalamic–pituitary–gonadal axis, ultimately leading to the release of testosterone in male animals. The acceptance of surgical castration without anaesthesia by the public may diminish, especially when effective, non-surgical, pain free methods are available. These vaccines have made their entry in pig production, however, also here some getting used to (testicle containing boars are slaughtered and processed) will be required. Public acceptance of this technique will drive its future use.

Interesting strategies for vaccination against enzootic bovine leukosis are developed and tested in Argentina, many regulatory hurdles need to be taken before this promising approach also can be used in North America. In principle the cow will be infected with an

attenuated BLV provirus which is created by deleting genes dispensable for infectivity but required for efficient replication. Once infected with this vaccine virus, and the provirus is present in the cell, no super-infection with a BLV wildtype strain is possible. The vaccine virus is not excreted; therefore, transmission of this vaccine is not taking place. Another tool in the control of this virus.

New adjuvants for existing and new vaccines are explored. Apart from the widely used Alum salts, emulsions in various forms O/W, W/O, WOW and for example saponin molecules, new developments in Toll like receptor agonists or cytokines that can direct the immune response in specific ways are studied. With the ever-evolving knowledge about immunology, targeting the innate components of the immune system could provide a better response with less side effects.

Another trend that soon will make its entrance in cattle vaccination are biodegradable polymeric nanoparticles that can be constructed from organic or inorganic materials to mimic for example a virus. Molecules can be delivered that self-assemble in to 'empty' viruses (viral like particles), which do not contain genetic material, hence, cannot replicate. These are easier to produce and cheaper than conventional approaches.

Nucleic acid-based platforms are by far the most versatile and have enormous potential. Both DNA or mRNA-based methods are currently developed and, in a few instances, already used in veterinary vaccinology. In swine production systems mRNA techniques are used against influenza- and rotavirus, and it will not stop there. This mRNA platform holds a lot of promise and there is substantial improvement expected in their efficacy, the duration of immunity and their practicality for use on farm. Despite the very mixed reviews by many experts and non-experts, this type of vaccine will create a way to quickly create a vaccine in case of outbreaks with new or emerging pathogens and enable the development of vaccines for difficult to culture pathogens. These mRNA vaccines generally include adaptations in the genomic material to ensure the longer persistence in the cell (several days). Normal mRNA molecules are very quickly degraded (within hours), they are only used once and recycled quickly thereafter. Also, these molecules may be recognized by the innate immune system, and cleared before they can produce the proteins that should trigger the adaptive immune response. To generate an even higher amount of protein, so called self-amplifying mRNA molecules are under development (saRNA) which should in theory provide a more robust stimulation of the adaptive immune system.

Use of DNA/mRNA vaccines will drive the use of needle free application devises (which is very good news for BLV control), but their use obviously doesn't have to be limited to these platforms. Most needle administered vaccines are delivered in the muscle although these tissues do not contain many cells that can process those antigens and initiate an immune response (such as dendritic cells). Delivery in, or just below the skin has many advantages, the targeting of specialized antigen presenting cells such as the dendritic cells (DC) could lead to a very efficient induction of immune responses. Dendritic cells are a class of 'professional antigen presenting cells'. When these cells are specifically targeted a higher

level of response can be expected: DCs and macrophages differ in their capacity to digest antigens. Macrophages endocytose antigens and rapidly digest them. In contrast, DCs sequester and preserve the captured antigen for later presentation. DCs initiate T cell immune response in the lymph nodes and spleen. Apart from these actions, through the excretion of cytokines and other chemicals to regulate the immune response. Targeting these cells could be very beneficial for the level and type of immune response that will be induced.

IDENTIFYING & MANAGING PREDATOR ATTACKS ON LIVESTOCK

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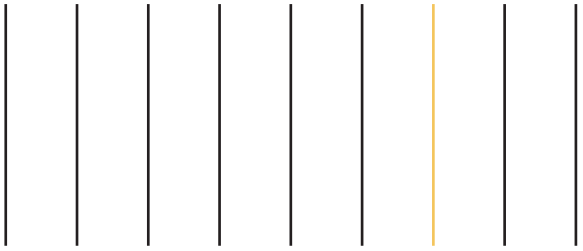

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Identifying and managing predator attacks on livestock

- Livestock predation statistics in the US and KS
- Evaluation of suspected predator attacks
- General characteristics of predator attacks
    - Coyotes
    - Dogs
    - Mountain Lion
    - Predatory/Scavenging Birds
- Commonly misidentified injuries
- Reporting procedure
- Connecting producers with assistance
- Managing livestock predation in KS
- Resources

KEEPING UP WITH ESTRUS SYNCHRONIZATION SYSTEMS FOR BEEF COWS & HEIFERS

SANDY JOHNSON
PHD

LARGE ANIMAL

Keeping up with estrus synchronization systems for beef cows and heifers

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June 2, 2024
Manhattan, KS

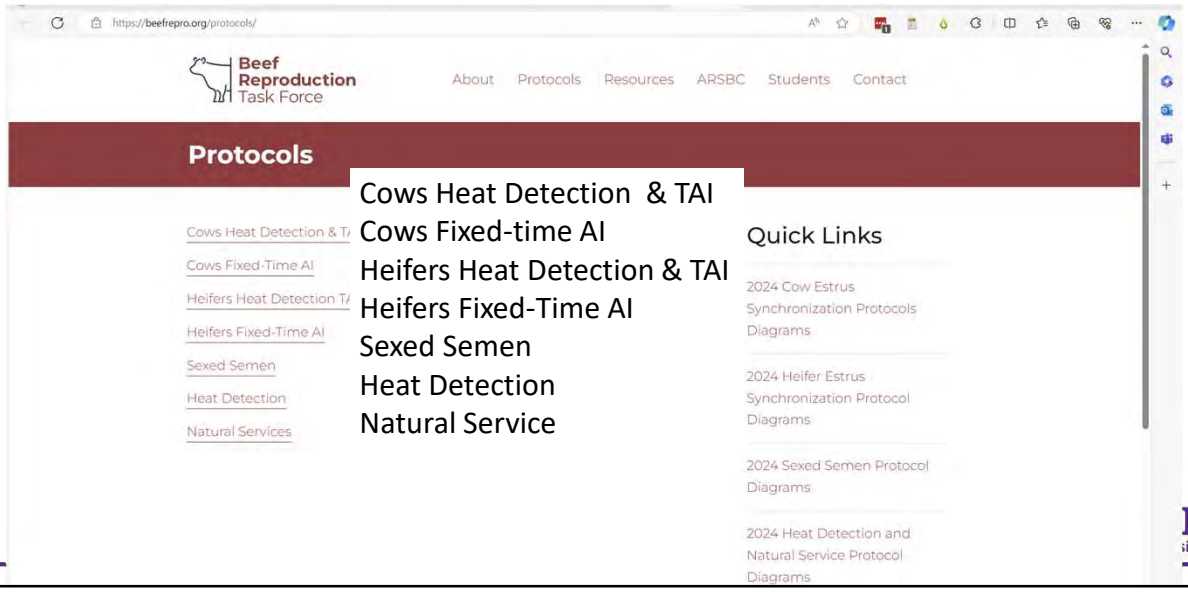
K-STATE Research and Extension

Outline

- Resources
- Sexed Semen
- Protocols
- Docility & Fertility
- Heterospermic semen packages
- Rapid rebreeding/resynchronization

K-STATE Research and Extension

BeefRepro.org



Cows Heat Detection & TAI
Cows Fixed-time AI
Heifers Heat Detection & TAI
Heifers Fixed-Time AI
Sexed Semen
Heat Detection
Natural Service

Estrus Synchronization Planner

Free download at

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Iowa Beef Center

Features

- Recommended systems for cows & heifers
- Select systems by type
  - Heat detect & AI systems
  - Heat detect & cleanup AI systems
  - Fixed-Timed AI Systems
- List of daily activities
- Generates Barn Calendar
- Cost per AI pregnancy
- Support materials

Estrus Synchronization Planner

Replace the example inputs (below) with your own.

Breed Type:	1=Bos taurus, 2=Bos indicus influence	1	
Semen Type:	1=Conventional, 2=Conventional & Sexed	1	
System Type:	1=Estrus AI, 2=Estrus AI + Clean-up AI, 3=Fixed-Time AI, 4=Split Time AI	3	
Synchronization Protocol:	*Select number from lists below.*	22	
Date to Start Breeding:	*Format date as "mm / dd / yyyy"*	9/15/2023	
Time of Day To Breed:	*Format time as "hh:mm AM or PM"*	8:00 AM	
GnRH:	1=Cystorelin, 2=Factrel, 3=Fertagyl, 4=OvaCyst, 5=GONAbreed	1	*2cc Cystorelin*
PG:	1= Estrumate, 2= EstroPLAN, 3= InSynch, 4=Lutalyse, 5= ProstaMate, 6=HiConc.Lutalyse, 7=Synchsure	4	*5cc Lutalyse*
Bull Turn In:	*Days after last AI*	14	
Gestation Length:	*Days*	281	

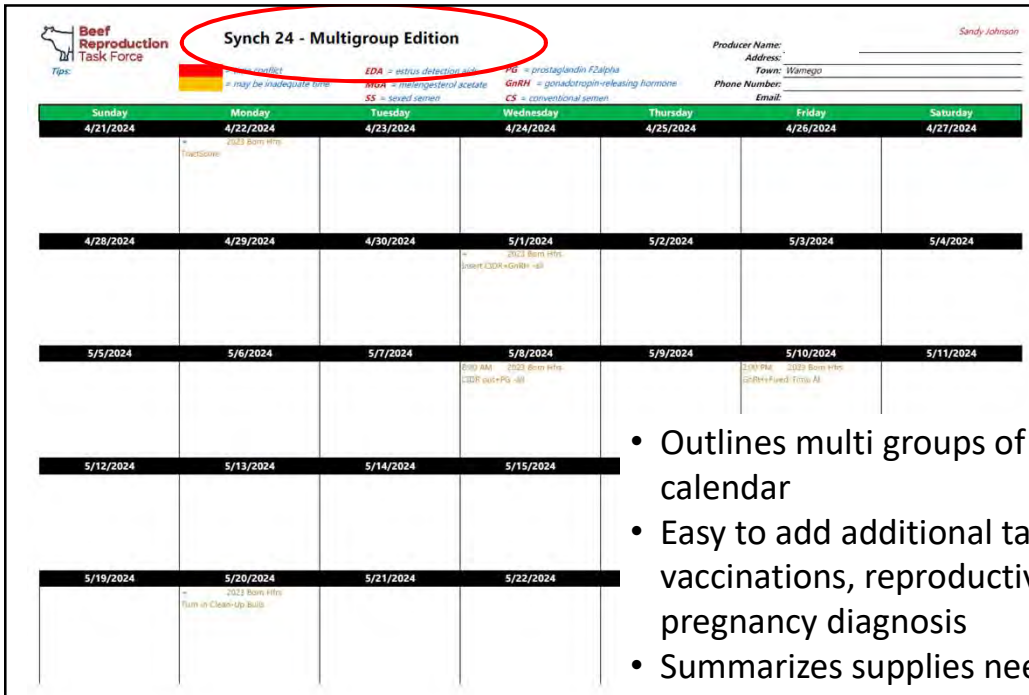
Calendar Printout Notes:

Output	
Expected Calving Date:	6/22/2024
Remove CIDR:	9/12/23 5:00 PM
Last PG Injection:	9/12/23 5:00 PM
Trips Through Chute	3
Head Worked per Hour (AI)	32
Group Size (head)	44

Cost Comparison	
Alternative System 1:	29
Alternative System 2:	39
Select number from lists below.	

Preferred Fixed-Time AI - Cow Protocols	*See Protocols*	**Preferred Fixed-Time AI - Heifer Protocols**
22 = 7 Day CO-Synch+CIDR -- Fixed-Time AI 63 +/-3		23 = 7 Day CO-Synch+CIDR -- Fixed-Time AI 54 +/- 2
29 = 5 Day CO-Synch+CIDR -- Fixed-Time AI 72 +/-2		27=MGA + PG -- Fixed-Time AI 72 +/-2
39=7 & 7 Synch -- Fixed-Time AI 66 +/- 2		32=14 Day CIDR+PG -- Fixed- Time AI 66 +/-2

Program | Planner Worksheet | Calendar | Print Out | Tips & Overview | Visual Protocols | notes



- Outlines multi groups of animals on one calendar
- Easy to add additional tasks – vaccinations, reproductive tract scores, pregnancy diagnosis
- Summarizes supplies needed

Democritus
c. 460 BC – c. 370 BC

Right testis produces males
Left testis produces females

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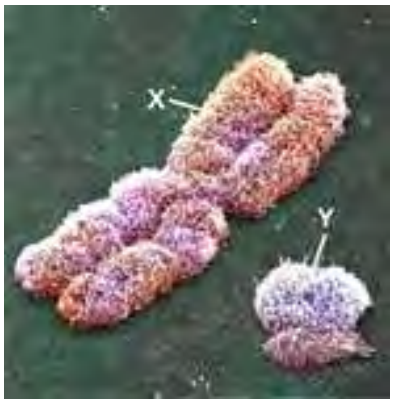

X – sperm have more DNA

Dye binds to DNA

Laser light causes dye to fluoresce

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Optimizing the use of sex-sorted semen

	Pregnancy rates		
Estrus	Conventional Semen @ 66 hr	Sex-sorted Semen @ 66 hr	Sex-sorted @ 66 hr with delay of non-estrous
Yes	**77%[a]**	**51%[b]**	**42%[b]**
No	**37%[c]**	**2%[d]**	**36%[c]**
Total	**56%**	**26%**	**39%**

- Treatment x estrous expression interaction ($P < 0.0001$)
- Pregnancy rates within a row with different superscripts are different ($P < 0.0001$)

Thomas et al., 2014

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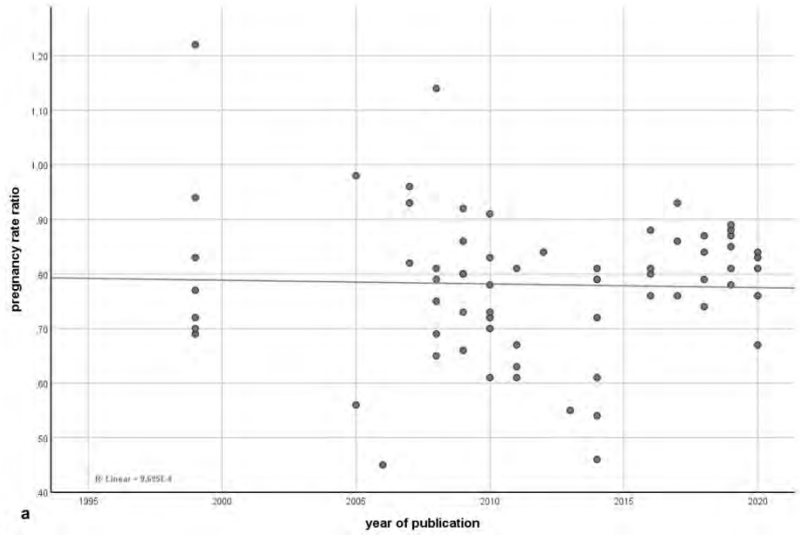
Variation in sexed semen results over time



Reese et al., 2021

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Beef Reproduction Task Force

SEXED SEMEN PROTOCOLS 2024

For additional synchronization protocols visit *BeefRepro.org*
Use of sexed semen can result in conception rates that are decreased compared to conventional semen used in the same situation

HEAT DETECTION

Sexed semen can be used on any female observed in estrus (heat) and following synchronization with any protocol on the Cow or Heifer Protocol Sheet.
For best results with sexed semen *perform AI 16 to 22 hr* after detecting female in estrus.
Use of estrus detection aids (EDA) is highly recommended.

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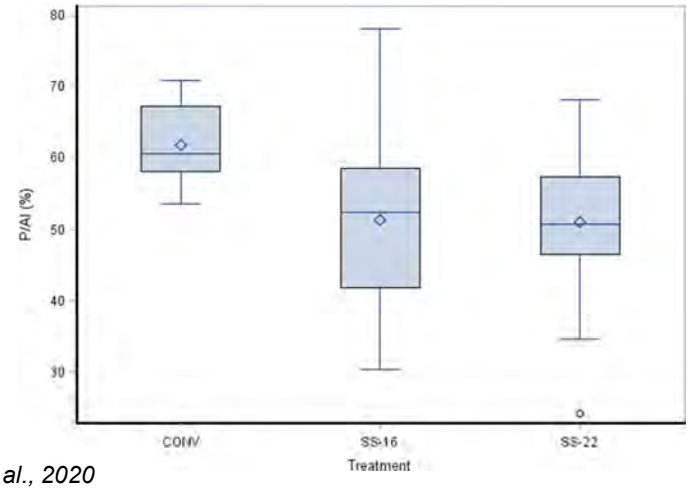
Variation in sexed semen



Drake et al., 2020
Journal of Dairy Science 2020 10312059-12068DOI: (10.3168/jds.2020-18847)

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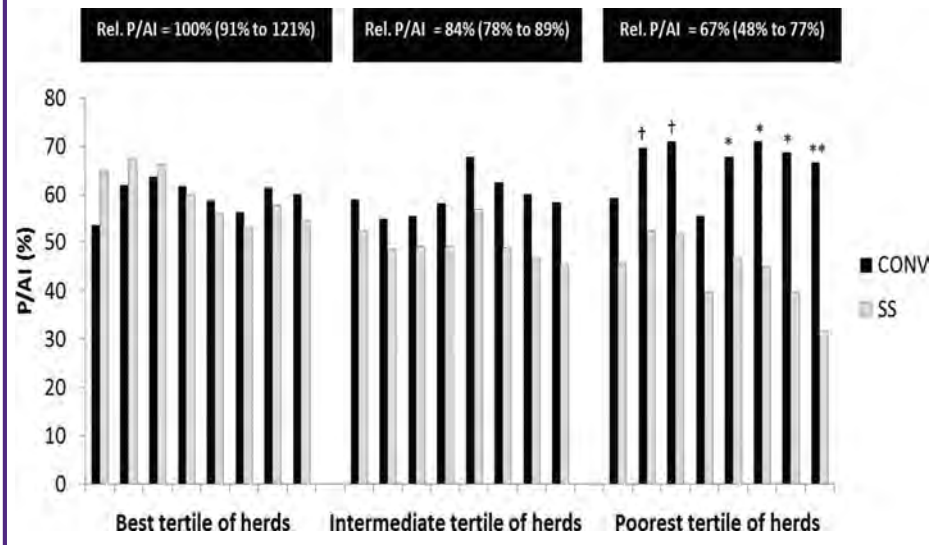
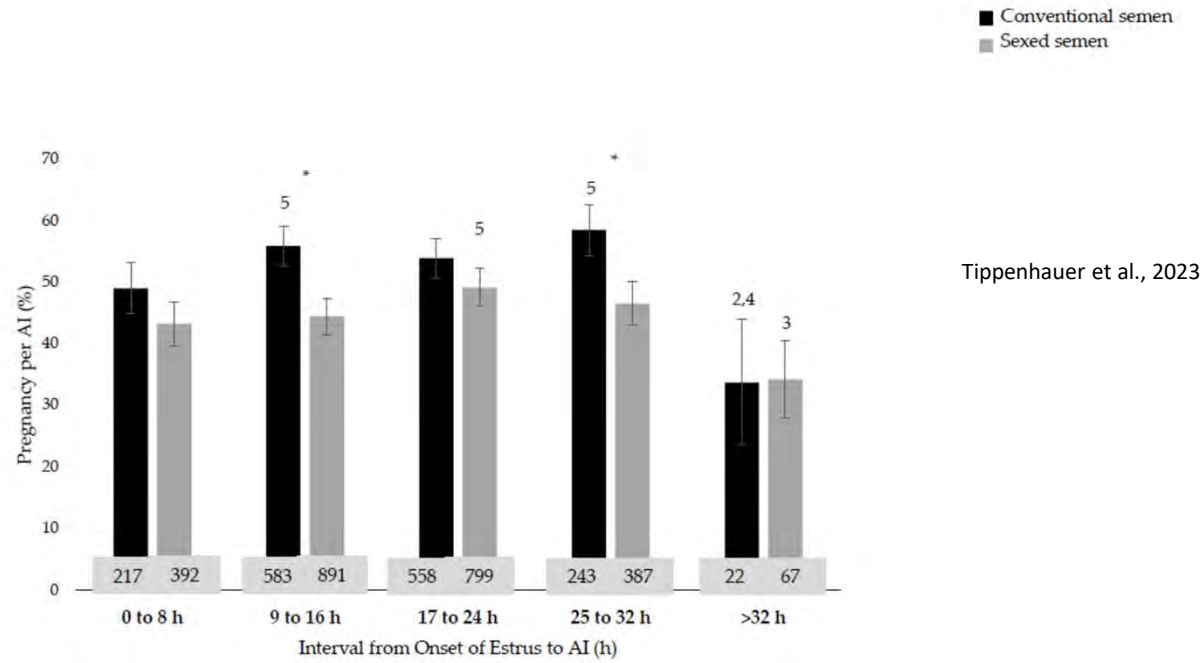
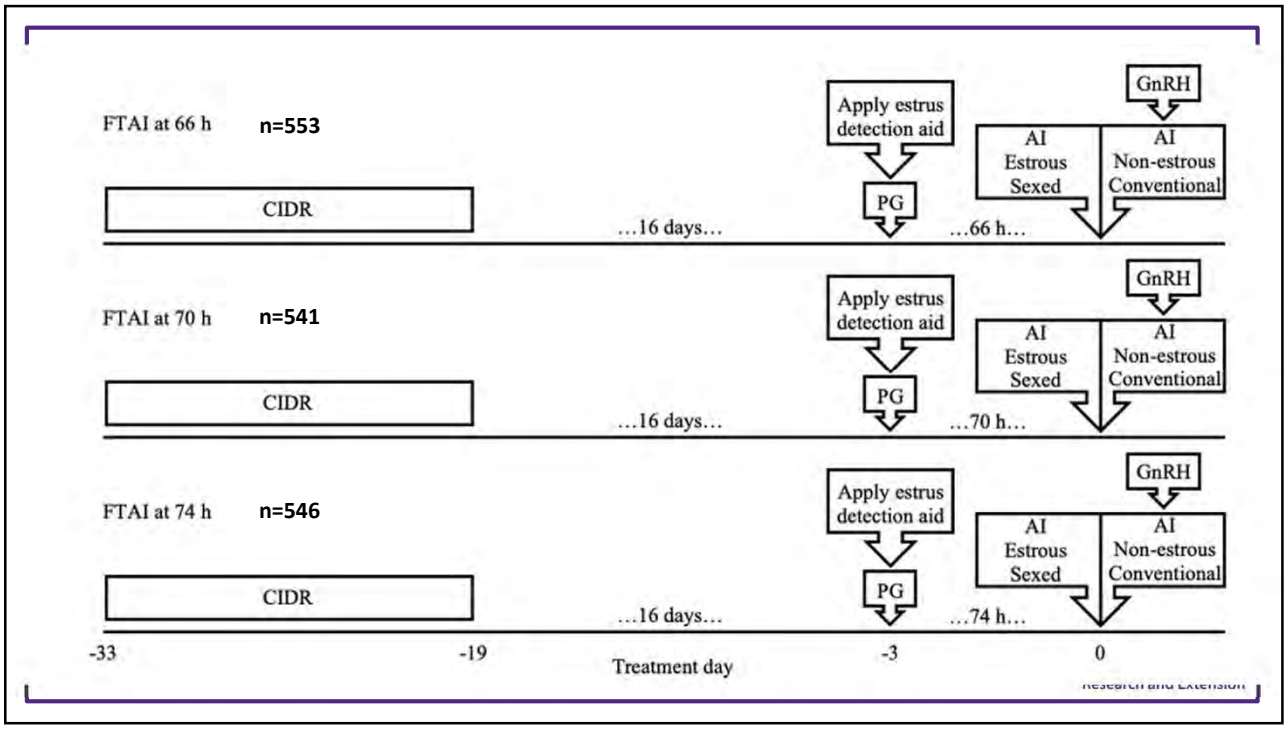


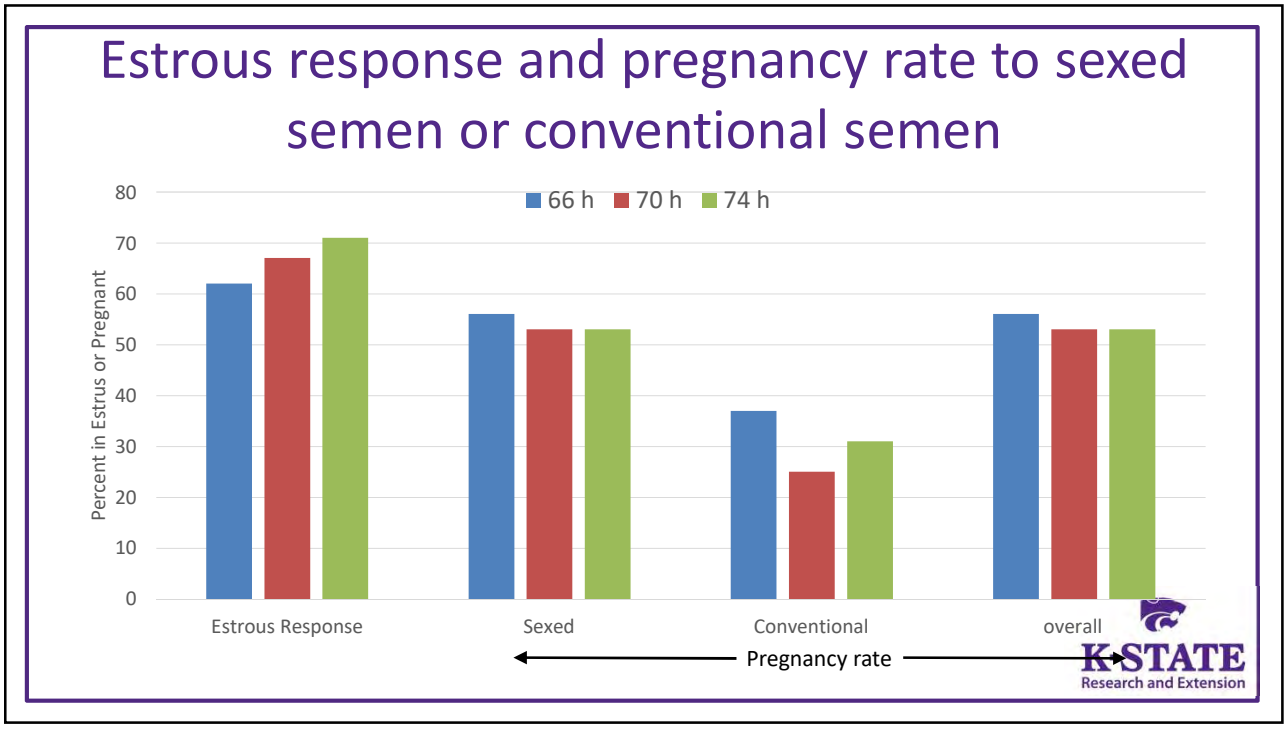
Drake et al., 2020
Journal of Dairy Science 2020 10312059-12068DOI: (10.3168/jds.2020-18847)

K-STATE Research and Extension

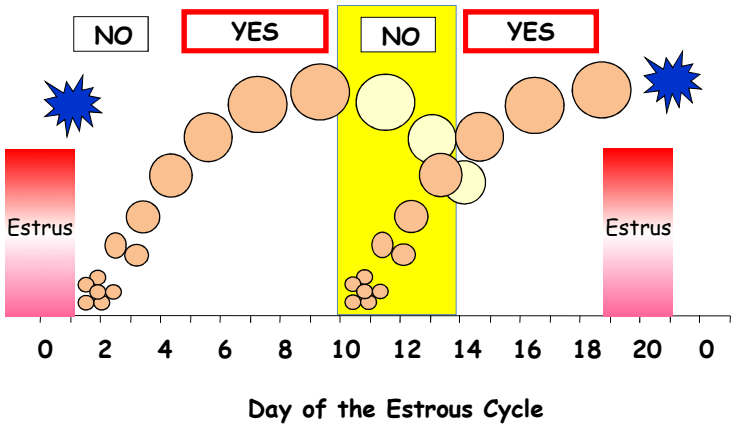


Tippenhauer et al., 2023


FTAI at 66 h
n=553
CIDR
…16 days…
Apply estrus detection aid
PG
…66 h…
AI Estrous Sexed
GnRH
AI Non-estrous Conventional
FTAI at 70 h
n=541
CIDR
…16 days…
Apply estrus detection aid
PG
…70 h…
AI Estrous Sexed
GnRH
AI Non-estrous Conventional
FTAI at 74 h
n=546
CIDR
…16 days…
Apply estrus detection aid
PG
…74 h…
AI Estrous Sexed
GnRH
AI Non-estrous Conventional
-33
-19
Treatment day
-3
0


Estrous response and pregnancy rate to sexed semen or conventional semen
66 h
70 h
74 h
Percent in Estrus or Pregnant
80
70
60
50
40
30
20
10
0
Estrous Response
Sexed
Conventional
overall
Pregnancy rate
K-STATE
Research and Extension

GnRH-Induced Ovulation During a Follicular Wave



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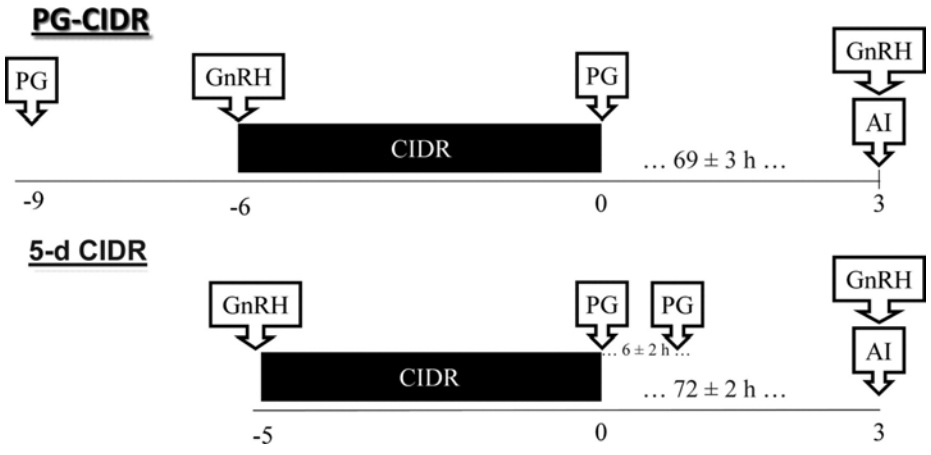
Pre-Synchronization



Perry et al., 2012

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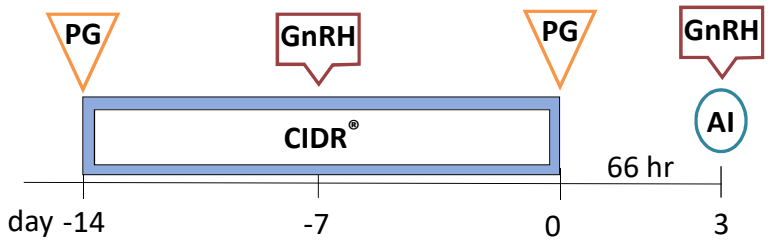
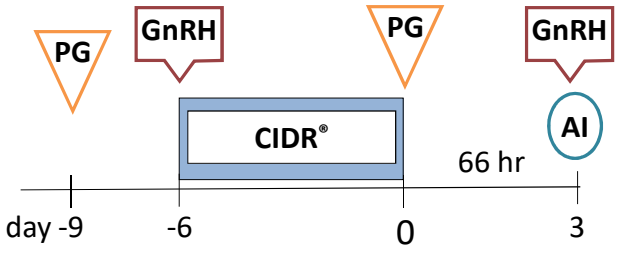
7&7 Synch



PG 6-day CIDR® & TAI



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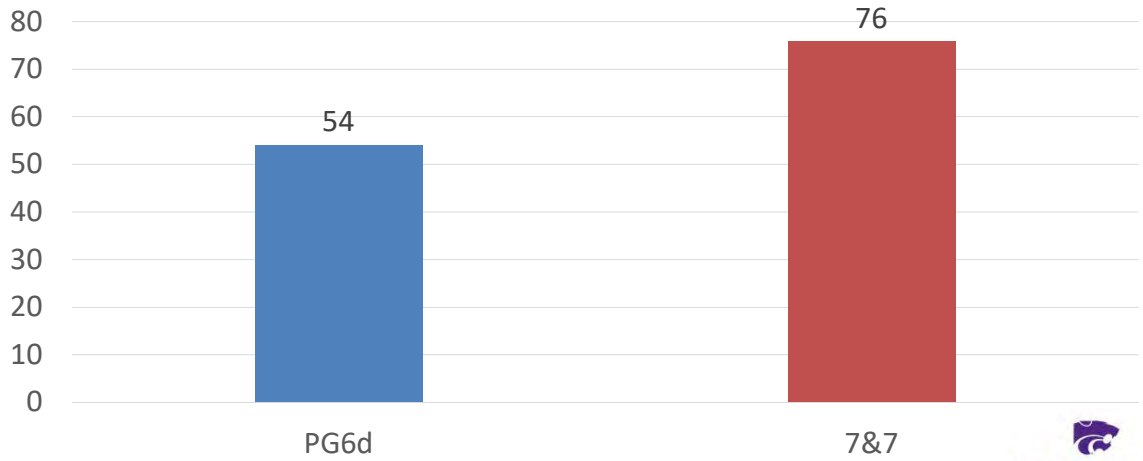
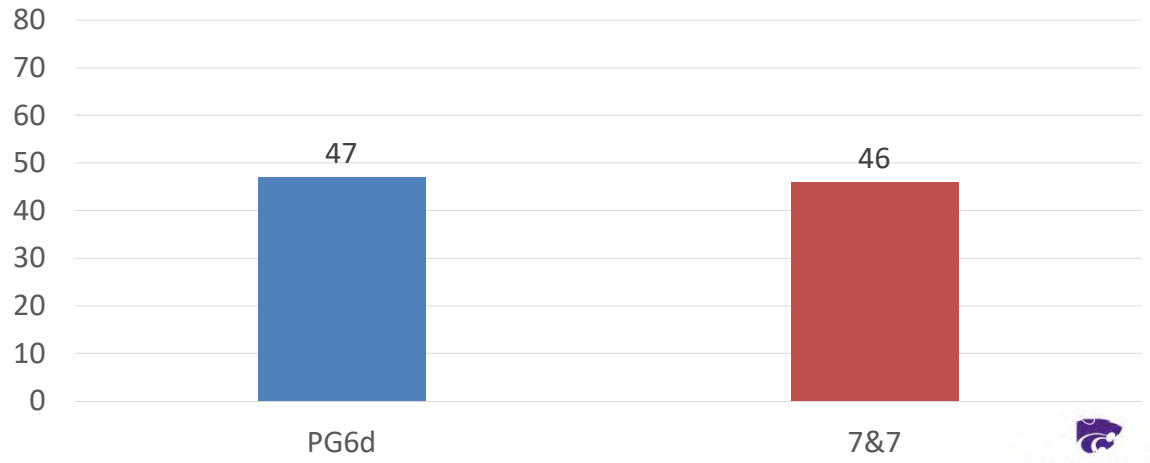
Estrous Response in Beef Cows



Ketchum et al., 2024

K-STATE Research and Extension

Pregnancy rate to fixed-timed AI

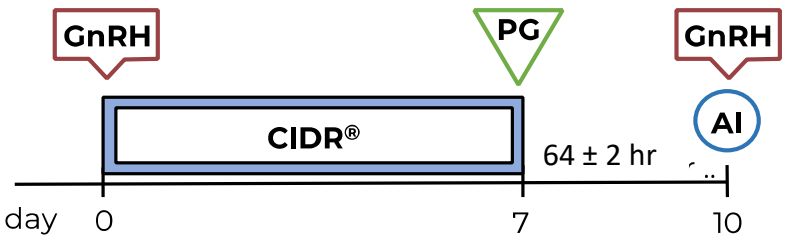


Ketchum et al., 2024

K-STATE Research and Extension

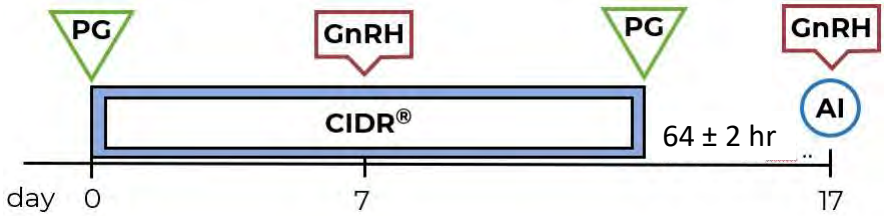
7-day CO-Synch+CIDR®

Pancini et al., 2022



n	BCS	DPP
606	5.5	81
610	5.5	80

7&7 Synch



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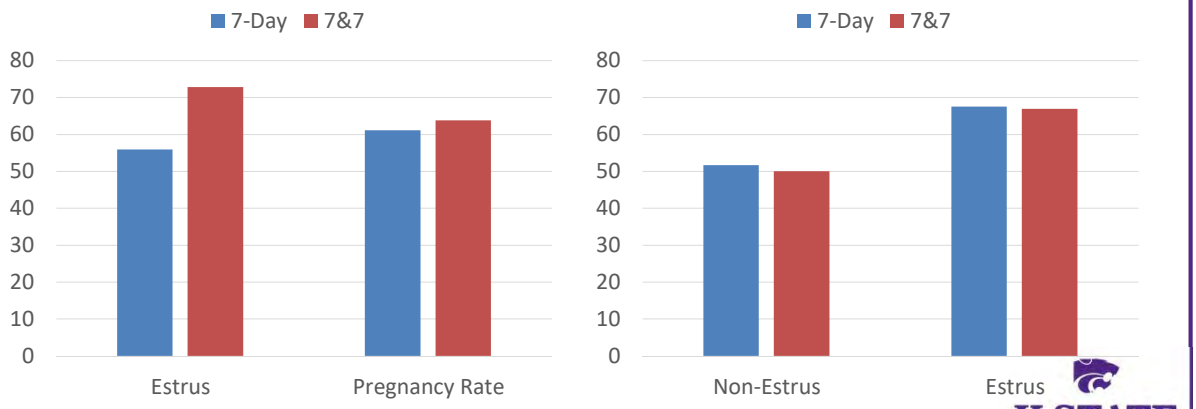
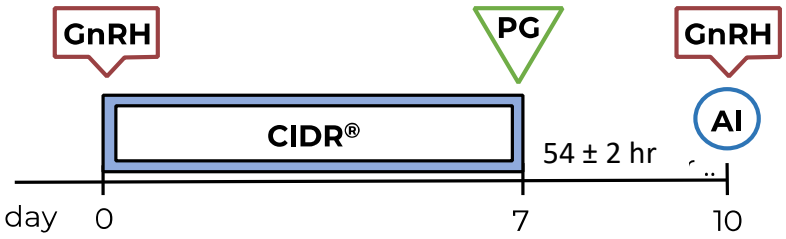
Beef Cows at Fixed-Time AI

*** Treatments differ P<0.01**

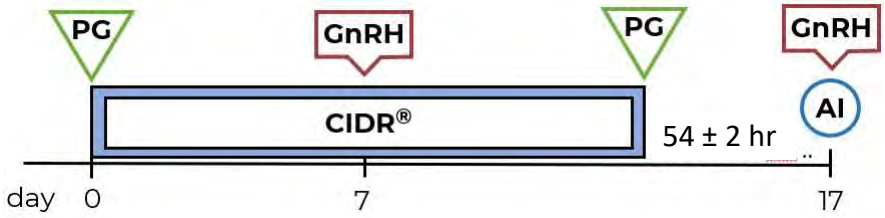


K-STATE Research and Extension

7-day CO-Synch+CIDR®



7&7 Synch



n
779
773

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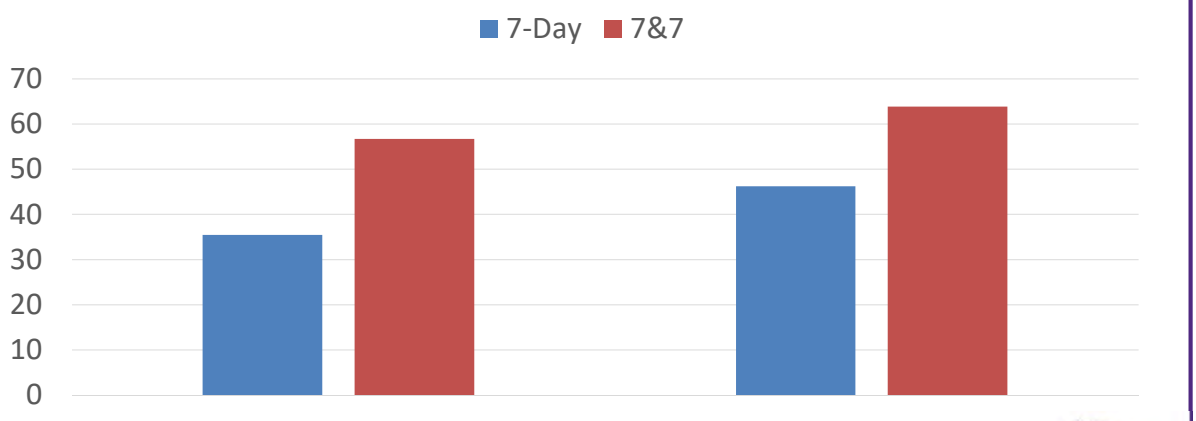
Beef Heifers at Fixed-Time AI



Trt P=0.001; Loc P<0.001

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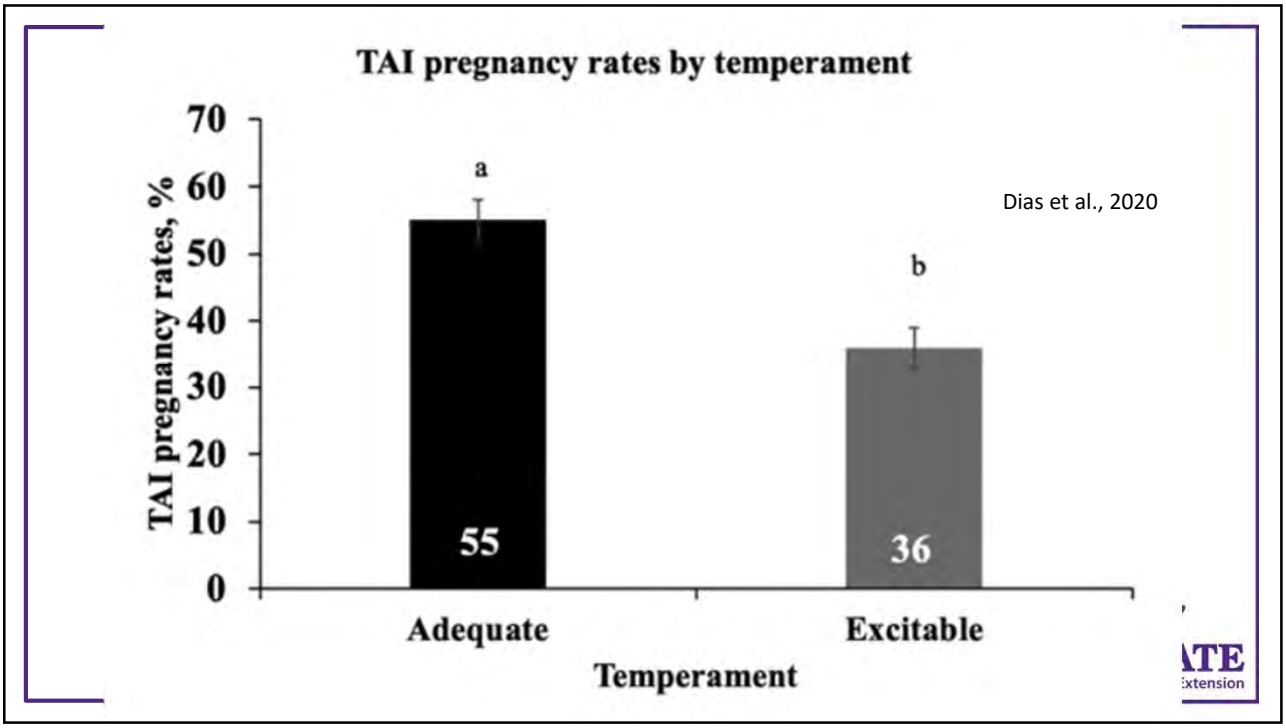
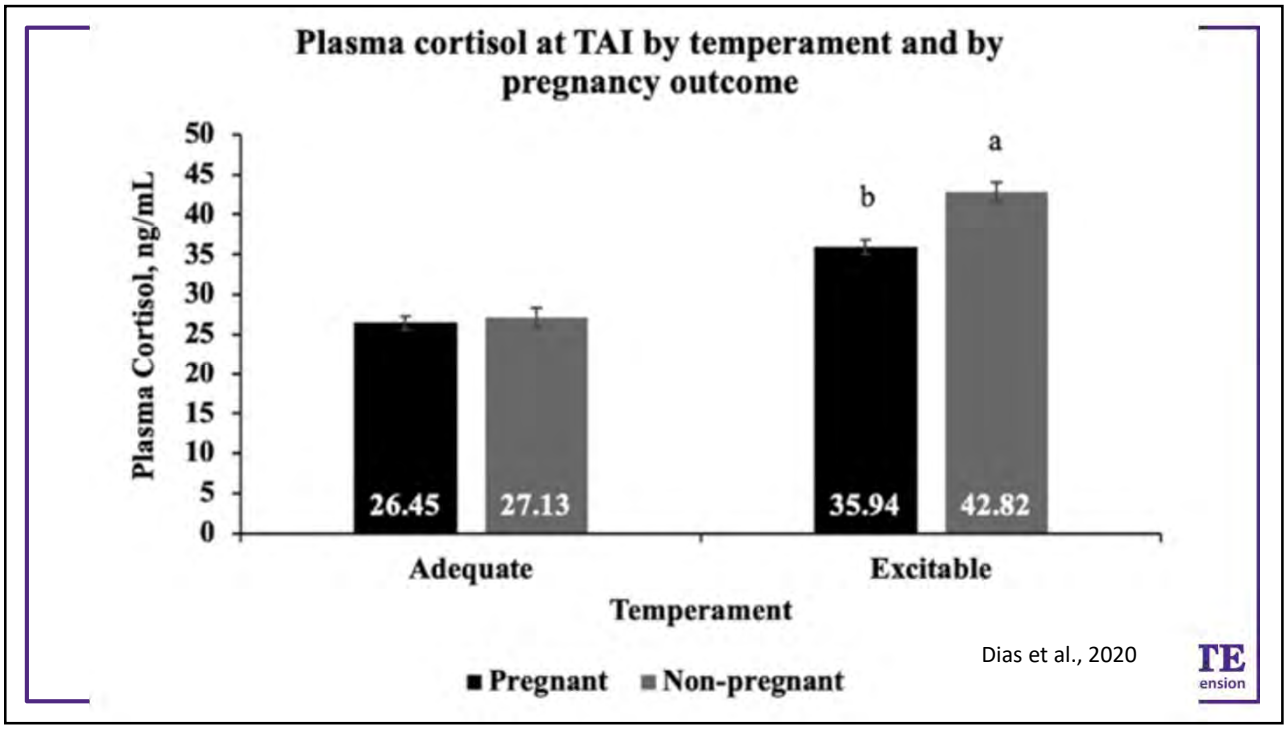
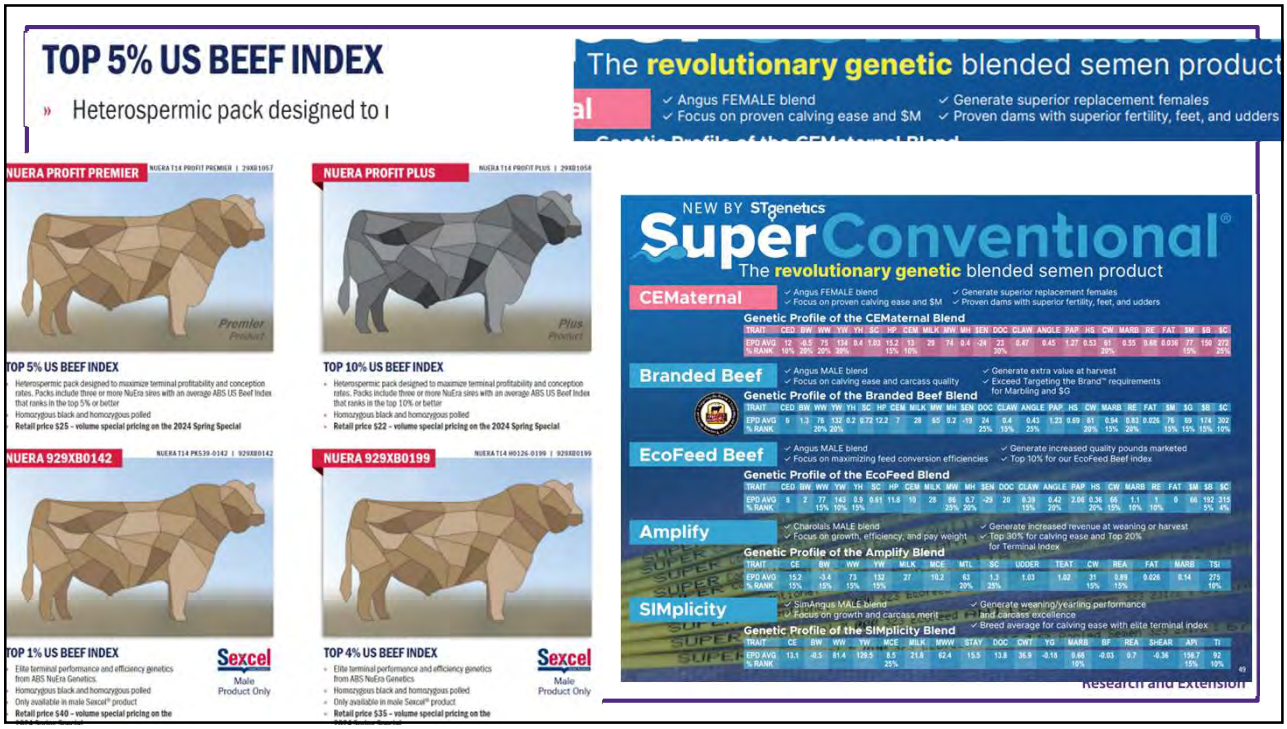


Dias et al., 2020


Plasma cortisol at TAI by temperament and by pregnancy outcome
Plasma Cortisol, ng/mL
50
45
40
35
30
25
20
15
10
5
0
26.45
27.13
35.94
42.82
a
b
Adequate
Excitable
Temperament
Pregnant
Non-pregnant
Dias et al., 2020
TE
ension


TOP 5% US BEEF INDEX
Heterospermic pack designed to
The revolutionary genetic blended semen product
Angus FEMALE blend
Focus on proven calving ease and $M
Generate superior replacement females
Proven dams with superior fertility, feet, and udders
NUERA PROFIT PREMIER
TOP 5% US BEEF INDEX
Retail price $25 - volume special pricing on the 2024 Spring Special
NUERA PROFIT PLUS
TOP 10% US BEEF INDEX
Retail price $22 - volume special pricing on the 2024 Spring Special
NUERA 929XB0142
TOP 1% US BEEF INDEX
Sexcel
Male Product Only
NUERA 929XB0199
TOP 4% US BEEF INDEX
Sexcel
Male Product Only
NEW BY STgenetics
SuperConventional
The revolutionary genetic blended semen product
CEMaternal
Genetic Profile of the CEMaternal Blend
Branded Beef
Genetic Profile of the Branded Beef Blend
EcoFeed Beef
Genetic Profile of the EcoFeed Blend
Amplify
Genetic Profile of the Amplify Blend
SIMplicity
Genetic Profile of the SIMplicity Blend
Research and Extension

Heterospermic semen packages

- 2 or more males mixed on equal # basis
- Disproportion of offspring from 1 male

- Takes advantage of differences in semen characteristics

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Exploiting differences in semen

- Time to capacitation
- Longevity in tract
- Survival of freezing or thawing
- Freezing & thawing post sex-sorting

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Effects of heterospermic insemination on conception rates of lactating dairy cows

DeJarnette et al., 2008

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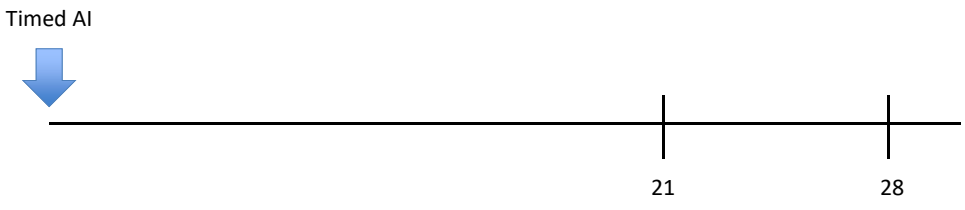
Resynchronization



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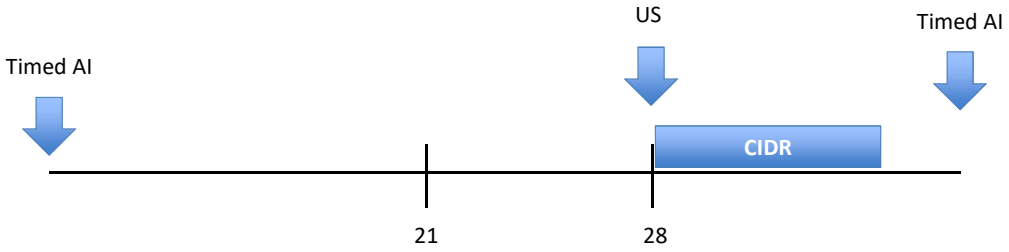
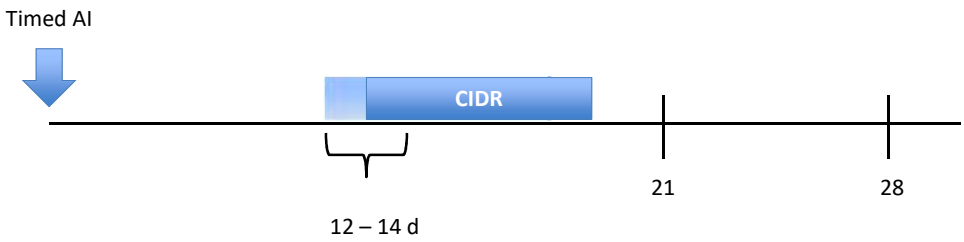
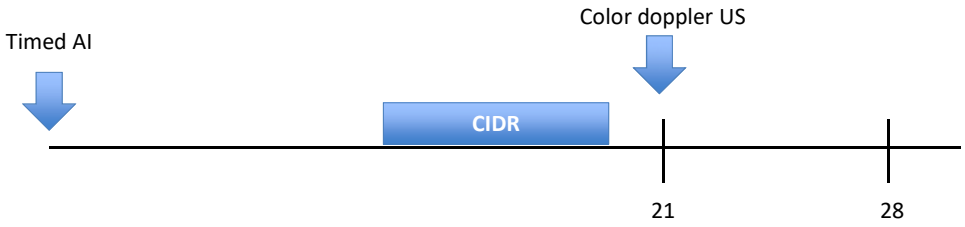
Resynchronization



Resynchronization



Resynchronization



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True Positive

False Negative

Siqueira et al., 2013

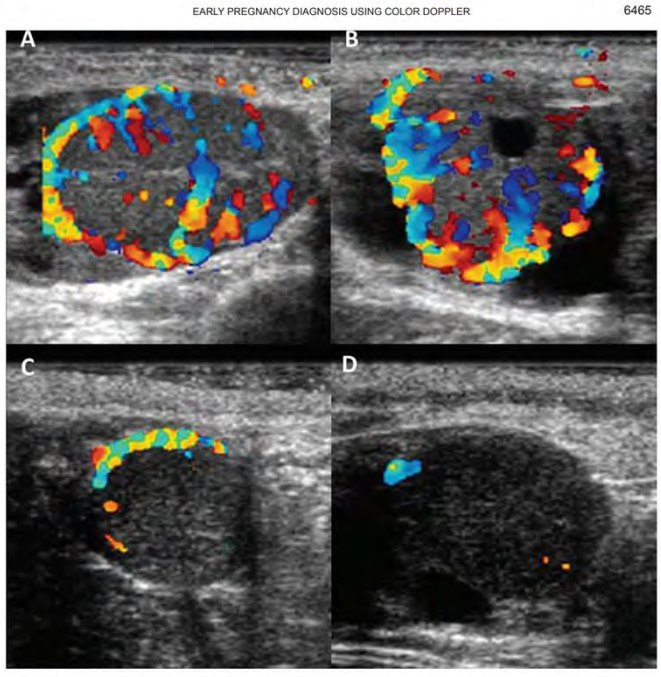

Figure 1. Doppler ultrasonographic images representing the 4 categories observed after pregnancy diagnosis using the corpus luteum blood flow at 20 d after AI (CLBF-d20) test: true positive (A), false positive (B), false negative (C), and true negative (D).

False Positive

True Negative

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Table 1
Studies comparing the use of Doppler ultrasonography to detect luteal function for diagnosis of pregnancy status between day 17 and day 22 and the B-mode ultrasonography for detection of embryo after day 28 of pregnancy in beef and dairy cows and heifers.

Authors	Type/breed	Parity order	Type of service	Moment of gestation, d	Animals, n	Conception rate, %	Accuracy, %	False positive, % (total)	False negative, % (total)	PPV, %	NPV, %
Utt et al., 2009	Beef (Crossbreed)	Cows	TET	17	50	46	60	30.6	9.4	54.4	73.3
				19			68.8	24.6	6.6	61.4	82.9
				21			71.4	21	7.6	64.8	81.5
Siqueira et al., 2013	Dairy (Holstein-Gir)	Parous cows	TAI	20	317	46.1	74.6	24.6	0.7	64.8	97.7
		Heifers			209	47.4	76.6	22.7	0.6	67.2	98
Pugliesi et al., 2014	Beef (Nelore)	Parous cows	TAI	20	111	37.8	91	9	0	80.8	100
Guimarães et al., 2015	Beef (Nelore)	Parous cows	TET	21	163	43.6	88.3	11.7	0	78.9	100
Scully et al., 2014[1]	Dairy (*Bos taurus*)	Parous cows	AI after estrus	18	80	52.8	68.1	20.9	11.1	66.6	70.3
				19	80	56.8	82.4	13.5	4.1	79.5	88
				20	90	42.2	77.7	17.3	4.9	70.8	87.8
				21	94	45.2	87.1	11.8	1.1	78.8	97.5
Pugliesi et al., 2018	Beef (Nelore)	Parous cows	TAI	22	246	49.6	94.7	5.3	0	90.4	100
		Heifers			231	41.6	90	10	0	80.5	100
Araíde et al., 2018	Beef (Nelore)	Parous cows	TET	22	221	35.5	83.8	16.2	0	68.8	100
Andrade et al., 2019	Beef (Nelore)	Heifers	TAI	21	113	–	87.8	12.2	0	77.3	100
Dalmaso de Melo et al., 2020	Beef (Nelore)	Parous cows	TAI	20	144	58	93	7	0	89	100
		Heifers			100	52	88.3	11.7	0	81.8	100
Wellert et al., 2020	Beef (Angus-cross)	Parous cows	TAI	21	84	–	–	–	0	89.4	100
		Heifers			25				0	75	100
Dubuc et al., 2020	Dairy (Holstein)	Parous cows	AI	21	1 632	22	62.1	37.5	0.4	52	98.1
Holton et al., 2022a	Beef (*Bos taurus*)	Parous cows	TAI	20	208	52.9	87	13	0	80	100
				22	209	52.6	92	8	0	85	100
Holton et al., 2022b	Beef (*Bos taurus*)	Heifers	TAI	20	183	–	90	10	0	86	100
				22		–	92	8	0	90	100
Madoz et al., 2022	Dairy (Holstein)	Parous cows	TAI	19/20	131	37.4	74.8	24.5	0.7	60	98.2
		Heifers									
Ferraz et al., 2022	Dairy (Holstein)	Parous cows	TAI	21	140	28.6	53	46.3	0.7	38	98
		Heifers			32	31.3	66	34	0	48	100

Abbreviations: PPV = positive predictive value; NPV = negative predictive value; TET = timed-embryo transfer; TAI = timed-artificial insemination; AI = artificial insemination.
[1] This study also considered the uterine echotexture and corpus luteum size as additional criteria to the luteal blood perfusion for diagnosis of non-pregnant animals.

Pugliesi et al., 2023

Research and Extension

Accuracy associated with color doppler imaging to detect CL blood flow / pregnancy

Accuracy	75	91	87	91	92	94
False Positive	24	9	12	9	8	6
False Negative	.5	0	0	0	0	0
Day			20	20	22	22
Type	Holstein	Nelore	Beef cows	Beef Heifers	Beef Cows	Beef Heifers
Year	2014	2013	2022	2022	2022	2022

Research and Extension

- Resources
- Sexed Semen
- Protocols
- Docility & Fertility
- Heterospermic semen packages
- Rapid rebreeding/resynchronization

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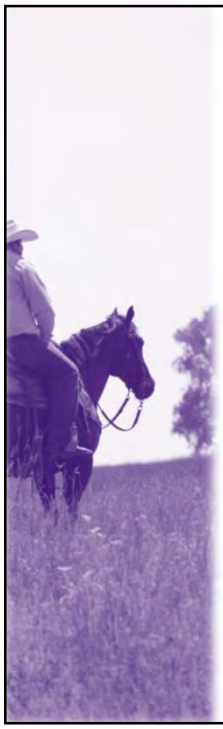
HEIFER MANAGEMENT CONSIDERATIONS FOR FERTILITY & LONGEVITY

SANDY JOHNSON
PHD

LARGE ANIMAL



Heifer Management Considerations for Longevity and Fertility

Sandy Johnson, PhD
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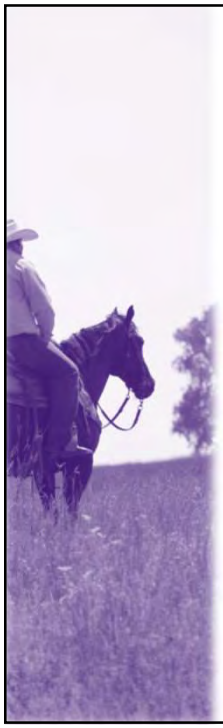
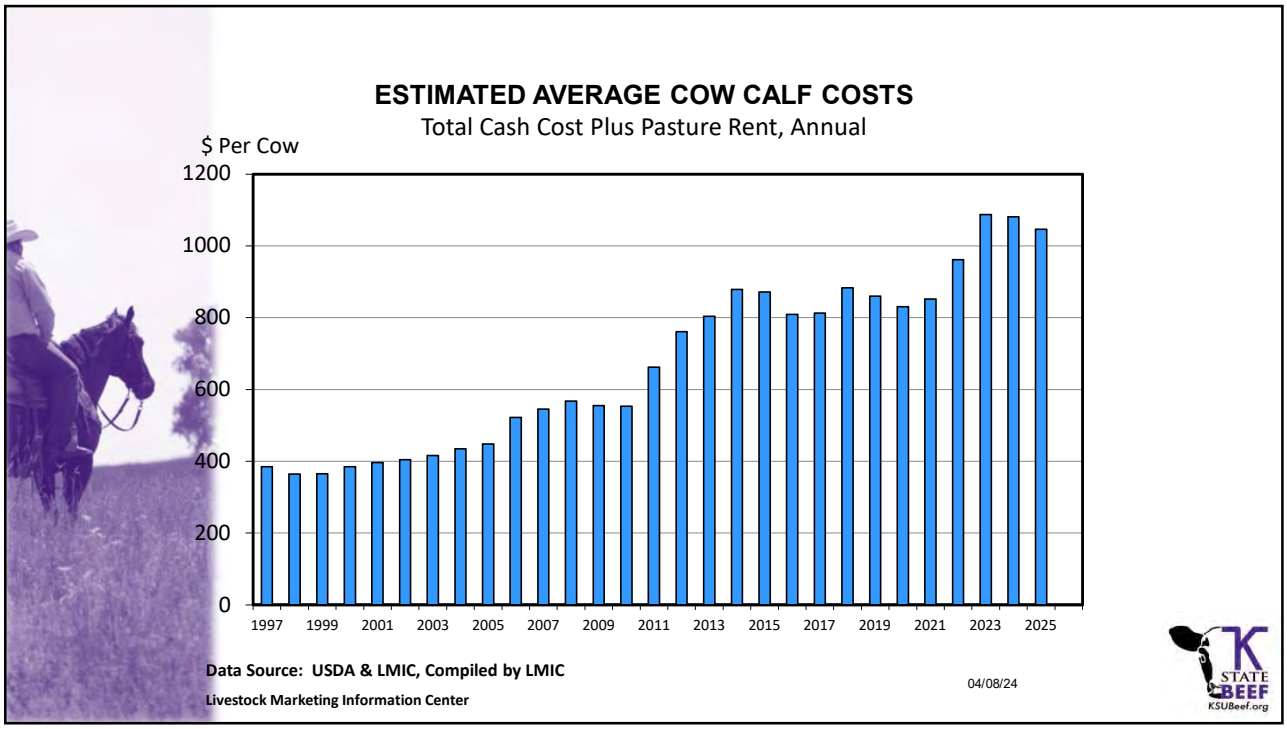
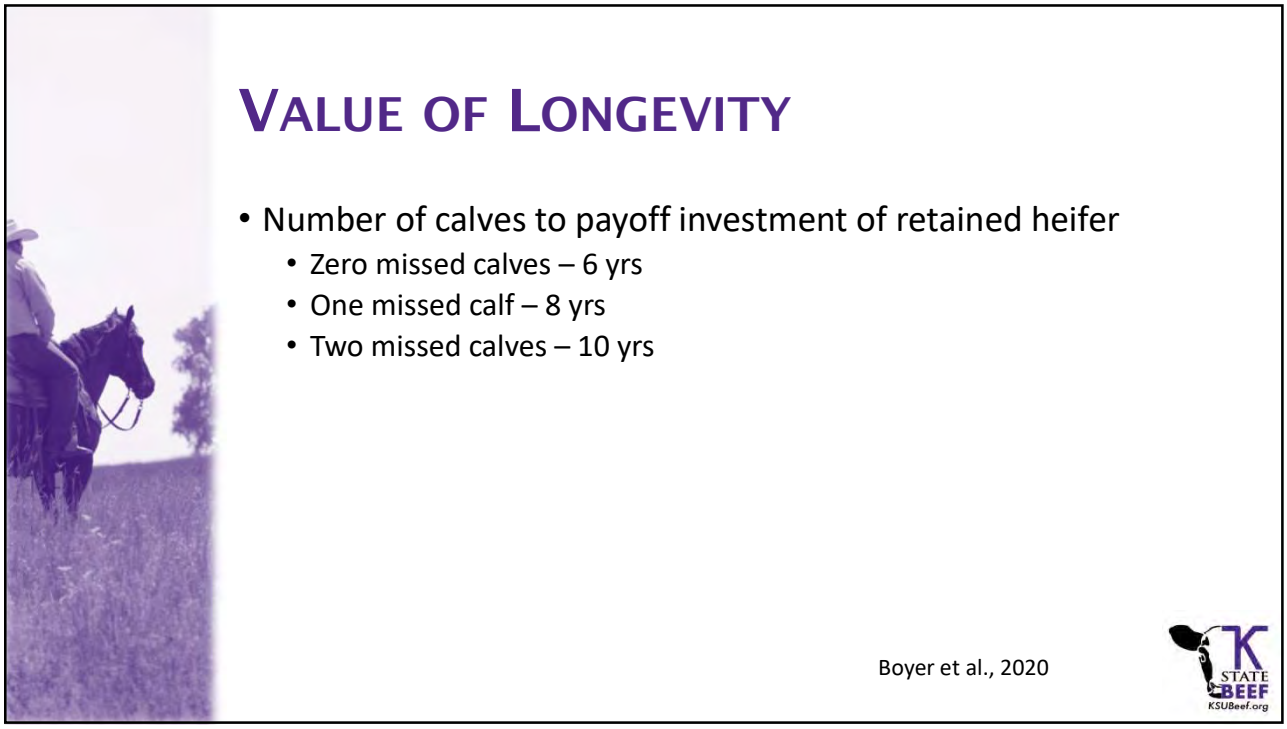
June 2, 2024
Manhattan, KS



Considerations

- Production System
- Marketing Endpoint
- Production Goals

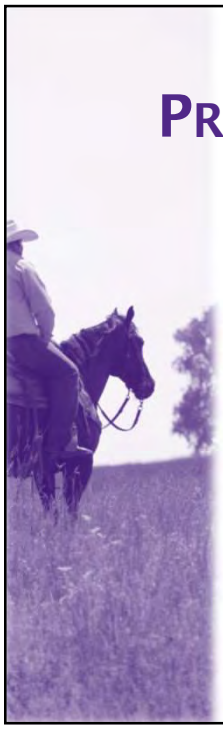




Value of Longevity

- Number of calves to payoff investment of retained heifer
  - Zero missed calves – 6 yrs
  - One missed calf – 8 yrs
  - Two missed calves – 10 yrs

Boyer et al., 2020

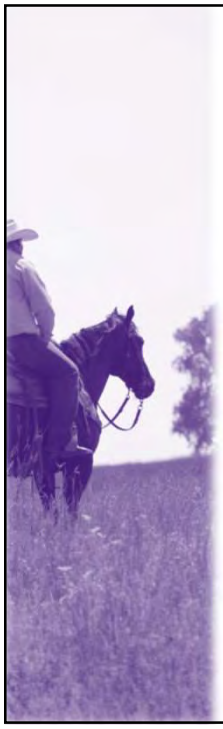


Productive Years & Cow Depreciation

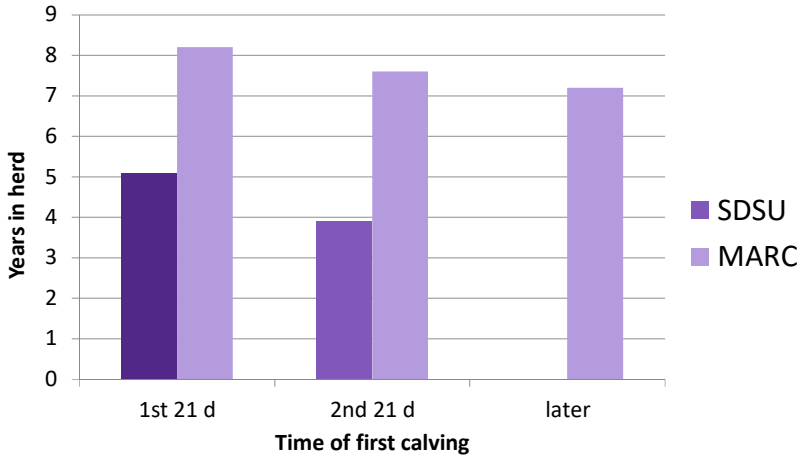
- Value of replacement entering herd
- Sale value when she exits
- Number of years in production

$2000 - $1000 = $1000

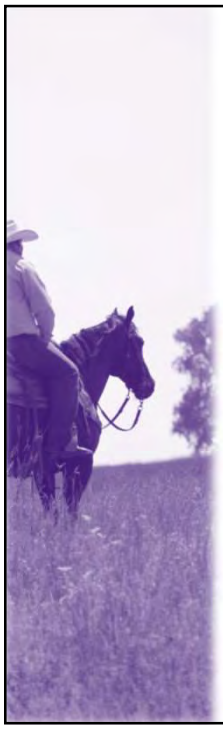
4 yrs - $250/yr
5 yrs - $200/yr
6 yrs - $167/yr
8 yr - $125/yr



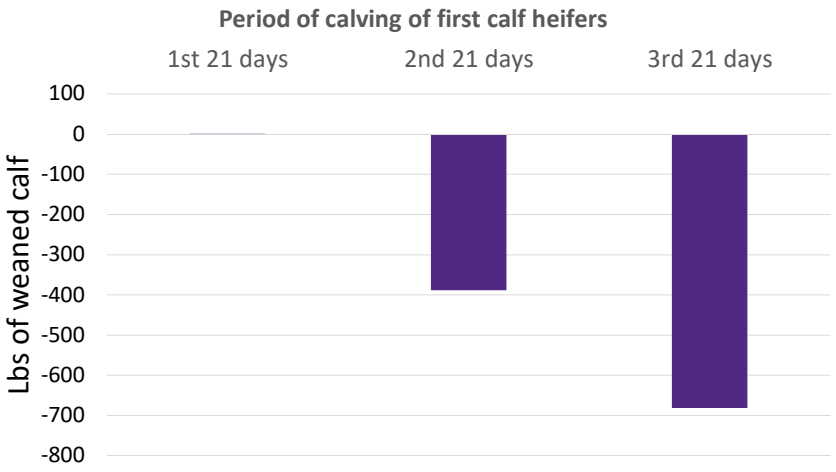
Longevity in herd based on calving date as heifer



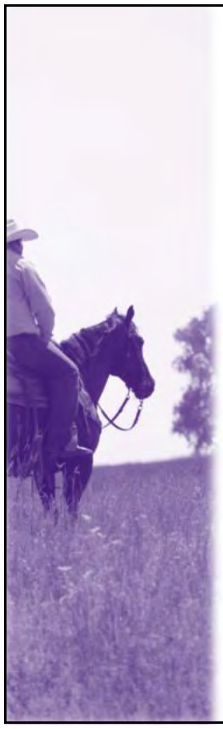
Cushman et al., 2013



Lifetime weaning weight disadvantage of heifers that conceive later in the first breeding season



Cushman et al., 2013



Opportunity

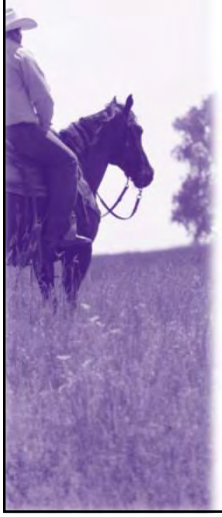
- Leave bull in longer
- Stage pregnancies to identify those that conceive early

- Market opens and late breds

Postweaning Systems

Cost
Performance

Shifts in heifer development



THEN

- Emphasis on puberty
- Target weight 60 – 65%
- Cheap grain
- Feedlot system

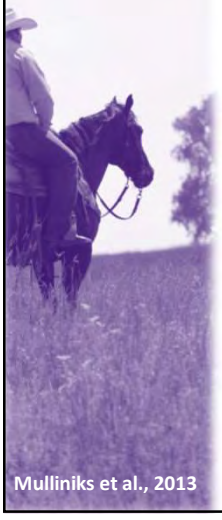
NOW

- Puberty less of an issue - heifers becoming pregnant on the cow
- Higher production costs - lower target weight reduce development costs
- Open yearling heifers profitable

Summer gains followed the reverse order of winter gains. (Lemenager et al., 1980)

- Heifers wintered with no supplement exhibited compensatory gains on summer grass when compared to heifers wintered with supplemental feed. Joubert (1954), Zimmerman *et al.* (1958) and Short and Bellows (1971)

	Ground Ear Corn lbs /hd/day winter phase		
	0	2.7	5.4
Winter ADG	.07	.48	.77
Summer ADG	1.72	1.50	1.32



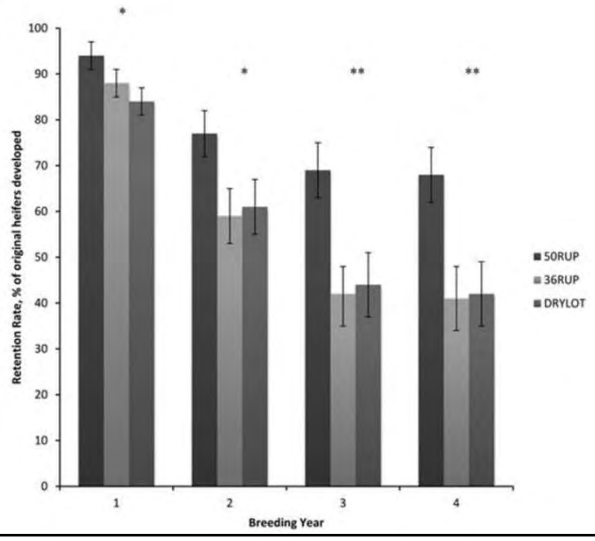
Growth & reproductive performance of heifers grazing native dormant range with protein supplement or in drylot

Item	36RUP	50RUP	Drylot	P-Value
BW				
Weaning	491	493	493	0.97
Breeding	607	607	693	<0.01
ADG				
Initial to breeding	0.59	0.57	1.52	<0.01
Breeding to preg	1.87	1.76	1.34	<0.01
% mature BW	51	51	58	<0.01
Pregnancy rate, %	88	94	84	0.10
Calving date	66	65	63	0.89
Net Return/Heifer developed	$256.03	$268.86	$168.85	

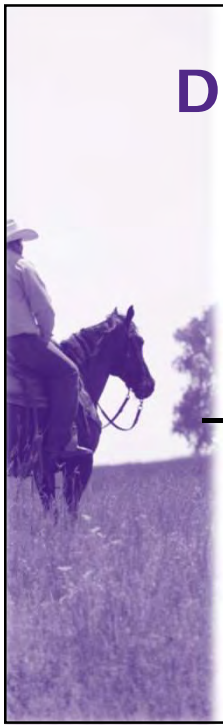
Mulliniks et al., 2013

Retention of heifers fed 2 types of protein supplementation or fed in drylot

Figure 1.



Mulliniks et al., 2013



Design

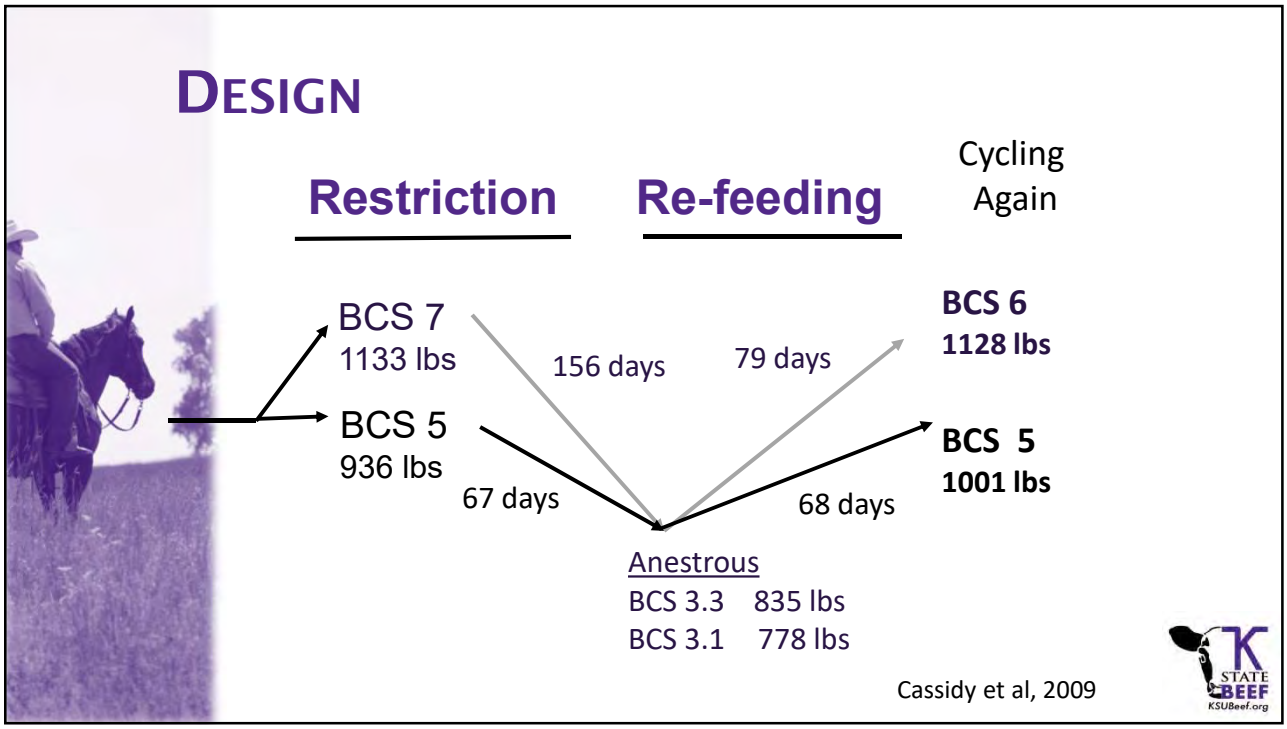
Restriction **Re-feeding**

BCS 7

BCS 5

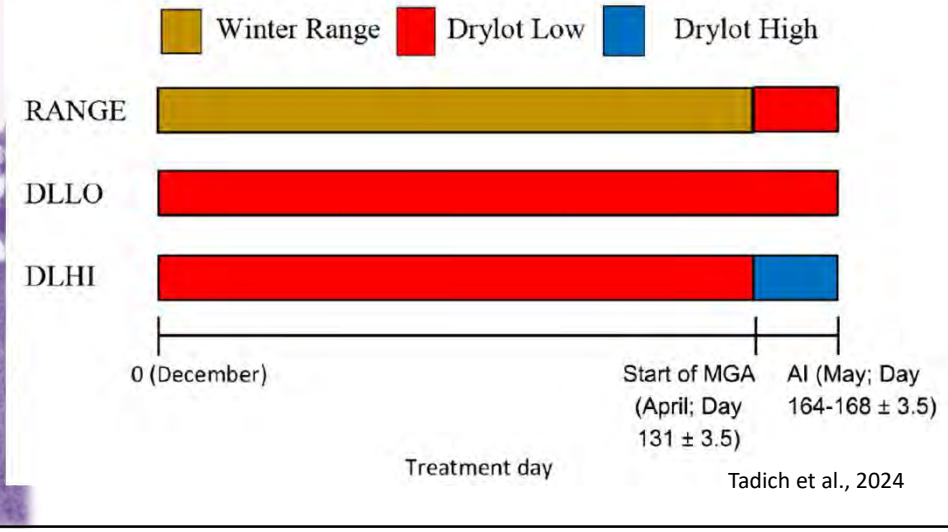
Cassady et al 2009

Design



Cassidy et al, 2009

Effects of short-term nutritional increase before AI



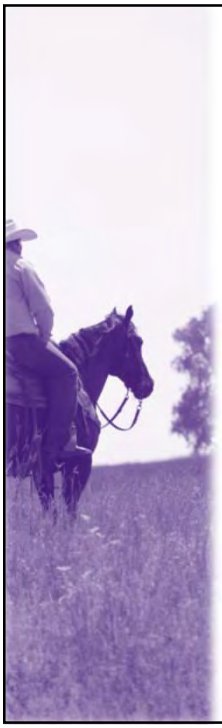
Tadich et al., 2024

Effect of nutritional increase on reproductive performance during a 33-d synchronization treatment period in beef heifers

Item	Range	DLLO	DLHI
n	3	3	3
Initial BW	482	480	482
Development ADG	0.57[b]	1.41[a]	1.41[a]
Prebreeding BW	686[b]	799[a]	825[a]
% Mature BW	57[b]	66[a]	68[a]
Breeding ADG	1.52[b]	0.84[a]	0.77[a]
Final Preg BW	909[b]	972[a]	986[a]

[a,b] Means differ P <0.02

Tadich et al., 2024



Effect of nutritional increase on reproductive performance during a 33-d synchronization treatment period in beef heifers

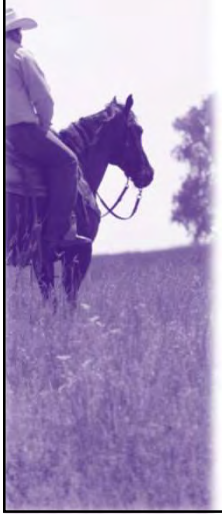
Item	Range	DLLO	DLHI	P-value
n	3	3	3	
Cycling (P4), %	14	62	24	0.16
Detection of estrus, %	70	93	89	0.07
AI Pregnancy Rate, %	49	63	69	0.34
Final Pregnancy Rate, %	84	95	93	0.09
Calving Rate, %	77	85	93	0.11
Calved in first 21 d, %	42	41	55	0.23

Tadich et al., 2024

How big at first breeding?

% Mature BW	Yearling Preg Rate	2-yr-old Preg Rate	3-, 4-, 5-yr-old Preg Rate	Calve first 21 d
70	85	92	ND	65
65	85	90	ND	65
60	83	87	ND	76
55	80	82	ND	77
50	73	75	ND	76

Crouch et al., 2024



How much should they weigh?

65% of mature weight

- Tried and true
- At one time needed to obtain puberty
- Good early fertility

1800 x .65 = 1170
1400 x .65 = 910
1200 x .65 = 780

55% of mature weight

- Decrease heifer development cost
- Develop grazing skills
- Show compensatory gain on summer grass
- Riskier

1800 x .55 = 990
1400 x .55 = 770
1200 x .55 = 660

Reproductive Tract Scores (RTS)

RTS	Uterine horns	Ovarian Measurement (mm) Length	Height	Width	Ovarian Structures	Description
1	Immature < 20 mm diameter No tone	15	10	8	No palpable follicles	Infantile
2	20-25 mm diameter No tone	18	12	10	8 mm follicles	Prepubertal
3	20-25 mm diameter Slight tone	22	15	10	8-10 mm follicles	Peripubertal
4	30 mm diameter good tone	30	16	12	> 10 mm follicles CL possible	Cycling
5	> 30 mm diameter	> 32	20	15	CL present	Cycling

Adapted from Anderson et al., 1991

Table 1. Distribution of animals by ovarian score (OS) and uterine score (US) in Experiment 1.

		Ovarian score[1]				
		2	3	4	5	Total
Uterine Score[2]	2	0.6 % (3/469)	2.1 % (10/469)	0.0 % (0/469)	0.0 % (0/469)	2.8 % (13/469)
	3	1.5 % (7/469)	26.4 % (124/369)	1.1 % (5/469)	3.0 % (14/469)	32.0 % (150/469)
	4	0.0 % (0/469)	1.7 % (8/469)	4.1 % (19/469)	12.0 % (56/469)	17.7 % (83/469)
	5	0.4 % (0/469)	12.0 % (56/469)	0.4 % (2/469)	35.2 % (165/469)	47.6 % (223/469)
	Total	2.1 % (10/469)	42.2 % (198/469)	5.5 % (26/469)	50.1 % (235/469)	

Smith et al., 2022

Table 6. Pregnancy outcomes of heifers by reproductive tract score[1] (RTS) in Experiment 2.

	Conceived to first AI service		Failed to become pregnant	
RTS[1]	%	Proportion	%	Proportion
2–3	60.9%[a]	14/23	17.4%[a,b]	4/23
3–2	62.2%[a]	23/37	13.5%[a,b]	5/37
3–3	68.9%[b]	2511/3643	14.4%[a,b]	526/3643
3–4	69.1%[b,c]	1215/1759	12.2%[a]	213/1749
4–3	66.7%[b,c]	1100/1649	13.7%[b]	226/1649
4–4	69.6%[c]	9938/14,274	13.9%[b]	1990/14,274

Smith et al., 2022

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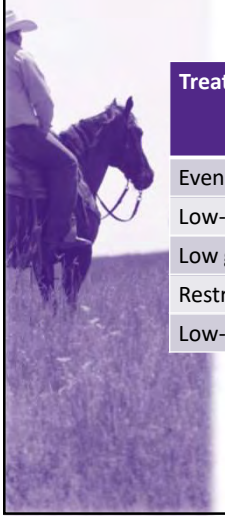
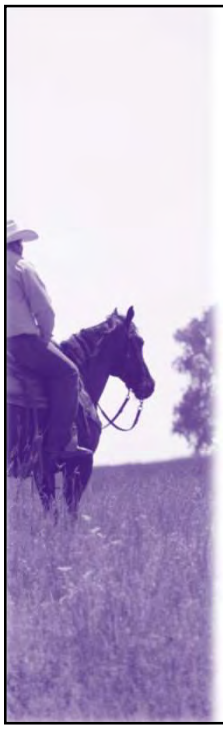
Timing of Weight Gain

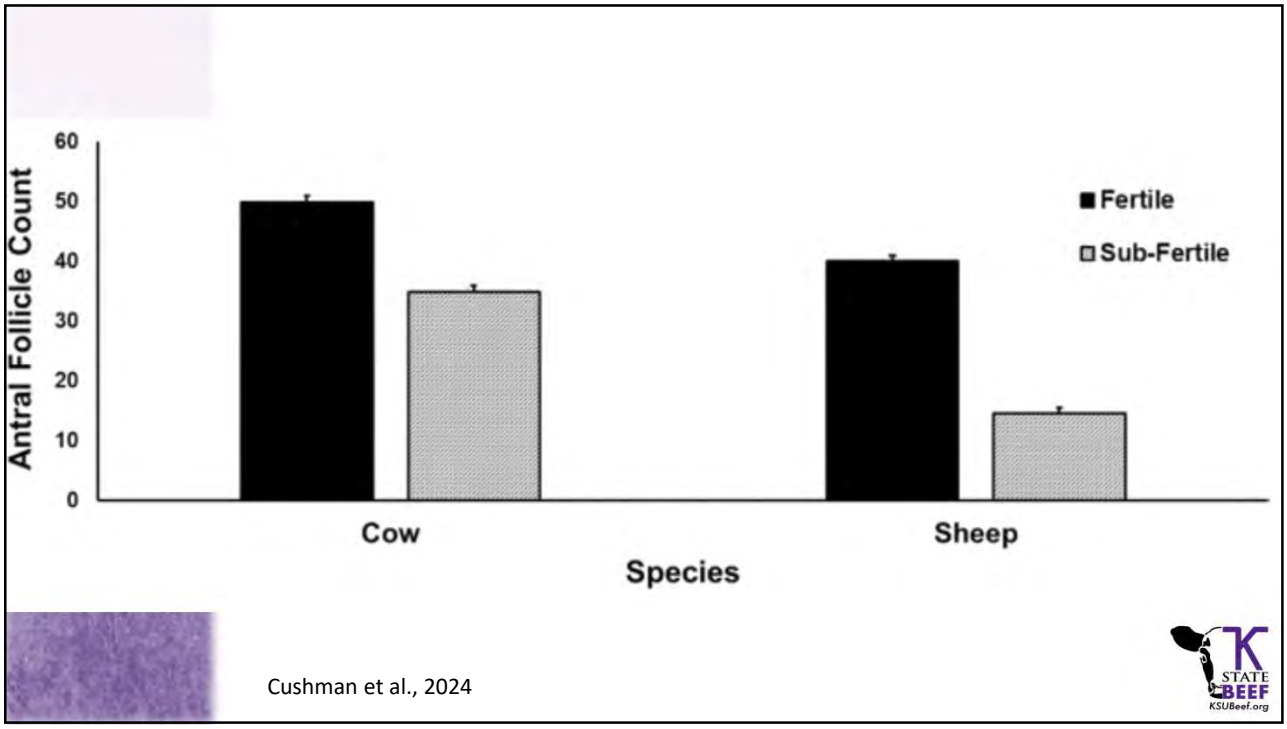


Treatment	Age at puberty	Heifer pregnancy rate	Mean calving date	2nd year pregnancy rate	Reference
Even gain vs Late gain	INCR	NS	_	_	Lynch et al., 1977
Low-High vs High	_	NS	NS	NS	Freetly et al., 2001
Low gain vs High gain	DECR	NS	NS	NS	Funston & Deutscher, 2004
Restricted vs Control	INCR	NS	_	_	Roberts et al., 2009
Low-High vs Constant	NS	NS	NS	_	Rosasco et al., 2017

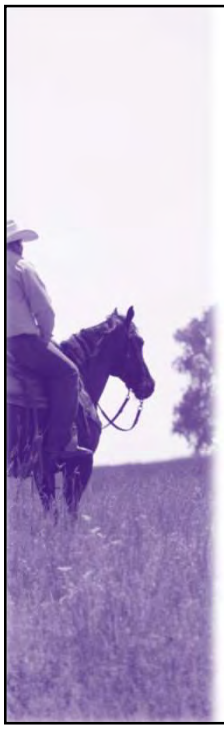


Ovarian Reserve

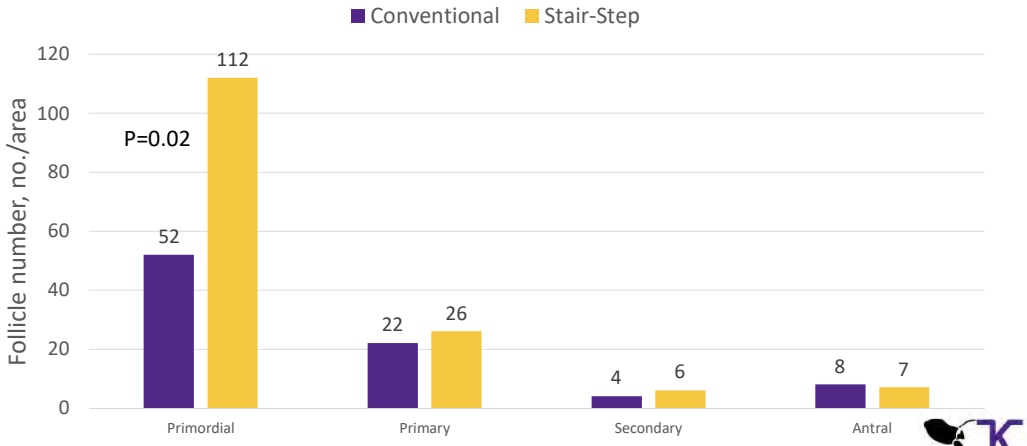
- Germ cells – number increases to mid-gestion then declines
- Positive association between antral follicle count and reproductive tract size



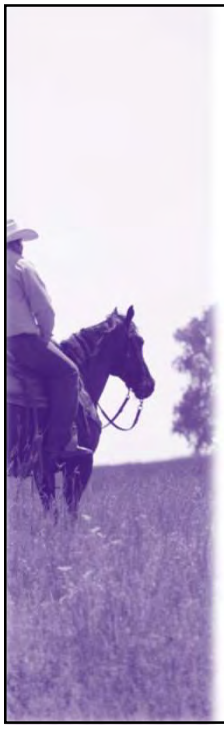
Cushman et al., 2024



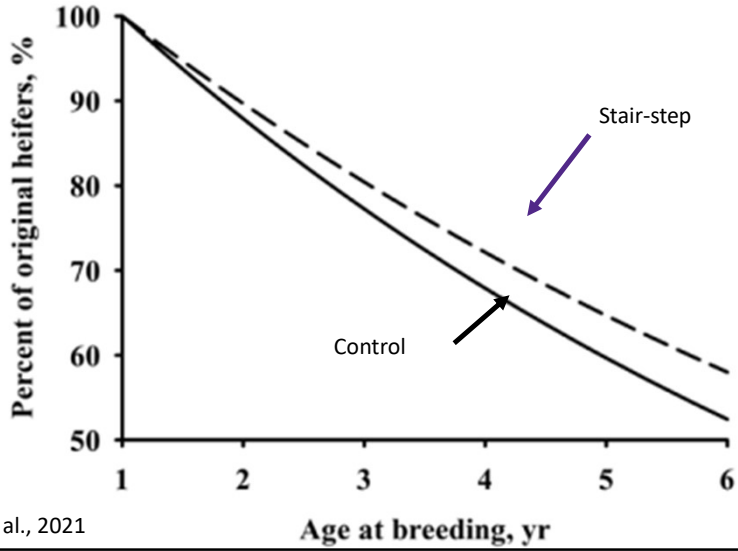
Control vs Stair-Step development diet and ovarian Histology



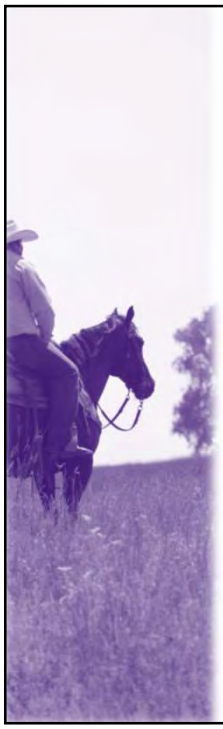
Freetly et al., 2014



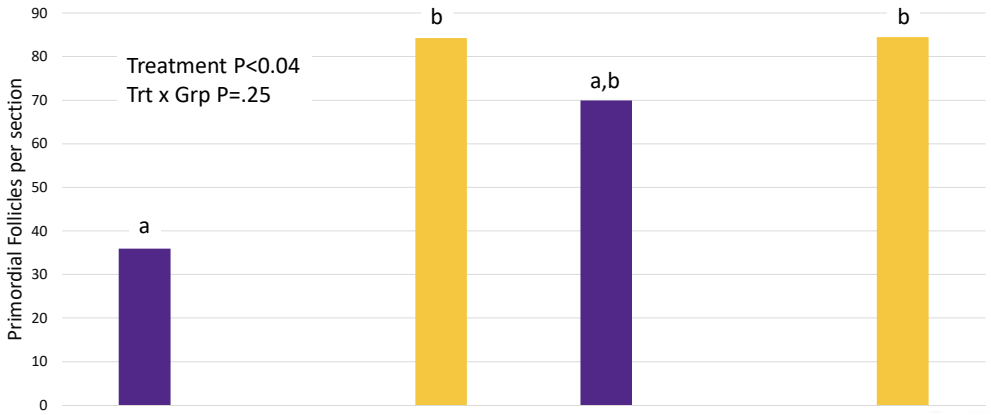
Retention of Cows Raised on Different Postweaning Growth Patterns



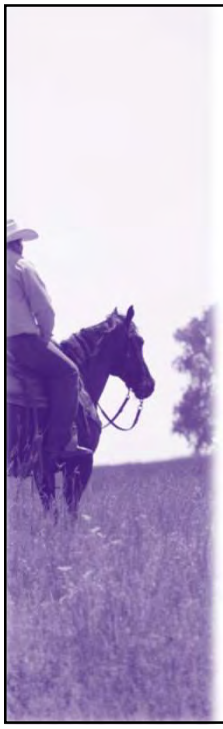
Freetly et al., 2021



Effect of Nutritional Programming on the Ovarian Reserve



Rosasco et al., 2020

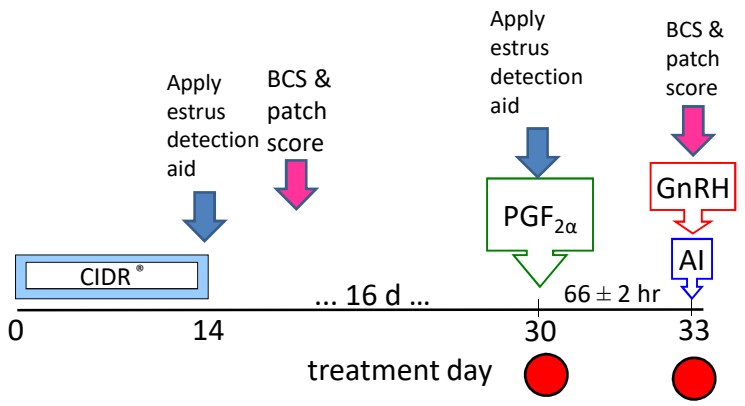


Implications

- Need to weigh heifers and balance diets

Objective to compare fertility in two systems

Year	Trt starting date	Days before CIDR	n
2017	3/16	-7	169
2018	3/7	-17	86
2019	3/24	0	97
2020	3/23	0	130



Serum sample

AI Preg Check 53 – 64 d after FTAI

2017 – 10 days to bull turnout
2018, 2019, 2020 – AI only

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Nutrient content of triticale

Start of grazing

Year	CP	ADF	NDF
2017	28.8	22.5	45.2
2018	20.2	24.4	47.1
2019	29.3	20.8	41.4
2020	27.8	21.3	39.6

at AI

Year	CP	ADF	NDF
2017	22.1	28.8	47.8
2018	17.8	32	56.2
2019	15.0	34.1	55.3
2020	12.6	28.5	52.2

Drylot ration composition, % DM

	2017	2018	2019	2020
Forage Sorghum Hay	69.1		41.4	48.4
CRP Hay		32.2		
Triticale Silage		47.0	33.7	
DDG	21	10.7	12.8	
WDG				26.8
Corn	9.9	10.1	12.1	23.3
CP	11.7	10.7	10.6	14.1
Ne_m Mcal/lb	.70	.57	.69	.78
Ne_g Mcal/lb	.43	.31	.41	.49

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Weight gain during treatments

	Starting Weight		Ending Weight		ADG	
Year	Drylot	Triticale	Drylot	Triticale	Drylot	Triticale
2017	773	781	823	837	1.23	1.41
2018	813	797	887	888	1.48	1.82
2019	775	778	856	898	2.53	3.75
2020	662	656	766	755	3.15	3.02
all	757	752	834	**845**	2.16	**2.51**
Age		**		**		NS
Year		**		**		**
Trt		NS		*		*
Trt x Y		NS		*		*

* P<0.05; ** P<0.001; NS = no statistical difference

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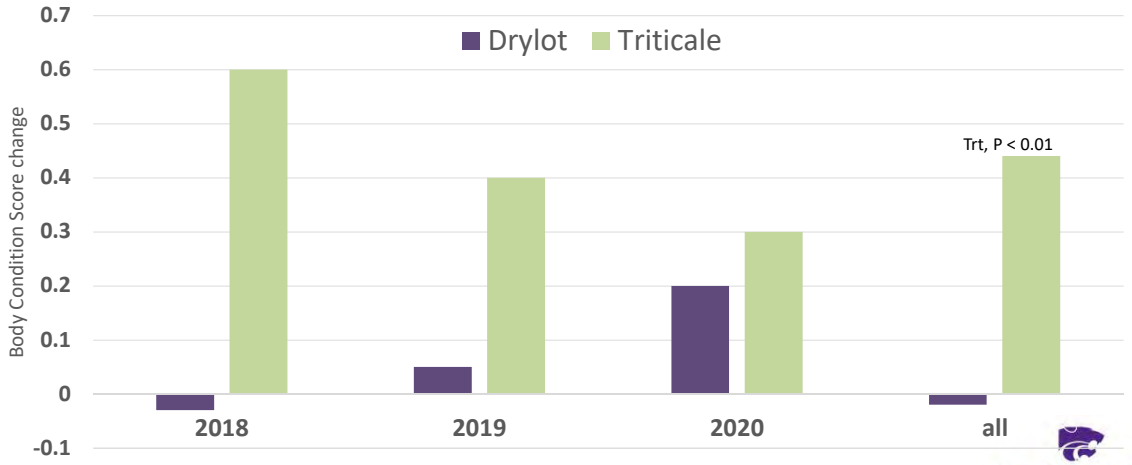
Body condition change from CIDR removal to AI



Trt, P<0.01
Trt x Yr, P<0.01

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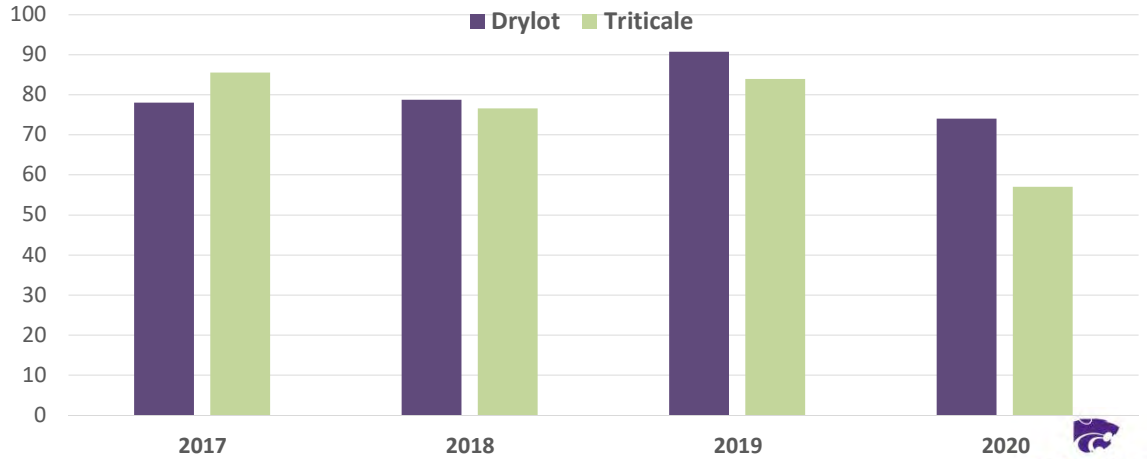
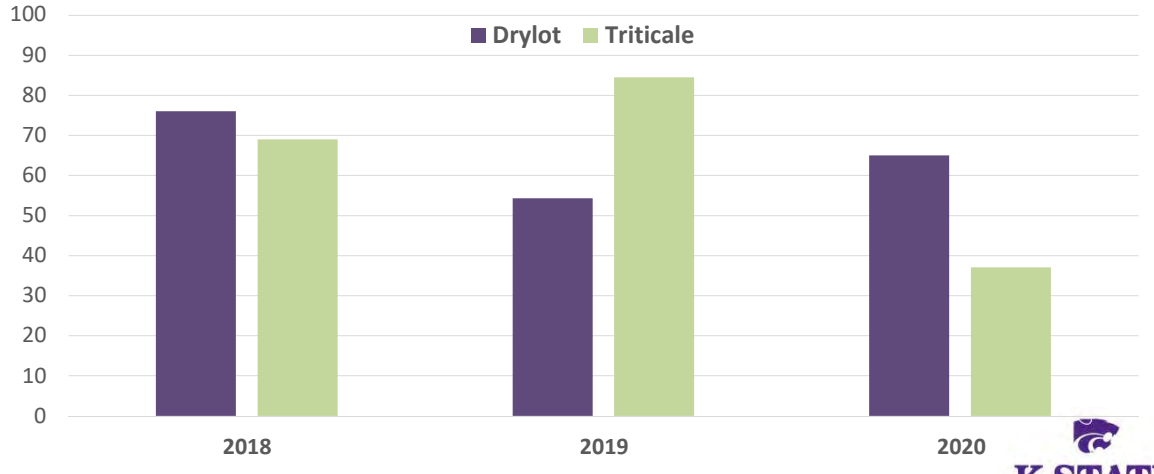
Proportion of heifers with patch scores of ≥ 3, 5 to 6 days after CIDR removal



Age P=.29, Year P=0.002, Treatment P=0.29, Treatment x Year P=0.14

K-STATE Research and Extension

Proportion of heifers with patch scores of ≥3 at AI.



Age P=.36, Year P=0.001, Treatment P=0.98, Treatment x Year P<.001

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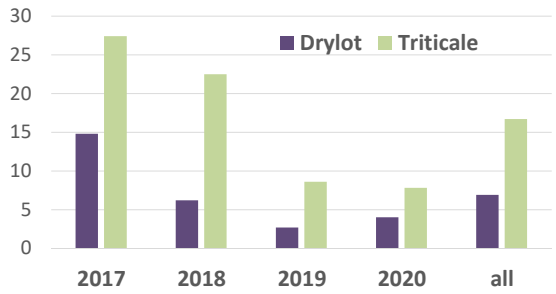
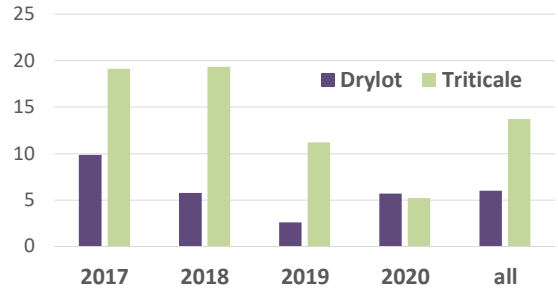
Blood Urea Nitrogen (mg/dL)

At PGF



Age	NS
Year,	**
Treatment	**
Trt x Year	**

At Insemination

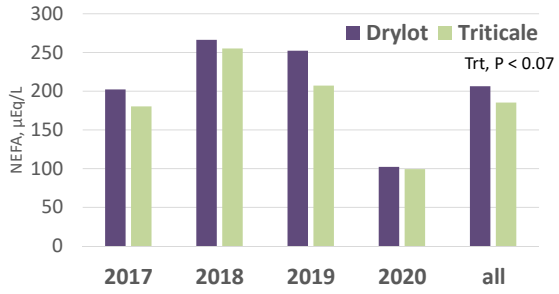


Age	*
Year,	**
Treatment	**
Trt x Year	**

K-STATE Research and Extension

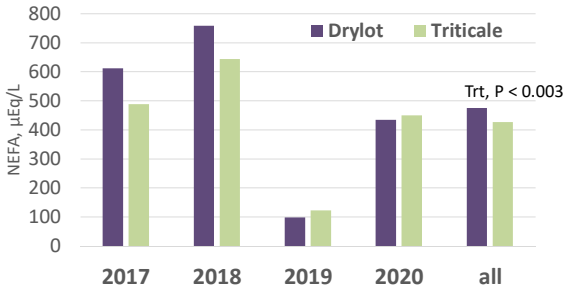
Concentrations of NEFA

At PGF



Year P<0.001, Treatment P=0.07, Treatment x Year P=0.21

At Insemination



Year P<0.001, Treatment P=0.003, Treatment x Year P<0.001

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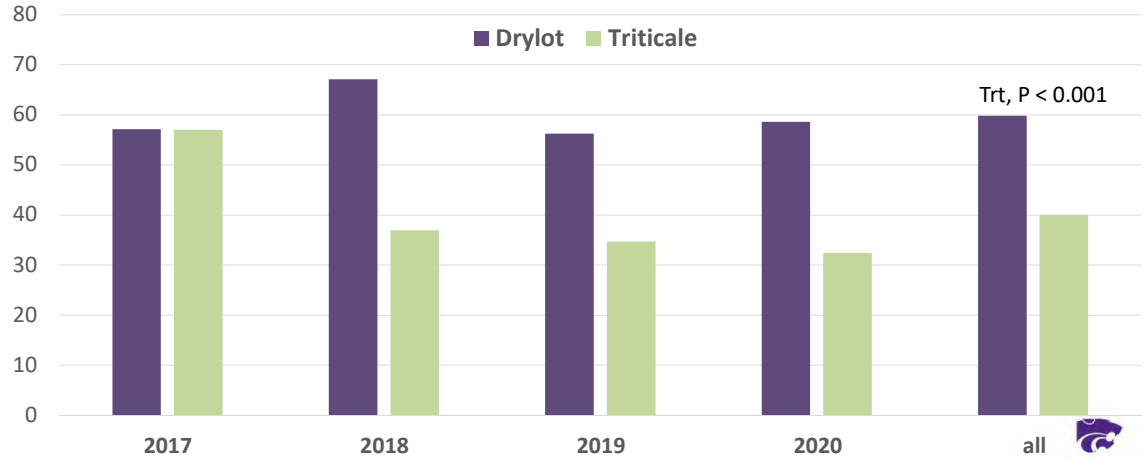
AI Pregnancy rate



Year P=.16; Treatment P<0.001, Treatment x Year P=0.05

K-STATE Research and Extension

Summary

- Costs and longevity
- Early bred heifers have huge advantage / late bred heifers are high risk
- Pattern of gain
  - Cost
  - Some restriction seems beneficial in longevity
  - Target development wt may depend on risk tolerance
- Lush vs drylot System

K-STATE Research and Extension

Sandy Johnson, PhD
sandyj@ksu.edu
www.KSUBeef.org

THE FINER POINTS OF DIAGNOSTIC INVESTIGATIONS OF COMMON FOOD ANIMAL TOXINS

SCOTT FRITZ
DVM, DABVT

LARGE ANIMAL

The Finer Points of Diagnostic Investigations of Common Food Animal Toxins

Scott Fritz DVM, DABVT
Clinical Assistant Professor of Toxicology
Kansas State University College of Veterinary Medicine

Diagnostic investigations involving food animals can be a frustrating endeavor. Often, the presenting complaint directed towards veterinarians is "found dead." Lack of clinical signs makes rapid identification of the affected organ system impossible. Furthermore, once an animal expires, the clock is already ticking regarding diagnostic sample quality. Issues that arise during the summer months are even more complicated by lack of daily observation and high ambient temperatures that can ruin a carcass in a couple of hours. This presentation addresses common challenges veterinarians can expect to encounter when working through these frustrating and sometimes catastrophic cases. The outline below should help remind readers of the discussion points from the presentation. It is important to recognize diagnostic medicine is always changing and many laboratories do not employ a veterinary toxicologist as part of the diagnostic team, much toxicology testing is done on a referral basis. As such, each situation should be approached independently and frequent communication with a diagnostic laboratory offers the best chance at a definitive diagnosis.

Nitrate/Nitrite

- Ideal diagnosis:
    - Brown discoloration of tissues
    - Elevated nitrate concentrations in ocular fluid
    - Elevated nitrate concentrations in the source
    - Confirmation of exposure to a source
- Challenges
    - The source may be totally consumed
    - The source may change prior to sampling
    - There may be a hot spot that cows consumed
    - Endogenous production of intraocular nitrate by postmortem bacteria
        - Assays cannot differentiate

Non-Protein Nitrogen

- Ideal Diagnosis
    - Response to therapy in sublethally-exposed cohorts
    - Basic rumen pH (>8)
    - Elevated ammonia in ocular fluid
    - Elevated NPN concentrations in the source
    - Evidence of accidental consumption
    - Clinical signs in minutes to hours after consumption of elevated NPN in the diet
- Challenges
    - Rumen pH reverts to normal over time

    - Ammonia is volatile so it disappears quickly
    - The source can change

Neurotoxins that can cause laminar cortical necrosis

- Ideal Diagnosis
    - Histologic diagnosis
    - Toxic concentrations of lead in liver/kidney or,
    - Toxic concentrations of sodium in the brain or,
    - Toxic concentrations of sulfur in the total diet including drinking water
- Challenges
    - Delayed sampling can ruin brain lesions
    - Death may be too rapid for brain lesions to develop
    - If only fixed brain is submitted, sodium quantification is not useful
    - Feed and water sulfur sources are additive, all need analyzed

Ionophores

- Ideal Diagnosis
    - Compatible timeline of events – off feed event, transient diarrhea
    - Histologic evidence of myocardial degeneration and necrosis
    - Toxic concentrations in feed
- Challenges
    - Often mis-diagnosed as respiratory disease early
    - Delay in clinical effects can be over a week after the over dose
    - Offending feed is often gone

Abortive toxins

- Ideal Diagnosis
    - Lack of identification of infectious etiologies
    - Proof of exposure in the dam
    - Clinical signs in the dam for certain toxins
    - Detection of compound in various fetal or maternal samples – toxin dependent
- Challenges
    - Robust rule outs of infectious causes
    - Abortion could be secondary issue
    - A test does not exist for everything

Plants

- Ideal Diagnosis
    - Confirmation of possible exposure
    - Compatible clinical signs, gross and/or histologic lesions
    - Confirmation of ingestion
- Challenges
    - When a plant is eaten it no longer exists

- Lack of daily observation on pasture
- Delay in sampling can limit histologic examination
- Delay in clinical signs can be months for certain plants
- Unknown toxic principle
- Lack of tests for toxic principle in others

BEEF CATTLE MINERAL NUTRITION

STEVE ENSLEY
BS,DVM, MS, PHD

ROBERT LARSON
DVM, PHD, DACT, DACVPM (EPIDEMIOLOGY), ACAN

LARGE ANIMAL

Beef Cattle Nutrition:
Mineral Nutrition

Dr. Bob Larson
Dr. Steve Ensley

Macrominerals

- Salt (NaCl) is the mineral needed consistently and in the largest amount (1 to 2 oz. daily)

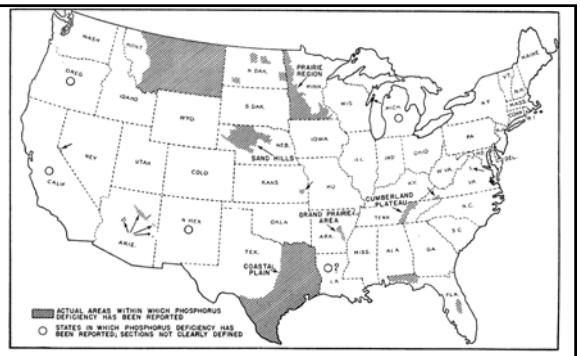
Macrominerals

- Calcium is usually supplied in adequate amounts in forage. Higher requirement during lactation

Macrominerals

- Phosphorus is deficient in some areas of U.S. and during some production phases (lactation)

  Maturity of forage affects supplementation needs



Phosphorus deficient soils (and plants) tended to be most problematic in the Northern Great Plains and Midsouth. States with low soil P include the Coastal Plain of Texas (southeastern 1/3 of Texas), Montana, Western Minnesota, portions of North Dakota, the Sandhills of Nebraska, and isolated areas in other states (particularly mid-south)

Macrominerals

- Magnesium supplementation is required when grazing wheat pasture or lush early-growth cool season grasses

  (↑potassium & ↓ magnesium)

Macrominerals

- Potassium is rarely required with a forage-based diet

  Deficiency reported with badly weathered hay

Microminerals

- Six trace minerals potentially deficient in forage-based diets:

Copper	Cobalt
Iodine	Selenium
Zinc	Manganese

Microminerals

- Copper
  - Molybdenum and sulfur levels impact copper utilization
  - Iron can also impact copper utilization

Copper Functions

- Formation of hemoglobin
- Incorporation into ceruloplasmin
- Iron movement
- Protection from oxidation
- Involvement in immune response (maybe not ruminants)

Copper Functions cont.

- Co-factor in many enzyme systems
  - Prostaglandin synthesis
  - Collagen and elastin synthsis
  - Conversion of L-tyrosin to melanin

Signs of Copper Deficiency

- Reduced fertility (male and female)
- Increased risk of retained placenta
- Increased risk of abomasal ulcers
- Iron anemia
- Ataxia and dummy calves
- Foot problems (cracks, abscesses, etc.)

Signs of Copper Deficiency

- Grey hair coat
- Poor performance / wt. gain
- Impaired immune response - poor response to vaccination
  (maybe not ruminants)

Copper Antagonists

- Molybdenum
  - Usually associated with alkaline soil
  - Legumes accumulate more than grasses
  - Cu:Mo ratio should be >6:1
    - Borderline ratio of 2-3:1
    - Toxic levels <2:1

Copper Antagonists

- Sulfate
  - Sulfates and molybdenum both needed to form thiomolybdates
- Iron
- Other minerals: phosphorus, zinc, lead, calcium, cobalt, mercury, selenium, tin, silver, tungsten...

Copper Antagonists

- Others
  - Protein
  - Estrogen
  - Nitrates

Microminerals

- Cobalt
  - Not much is known ?

Microminerals

- Iodine
  - Deficiencies seldom reported ?
- Selenium
  - Deficiency and toxicity reported (activity tied to Vit E)
  - Areas in Kansas

Microminerals

- Zinc

  Reported to be most commonly deficient in forage

- Manganese

  Occasionally deficient – calf defects
  Very poorly available from forage

Suspected trace mineral problems should be investigated not as a single element problem, but as an imbalance of several or all minerals

Factors in Mineral Imbalances

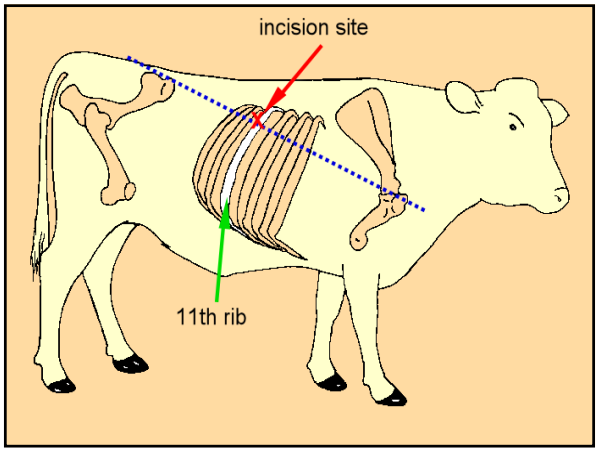
- Breed
- Growth rate
- Milk production
- Feed source
- Water source
- Crop / feed production practices

Microminerals

- If a trace mineral deficiency is suspected - a thorough diagnostic work-up is required

  Feed and water analysis

  Liver and serum sampling



Microminerals

- Supplementation Baseline

  Use sources available to animal
  (i.e. Copper oxide is poorly available)

Micromineral Forms

- Chelated minerals

Mineral chelated to 2 amino acids
Industry definition is not uniform
Much more expensive
Theory has some logic
Scientific data to support is lacking

Microminerals

- Supplementation Baseline

Provide 50% of NRC recommended levels of Cu, Zn, Co, Se, and I

Provide 100% of NRC recommended level of Mn

Interesting Case:

Too many open cows…..

KANSAS STATE UNIVERSITY

Introduction: First Contact

August 2020: Phone call from veterinarian in North Dakota. A client is concerned about poor fertility and thinks the problem may be copper deficiency. The veterinarian wants to know if I can help her interpret the mineral analysis.

Larson: Yes, I'll be glad to help, and I am going to pull Dr. Steve Ensley into the discussion as well. Please send me the lab reports and a history of the situation.

From: [redacted]
Sent: Thursday, August 13, 2020 11:02 AM
To: Robert Larson <rlarson@vet.k-state.edu>
Subject: [redacted] liver biopsy mineral analysis

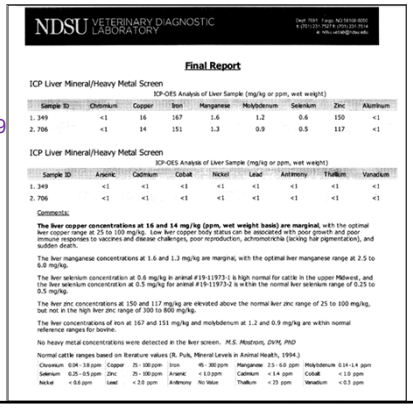
Dr. Larson,
Attached are a water sample report, mineral records for the biggest group of cattle (a high percentage of these are first and second calf heifers), the tag from the mineral they are feeding and also the liver biopsy report done on 11-22-19, and the recent liver biopsy results.

[redacted] is a "silver bullet" kind of client. He thinks copper deficiency is the issue with his cattle's low fertility rates and he decided to test these calves without necessarily our input but the feed company advised him to. He has commercial calves by Berlin, ND which is SE corner. That soil is alkaline high typically. What Dr. Hall from Utah had advised was to liver biopsy the cows at PG and then formulate a ration at that time to correct their imbalance. Richard wants to help his calves from this year now and also get an idea of a plan/know if what he was feeding was inadequate.

They are not feeding any DDG's.
Please let me know if you need any other information. Thank you.
[redacted]

Introduction: First Contact

Liver samples from 2 calves taken 11/18/2019



NDSU VETERINARY DIAGNOSTIC LABORATORY

Final Report

ICP Liver Mineral/Heavy Metal Screen

ICP-OES Analysis of Liver Sample (mg/kg or ppm, wet weight)

Sample ID	Chromium	Copper	Iron	Manganese	Molybdenum	Selenium	Zinc	Aluminum
1. 349	<1	16	167	1.6	1.2	0.6	150	<1
2. 706	<1	14	151	1.3	0.9	0.5	117	<1

ICP Liver Mineral/Heavy Metal Screen

ICP-OES Analysis of Liver Sample (mg/kg or ppm, wet weight)

Sample ID	Arsenic	Cadmium	Cobalt	Nickel	Lead	Antimony	Thallium	Vanadium
1. 349	<1	<1	<1	<1	<1	<1	<1	<1
2. 706	<1	<1	<1	<1	<1	<1	<1	<1

Comments:

The liver copper concentrations at 16 and 14 mg/kg (ppm, wet weight basis) are marginal, with the optimal liver copper range at 25 to 100 mg/kg. Low liver copper body status can be associated with poor growth and poor immune responses to vaccines and disease challenges, poor reproduction, achromotrichia (lacking hair pigmentation), and sudden death.

The liver manganese concentrations at 1.6 and 1.3 mg/kg are marginal, with the optimal liver manganese range at 2.5 to 6.0 mg/kg.

The liver selenium concentration at 0.6 mg/kg in animal #19-11973-1 is high normal for cattle in the upper Midwest, and the liver selenium concentration at 0.5 mg/kg for animal #19-11973-2 is within the normal liver selenium range of 0.25 to 0.5 mg/kg.

The liver zinc concentrations at 150 and 117 mg/kg are elevated above the normal liver zinc range of 25 to 100 mg/kg, but not in the high liver zinc range of 300 to 800 mg/kg.

The liver concentrations of iron at 167 and 151 mg/kg and molybdenum at 1.2 and 0.9 mg/kg are within normal reference ranges for bovine.

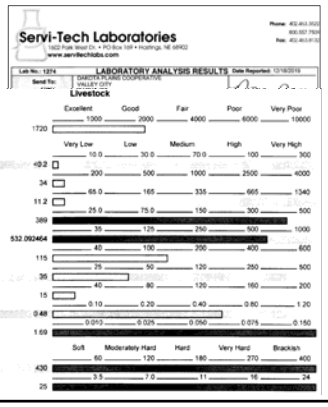
No heavy metal concentrations were detected in the liver screen. *M.S. Mostrom, DVM, PhD*

Normal cattle ranges based on literature values (R. Puls, Mineral Levels in Animal Health, 1994.)

Chromium	0.04 - 3.8 ppm	Copper	25 - 100 ppm	Iron	45 - 300 ppm	Manganese	2.5 - 6.0 ppm	Molybdenum	0.14 -1.4 ppm
Selenium	0.25 - 0.5 ppm	Zinc	25 - 100 ppm	Arsenic	< 1.0 ppm	Cadmium	< 1.4 ppm	Cobalt	< 1.0 ppm
Nickel	< 0.6 ppm	Lead	< 2.0 ppm	Antimony	No Value	Thallium	< 25 ppm	Vanadium	< 0.3 ppm

Introduction: First Contact

Water sample taken 12/16/2019



Servi-Tech Laboratories
1902 Fole West Dr. • PO Box 169 • Hastings, NE 68902
www.servitechlabs.com

Lab No. 1274 — LABORATORY ANALYSIS RESULTS — Date Reported: 12/18/2019
Send To: DAKOTA PLAINS COOPERATIVE, VALLEY CITY

Livestock

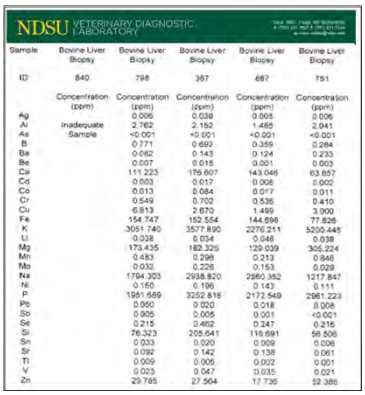
		Excellent	Good	Fair	Poor	Very Poor
Total Dissolved Solids (Calc) (TDS), mg/L	1720	1000	2000	4000	6000	10000

		Very Low	Low	Medium	High	Very High
Nitrate+Nitrite Nitrogen (NO3+NO2-N), mg/L	<0.2	10.0	30.0	70.0	100	300
Sulfate (SO4), mg/L	34	200	500	1000	2500	4000
Total Sulfur (S), mg/L	11.2	65.0	165	335	665	1340
Total Sodium (Na), mg/L	389	25.0	75.0	150	300	500
Chloride (Cl), mg/L	532.092464	35	125	250	500	1000
Total Calcium (Ca), mg/L	115	40	100	200	400	600
Total Magnesium (Mg), mg/L	35	25	50	120	250	500
Total Potassium (K), mg/L	15	40	80	120	160	200
Total Iron (Fe), mg/L	0.48	0.10	0.20	0.40	0.80	1.20
Total Manganese (Mn), mg/L	1.69	0.013	0.025	0.050	0.075	0.150

		Soft	Moderately Hard	Hard	Very Hard	Brackish
Hardness (CaCO3), mg/L	430	60	120	180	270	400
Hardness (CaCO3), grains/gal	25	3.5	7.0	11	16	24

Introduction: First Contact

Liver samples from 5 calves taken 07/29/2020



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Sample	Bovine Liver Biopsy	Bovine Liver Biopsy	Bovine Liver Biopsy	Bovine Liver Biopsy	Bovine Liver Biopsy
ID	840	798	367	667	751
	Concentration (ppm)	Concentration (ppm)	Concentration (ppm)	Concentration (ppm)	Concentration (ppm)
Ag		0.005	0.038	0.005	0.006
Al	Inadequate Sample	2.762	2.152	1.485	2.041
As		<0.001	<0.001	<0.001	<0.001
B		0.771	0.669	0.359	0.264
Ba		0.062	0.143	0.124	0.233
Be		0.007	0.015	0.001	0.003
Ca		111.223	176.607	143.046	63.857
Cd		0.003	0.017	0.008	0.002
Co		0.013	0.084	0.017	0.011
Cr		0.549	0.702	0.535	0.410
Cu		6.813	2.670	1.499	3.000
Fe		154.747	152.554	144.698	77.826
K		3051.740	3577.890	2276.211	5200.445
Li		0.038	0.034	0.048	0.038
Mg		173.435	182.325	129.039	305.224
Mn		0.483	0.296	0.213	0.846
Mo		0.032	0.228	0.153	0.029
Na		1794.303	2938.820	2860.352	1217.847
Ni		0.160	0.196	0.143	0.111
P		1951.589	3232.818	2172.549	2961.223
Pb		0.050	0.020	0.018	0.008
Sb		0.005	0.005	0.001	<0.001
Se		0.215	0.462	0.247	0.216
Si		76.323	205.641	116.691	56.506
Sn		0.033	0.020	0.009	0.006
Sr		0.092	0.142	0.138	0.061
Ti		0.009	0.005	0.002	0.001
V		0.023	0.047	0.035	0.021
Zn		29.785	27.564	17.736	52.386

Introduction: First Contact

Current mineral supplement

DLF BRDR 8P MINERAL
FOR BEEF CATTLE
CAUTION: USE ONLY AS DIRECTED
GUARANTEED ANALYSIS

4671984-106

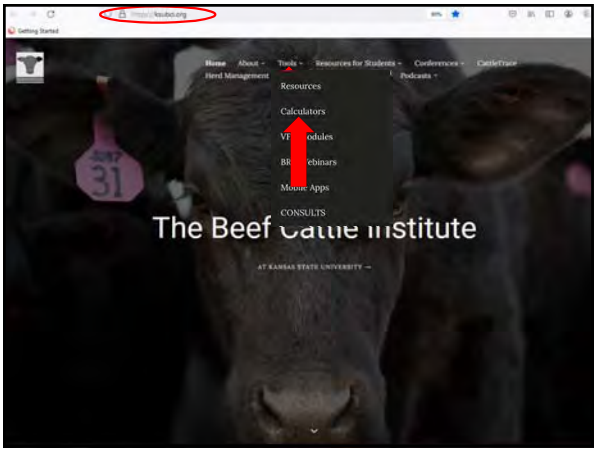
Calcium (CA) (MIN)	11.0000 %
Calcium (CA) (MAX)	13.0000 %
Phosphorus (P) (MIN)	8.0000 %
Salt (NACL) (MIN)	11.0000 %
Salt (NACL) (MAX)	13.0000 %
Magnesium (MG) (MIN)	2.0000 %
Potassium (K) (MIN)	1.0000 %
Manganese (MN) (MIN)	2500.0000 PPM
Copper (CU) (MIN)	2000.0000 PPM
Iodine (I) (MIN)	110.0000 PPM
Selenium (SE) (MIN)	30.0000 PPM
Zinc (ZN) (MIN)	6000.0000 PPM
Vitamin A (MIN)	200000.00 IU/LB
Vitamin D-3 (MIN)	12000.00 IU/LB
Vitamin E (MIN)	250.00 IU/LB

Next Steps:

What do you think?

What would you say/ask?

What would you do?



Put

Evaluating Mineral Feed Tags for Beef Cows
College of Veterinary Medicine
Kansas State University

er

Mineral			Will supply to total diet		Percentage of NRC Recommendation	NRC Reccommendation
Calcium	12.0	%	0.101	%	37%	0.27%
Phosphorus	8.0	%	0.067	%	29%	0.23%
Salt	11.0	%	0.093	%	132%	0.07%
Magnesium	2.0	%	0.017	%	17%	0.10%
Potassium	1.0	%	0.008	%	1%	0.65%
Cobalt	0	ppm	0.000	ppm	0%	0.10
Copper	2000	ppm	8.917	ppm	89%	10.00
Iodine	110	ppm	0.777	ppm	155%	0.50
Manganese	2500	ppm	9.590	ppm	24%	40.00
Selenium	30	ppm	0.115	ppm	115%	0.10
Zinc	6000	ppm	36.343	ppm	121%	30.00
vit A	200,000	IU/lb	43,750	IU	95%	46,091
vit D	12,000	IU/lb	2,625	IU	81%	3,250
vit E	250	IU/lb	55	IU	9%	591
thiamine	0	IU/lb	0	IU		

Zinc (Zl
Vitamin
Vitamin
Vitamin

PM
/LB
/LB
/LB

Next Steps:

- Bulls need attention – both pre-breeding BSE and continual monitoring during the breeding season.
- Need to address “momentum” by calving heifers ahead of cows and making sure BCS is good going into breeding
- I realize that the producer is concerned that trace mineral issues are contributing to the poor reproductive success. Although I don’t have the complete history and I have not been on the property, based on the patterns provided by the history, if a copper deficiency problem exists – I doubt that it is the primary problem.
- Continue to monitor liver copper and other minerals – key time points are near the start of the breeding season & at weaning.
- Try to locate some higher-copper and higher-manganese supplements (without raising selenium) - if commercial supplements aren’t available, we can help calculate a custom mineral mix.

Another Case:

Producer concerned that cows are not cycling…..

KANSAS STATE UNIVERSITY

Producer is very concerned about nutrition

Producer is very concerned about nutrition – particularly mineral nutrition as a cause of his poor reproductive efficiency.

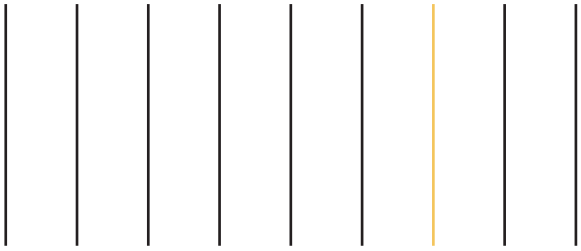
The 3 Minerals Have Important Differences

Jan 2018 2015-2016 May 2017

	Rangeland Pro Breeder Min 8 Availa 4	Rangeland Pro Breeder	Custom Ruffage Mate (8 oz /d)
Calcium	36%	36%	34%
Phosphorus	28%	32%	16%
Salt	191%	0%	58%
Magnesium	16%	2%	56%
Potassium	1%	7%	3%
Cobalt	187%	461%	38%
Copper	47%	22%	23%
Iodine	82%	59%	68%
Manganese	17%	10%	14%
Selenium	100%	100%	46%
Zinc	62%	31%	71%
Vitamin A	183%	183%	78%
Vitamin D	972%	972%	111%
Vitamin E	18%	18%	6%

DIAGNOSING REPRODUCTIVE FAILURE IN BEEF HERDS & / OR ASSESSING REPRODUCTIVE PERFORMANCE IN BEEF HERDS

TERRY ENGELKEN
DVM, MS



LARGE ANIMAL

INVESTIGATING THE CAUSES OF REPRODUCTIVE FAILURE IN BEEF HERDS

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Abstract

Reproductive efficiency is still the most important output factor affecting profitability of the cow/calf enterprise. While reproductive performance can be negatively impacted by many factors, infectious disease often plays a pivotal role in those situations where suboptimal reproductive performance is demonstrated. Early embryonic death, late-term abortion, delayed conception and "weak calf syndrome" may all be manifestations of a disease outbreak. Regardless of the cause, the end result is that the operation will have fewer pounds of calf to market after weaning. The practitioner plays a central role in understanding the relationship of infectious agents with the risk of exposure and the timing of gestational losses in order to utilize the proper diagnostics and determine why reproductive losses are occurring. Then herd health protocols can be built to minimize these losses in the future.

Utilization of Diagnostics

The diagnosis of reproductive failure may be one of the most frustrating undertakings for the practitioner and producer. In cases of abortion, an etiologic diagnosis is made less than 50% of the time.[1] Adequate information, including a herd history, with complete to a diagnostic laboratory is the most important step in a obtaining a definitive diagnosis.[2] Since diagnostic laboratories have different capabilities in handling an abortion case, it is prudent have a close working relationship with our diagnostic lab. Consultations with the pathologist are sometimes necessary to develop a systematic approach to working up reproduction losses. Submission of the appropriate tissue and body fluid samples will increase the chances of obtaining useful information. A review of the common pathogens, their timing of gestational loss, and commonly used testing modalities has been published.[3] However, the practitioner must keep in mind that there are many *noninfectious* causes of reproductive loss in cattle.

Serology has long been used as a diagnostic tool to define disease response in the individual animal and the movement of an organism within a population. When dealing with cases of abortion, serology must be interpreted with great caution.[3] Single serum samples have little to no value when diagnosing abortions as it is difficult to differentiate titers that arise from vaccination or natural exposure. However, a lack of titer may serve to rule out certain diseases. Paired sera may have limited value as well. Many of the bacterial and viral pathogens that cause abortion may infect the fetus or placenta long before the abortive event occurs. This lag time between infection and abortion may prevent the practitioner from detecting the rising or falling titers associated with the initial infection. This leads to the collection of two "convalescent" serum samples that will fail to detect the increase in antibody titer, if it indeed occurred. This is especially true when only affected females are sampled at the time when the abortion is noted. Overall, the time of seroconversion is dependent on the exposure of the agent and the amount of immunity established prior to the breeding and throughout gestation. Paired sera are much more useful when it is used as part of a complete diagnostic work-up that includes samples from the placenta, fetus, and fetal fluids.

Serologic profiling is one option to optimize the use of serologic testing. The basis of serologic profiling is analyzing titers from affected/aborted and nonaffected dams over the same time period.[2] It is

unclear how many samples are needed, but some suggest that the same number of affected and nonaffected animals, preferably at same stage of gestation and age, is adequate.[4] In herds with chronic gestational losses serum may be collected and frozen from a statistically relevant number of cows for future testing as needed. These frozen samples may be collected as the females are processed prior to breeding and/or at the time of pregnancy examination. Then, as fetal loss is detected, banked serum samples can be submitted along with acute and convalescent samples to provide a clearer serologic picture of the affected animals and their normal cohorts. This should give a more complete picture of when seroconversion occurred and what pathogens were involved.

In some cases, all samples will have elevated titers due to endemic infections of specific agents. For example, in herds endemically infected with bovine viral diarrhea virus (BVDV), all animals may have seroconverted yet have no clinical evidence of etiologic diagnosis of abortions.[5] In some instances, fetal/precolostral serology may be beneficial. Fetuses must be immunocompetent for specific agents (*Toxoplasma gondii*/*Neospora caninum*/BVDV/infectious bovine rhinotracheitis/*Brucella*) to produce serologic evidence in fetal fluids.[1,2,6] However, in some cases of premature placental separation, maternal serum antibodies may "leak" into the fetal circulation and give a false positive result on serology. While serology may be valuable in certain circumstances, the interpretation of these results should be carefully assessed as it relates to the entire diagnostic work-up and clinical signs in the herd.

Vaccination Protocol Design

While vaccines represent an important tool in protecting reproductive performance, they tend to be somewhat underutilized in beef herds.[3] When designing protocols to immunize the beef breeding herd against reproductive pathogens, there are several other important factors to consider. The potential at-risk level of the herd should be considered not only from the entry of potential pathogens, but also from the standpoint of the current disease level in the resident herd, different management groups on the ranch, breeding animal movement, and the potential side effects of the immunizing agents. While complete protection against every pathogen in every individual is not realistic, the goal would be to minimize the number of susceptible animals in the population. This should prevent epidemic outbreaks of reproductive disease as well as the establishment of chronic endemic losses in the cow herd.

While veterinarians and producers often think of individual vaccination protocols for different management groups on the ranch, vaccination programs should be viewed as a *continuum*. For example, if producers are developing their own replacement heifers, the suckling calf vaccination program should be viewed beyond the summer grazing season and fall weaning events. This vaccination program should be constructed to consider the probability that these young heifer calves will join the replacement pool, become pregnant, and eventually become a productive member of the mature herd. The suckling calf protocol should be designed to prepare the calf for post-weaning disease challenges and increase the calf's response to subsequent reproductive vaccination. Research has clearly shown that calves vaccinated at an early age will mount a cell-mediated immune response that will enhance the calf's ability to respond to subsequent vaccination or disease challenge. This approach will maximize protection against reproductive pathogens and minimize the potential for any negative vaccine side effects associated with the pre-breeding vaccination of seronegative females. These side effects may include multifocal areas of ovarian necrosis, hemorrhage and inflammatory cell infiltrate in the ovary, as well as the development of cysts in the corpus luteum. These lesions are transitory in nature, but can result in decreased reproductive performance in the short term.

Other factors to consider in vaccine selection include fetal protection and duration of immunity.[3] Recent advances in vaccine technology and diagnostic testing have allowed vaccine manufacturers to document the ability of their products to prevent disease organisms from spreading to the placenta and fetus following maternal infection. Challenge studies using virulent BVDV, infectious bovine rhinotracheitis (IBR), and *Leptospira borgpetersenii* (serovar *hardjo*) have shown that fetal protection against pregnancy wastage, BVDV persistent infection (PI), and leptospiral renal colonization and urine

shedding is possible following vaccination. While both modified-live viral and killed virus vaccines have demonstrated fetal protection against BVDV, typically modified-live vaccines provide better protection and a longer duration of immunity. Studies have also shown that this protection can last for 1 year or longer following vaccination of animals of various ages. The concepts of fetal protection and duration of immunity are especially important for beef operations as they are more likely to come in contact with adjacent herds and may only be handled for vaccination once per year.

Before constructing any vaccination program for a cow/ calf operation, the potential risk for exposure of the herd to a particular pathogen through herd additions or herd contact with clinical or inapparent carriers of a pathogen should be evaluated. The epidemiological terms "open," "closed," and "modified open" have been used to describe the potential risk level of a given herd.[3] When assessing the need for vaccination, factors such as risk-level management, the magnitude and etiology of previous reproductive losses, herd working patterns and animal management, and the producer's long-term goals should all be considered. Once this information is collected and evaluated, recommendations concerning the use of specific vaccine antigens, the type of vaccine needed, and the frequency of vaccination can be constructed to fit within the confines of the total ranch management plan.

Summary

The diagnosis of reproductive losses in beef herds can be frustrating. This is due in part to our inability to collect needed samples in a timely fashion, the immunological response of cattle to the pathogen, and the multitude of noninfectious causes of abortion. Whenever possible, diagnostic information should be combined biosecurity practices and vaccination to prevent reproductive loss. The goal of the immunization program should be to increase the level of collective herd immunity by minimizing the number of animals that are susceptible to reproductive disease. This will prevent not only epizootic outbreaks of pregnancy wastage, but should also control chronic endemic disease. The end result is that the practitioner can provide the client with cost-effective vaccine options to help insure optimum reproductive performance.

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MANAGING DIGITAL DERMATITIS IN FEEDYARDS

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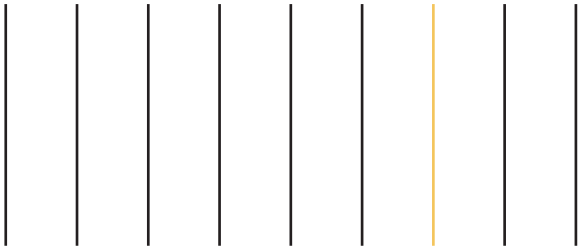

LARGE ANIMAL

Managing Digital Dermatitis in Feedyards

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Introduction

Reports of "hairy heel warts" or digital dermatitis (DD) have been described in cattle beginning in the early- to mid-1970's. While first described in dairy cows, more recent reports have centered on the development of DD in beef cattle operations. Over the years, this disease has been referred to as interdigital dermatitis, interdigital papillomas, Mortellaro's disease, and strawberry foot. While called by different names, the hallmark of this disease include well defined lesions on the heel that show erosions and ulceration, protruding wart-like structures, skin bearing thickened and elongated hairs, and the skin at the border of the lesion is thickened. Due to the location and relative lack of swelling, it is relatively easy to differentiate DD from other causes of lameness.

Cause of the Disease

A type of bacteria called *Treponema* have classically been blamed for the disease. This is based on consistent testing results that grew or identified the bacteria in the lesions. *Treponema* is a group of bacteria and should not be considered as one organism. There are at least five different *Treponema* organisms that are consistently isolated from DD lesions, but many others have also been identified. However, it is becoming more evident that DD lesions should be considered more like a "complex" that involves multiple species of bacteria, the immune response at the skin level, and environmental conditions.

Recent work done in dairy cattle at the College of Veterinary Medicine at Iowa State has shown that the bacterial population changes as the lesions move from early to late (chronic). DD lesions were sampled and profiled for bacterial DNA in order to determine differences in the populations of bacteria as these lesions aged. There were at least 11 different bacterial *families* represented in these lesions and the combination of bacteria changed dramatically as these lesions aged. While there was no indication of involvement of viruses or fungi, it is very clear that focusing on a single bacterium (such as *Treponema*) will not solve the puzzle of DD lesion development. Work at ISU CVM in feedlot cattle has shown very similar bacterial changes as dairy cattle.

The development of DD lesions in feedyards has not been well defined. It is common for lameness to be exhibited close to the normal reimplant date (90-120 DOF) but that can be highly variable. Lesions tend to worsen the last 60-90 DOF. Calves that have been through backgrounding programs / yards may arrive at the feedyard with active lesions. Other factors such as comingling, breed or genetics, history of feeding dairy animals, or size of the cattle may also have an impact of the prevalence of DD. It is believed that any factor that negatively impacts the integrity of the skin on the animal's heel can increase the likelihood of lesion development. Extremely wet pen conditions, excess manure buildup, exposed concrete edges, or rough surfaces can trigger pen outbreaks of this disease. Once established in the pen environment, it is difficult to eliminate the disease from the facility.

Treatment and Prevention

According to the American Association of Bovine Practitioners, a range of topical antibiotics are effective, but all are extra-label uses in the United States and require veterinary oversight. In individual cases, the lesion should be cleaned and dried and the antibiotic applied with a dressing or topical spray.

For topical spray treatments, oxytetracycline (mixed at 10–25mg/ml) or lincomycin (mixed at 1–8mg/ml) are effective when mixed with water in a 2–4 gallon hand sprayer and applied once or twice daily for 5–7 days. Alternatively, the prepared solution of oxytetracycline or lincomycin can be soaked into a gauze swab and wrapped on the lesion. Injectable antibiotics may be indicated for severe lesions, especially those on the dorsal aspect of the claw, but they are secondary to topical treatments and should not be used alone. In severe cases, a pain relief may also be indicated.

A range of different products are effective including copper sulfate (5%), zinc sulfate (5–10%), formalin (2–5%), and commercial chemicals containing quaternary ammonium compounds, organic acids, and other disinfectants. Recently, several new products which serve to activate copper sulfate have been released which allow lower concentrations (2%) to be used. It is essential that the volume of the foot bath is known so that the correct amount of chemical may be used to provide the appropriate final concentration. The volume in gallons may be calculated from the formula; length × width × depth (in inches) divided by 231. The University of Wisconsin has a "footbath calculator" available online that will match footbath dimensions with the proper amount of needed additives. Foot baths should be at least 8 feet long and 5 inches deep to ensure that enough contact is made between the chemical and the lesions. There are various options and locations that will work in a feedyard setting. The key is to put these in high traffic areas where the calves must walk through them with enough access to make recharging the bath easier. Minimizing the amount of manure on the feet will decrease the organic material tracked into the footbath and make the solution last longer.

Footbath frequency and solution selected will vary depending upon the cattle handling facilities, safety of the people working the cattle, and the percent of the pen that is affected.

Prevention still centers around the pen environment and avoiding negative impacts on the heel area of the calves. We have found that decreasing the moisture in the pen by more aggressive cleaning and decreasing animal density can be helpful. Scraping outdoor lots to remove manure and smooth out frozen hoof prints should improve foot health. Close observation of the feet of newly arrived cattle and recording their source can potentially identify problem sets of calves at arrival. Running cattle through a footbath at arrival should also be considered if active lesions are suspected in new cattle.

Future Needs and Direction

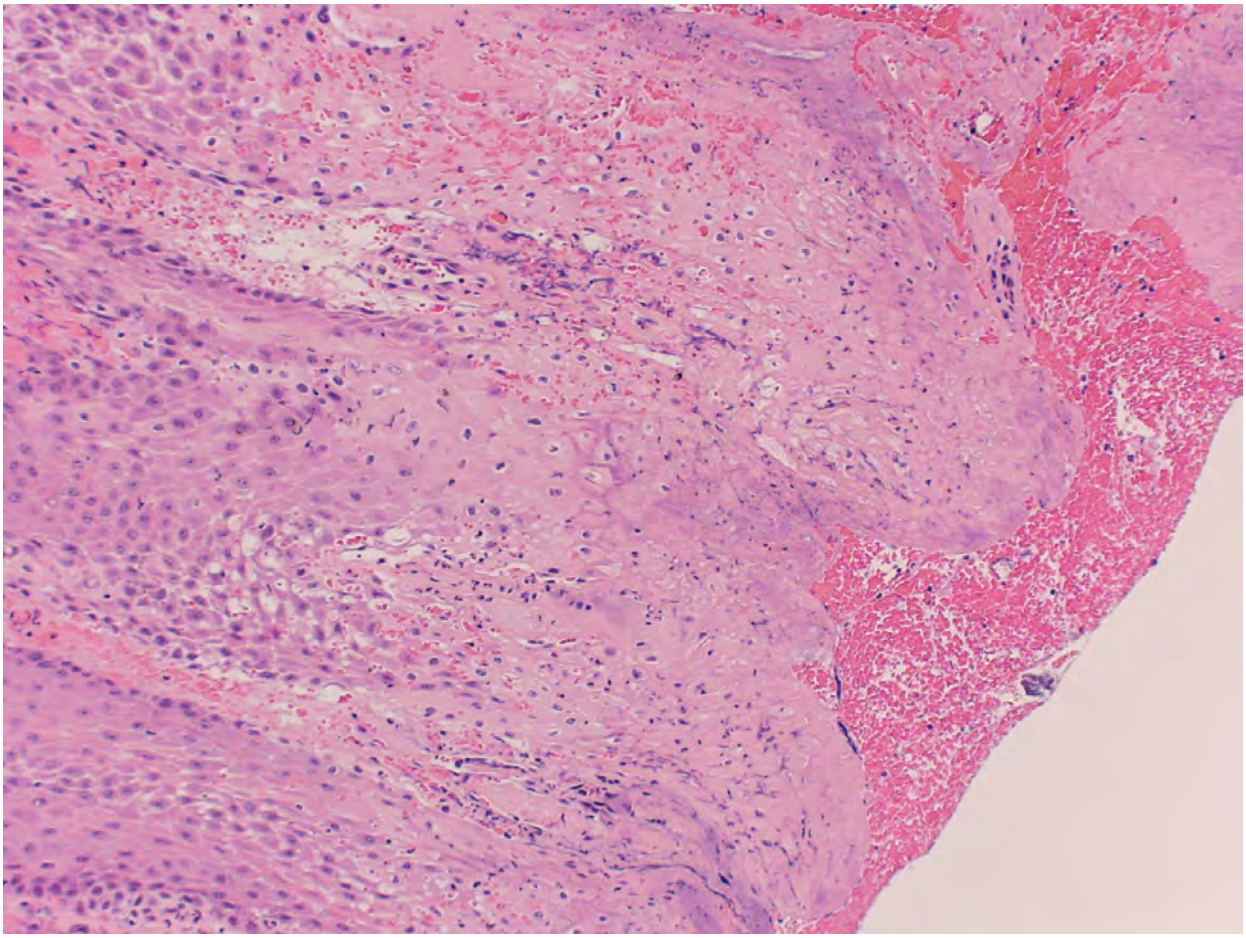
DD lesions are produced like many other disease complexes. There is some combination of how the organisms survive in the feedyard environment, animal factors affecting immunity and lesion development, and the various interactions among the bacteria found in clinical cases. Intervention strategies need to be developed that go beyond the routine use of footbaths containing caustic chemicals. Routine footbaths require increased labor, ingredient costs, and moving the cattle out of their routine. This can result in a decrease in feed intake that may last for several days. Since there seems to be no consensus as to how often cattle should be run through the footbath or the ideal ingredient mix, it would appear that there is widespread dissatisfaction with this option.

One option that we intend to explore at ISU is the ability to change the pen environment using litter treatments utilized by the poultry industry. This might be applicable for use in "indoor" pens such as monoslopes or hoop structures. These products would be periodically spread on the bedding pack and the feed pad in front of the bunks. The intent is to dry the pen out, decrease the pH of the pack and dramatically reduce the number of bacteria present. This should result in decreased active lesions and a reduction in trips through the footbath. Obviously, the cost and labor associated with this practice would have to be weighed against footbath use.

The development of a vaccine for DD would seem to be difficult. This is a polybacterial complex with populations that shift over time. Previous attempts to infer protection using *Treponema spp.* have not been successful. *Treponema* does not penetrate intact healthy skin and is more abundant in the more

chronic lesions. It would seem logical to target organisms found in the early lesions since they are there when the problem is initiated. As with other vaccines that target bacterial diseases, it is almost certain that a minimum of two doses would be required. Finally, the economics of any potential vaccine would have to weighed against the current use of footbaths.

Figure 1. Histopathology slide (magnified 1000X) using H&E staining of a digital dermatitis lesion ("hairy heel wart").



Histopathology report: Sections examined consist primarily of frond-shaped layers of keratin, with ballooning degeneration of epithelial cells and clusters of pyogranulomatous inflammatory cell populations. Surfaces are densely colonized by mixed bacterial flora including cocci, coccobacilli, bacilli, and delicate spirochetes. Localized areas of ballooning degeneration exhibit large numbers of delicate spirochetes in deeper cell layers. Lesions are consistent with infectious pustular pododermatitis ("hairy heel warts").

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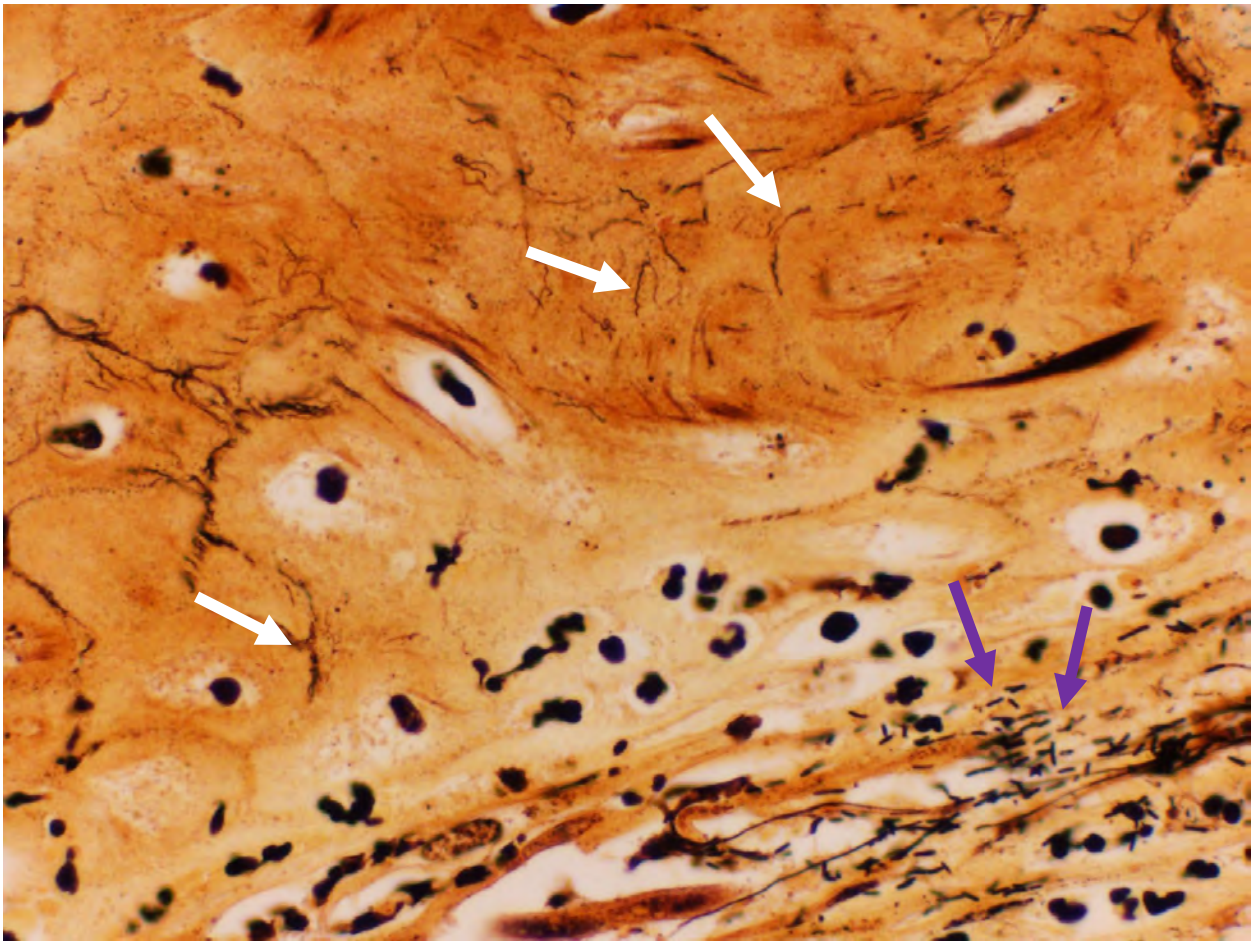

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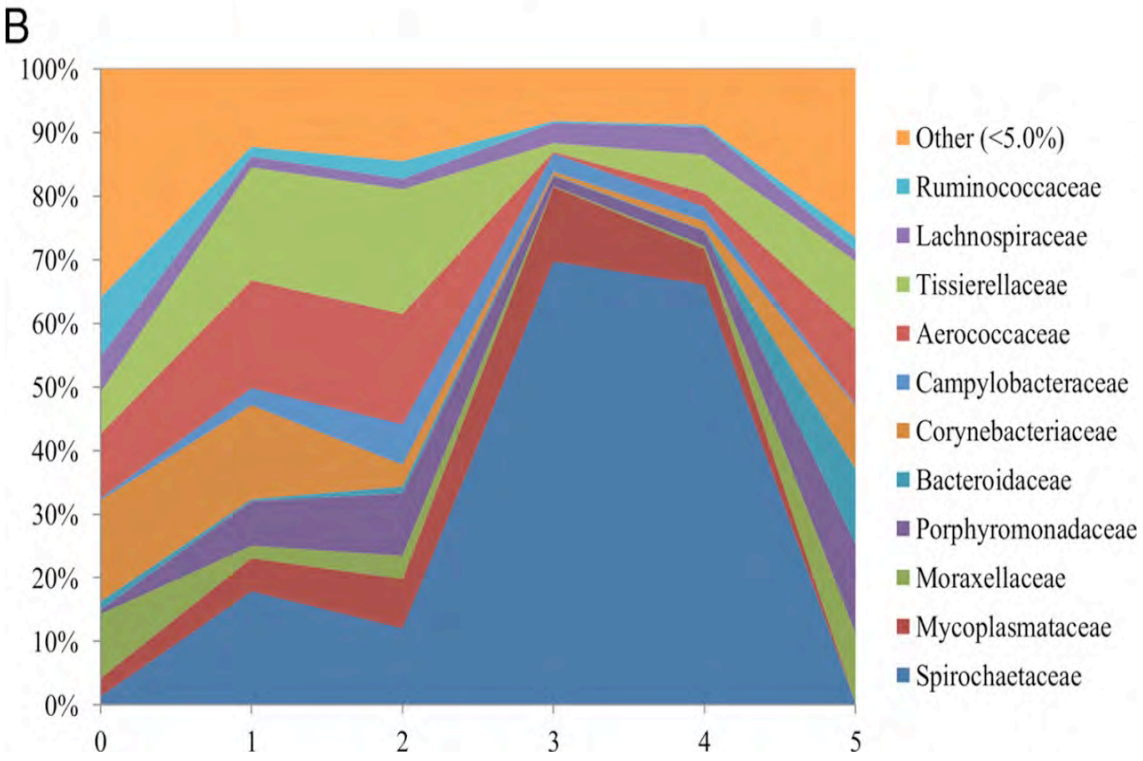
Figure 3. Relative abundance, by stage, of bacterial families that represent at least 5% of the bacterial reads acquired. (Top = Dairy Cattle; Bottom = Feedlot Cattle)



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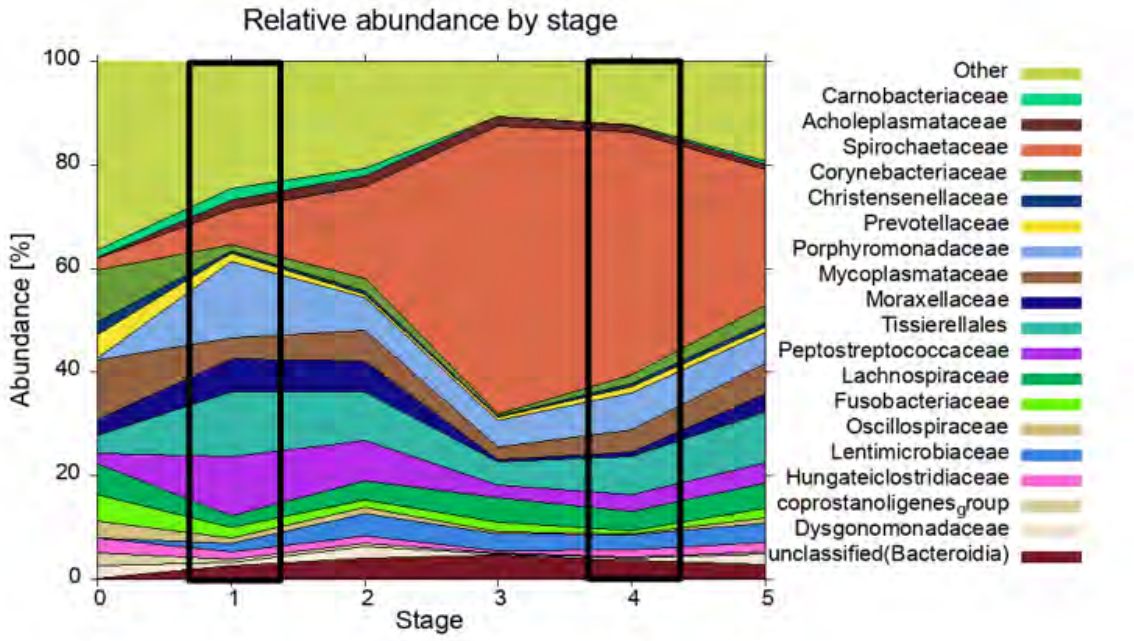

Engelken 2022 (*unpublished data*)

MANAGING HEALTH IN CONFINED COW/CALF OPERATIONS

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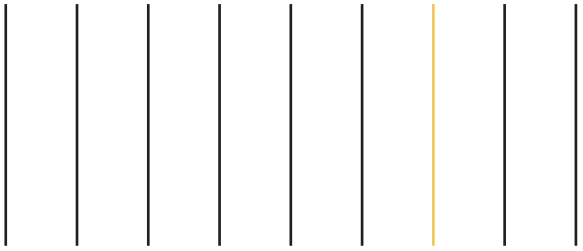

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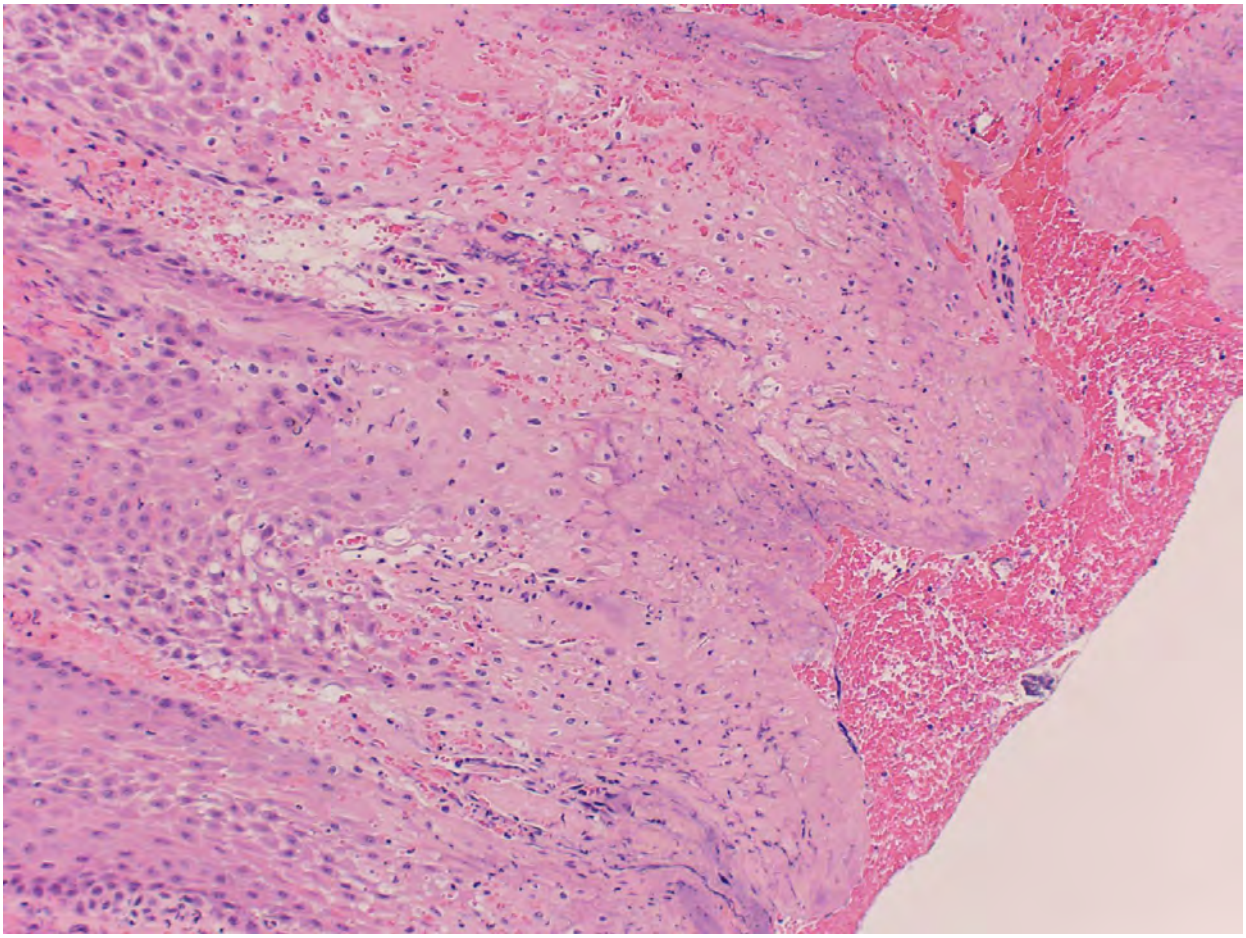

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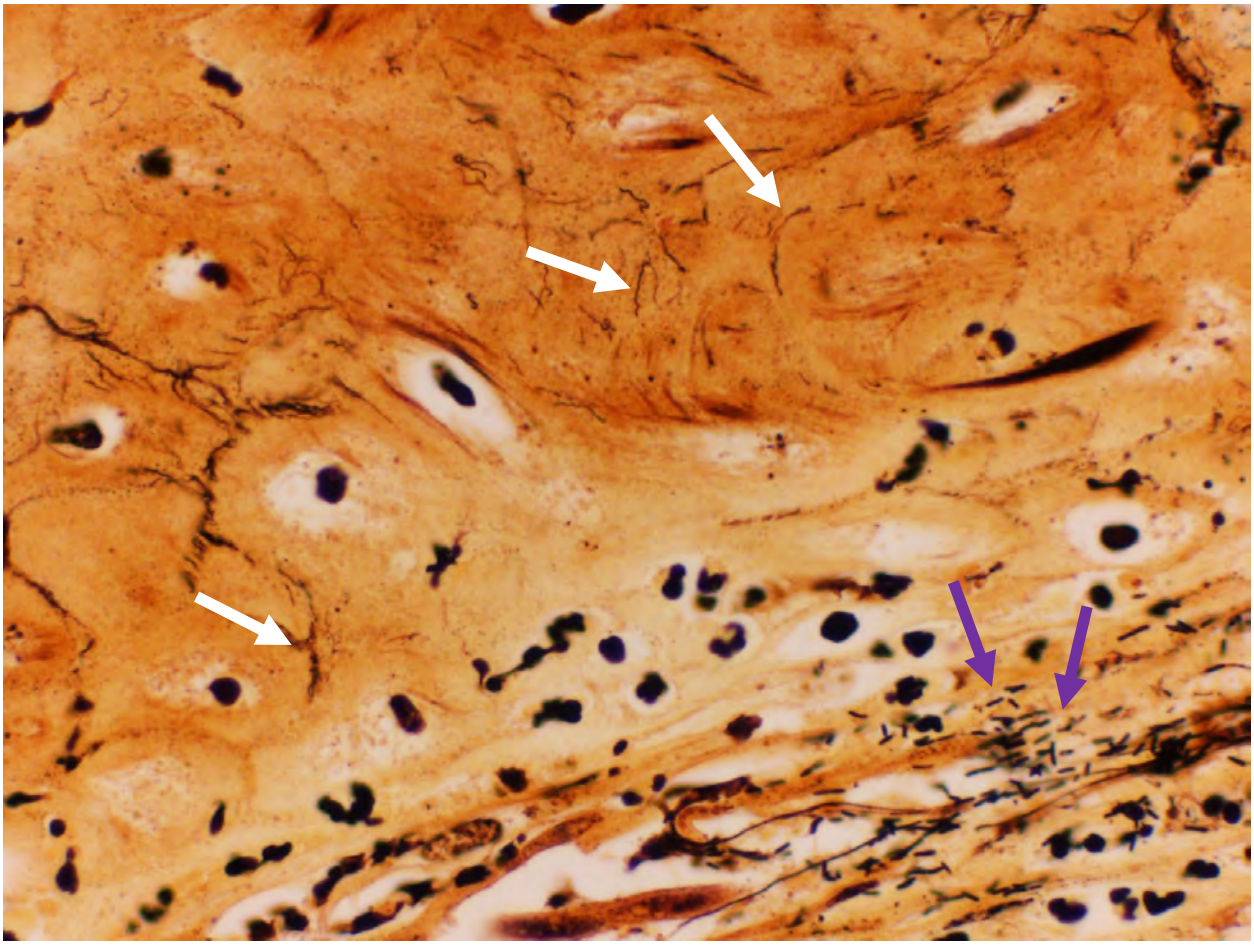

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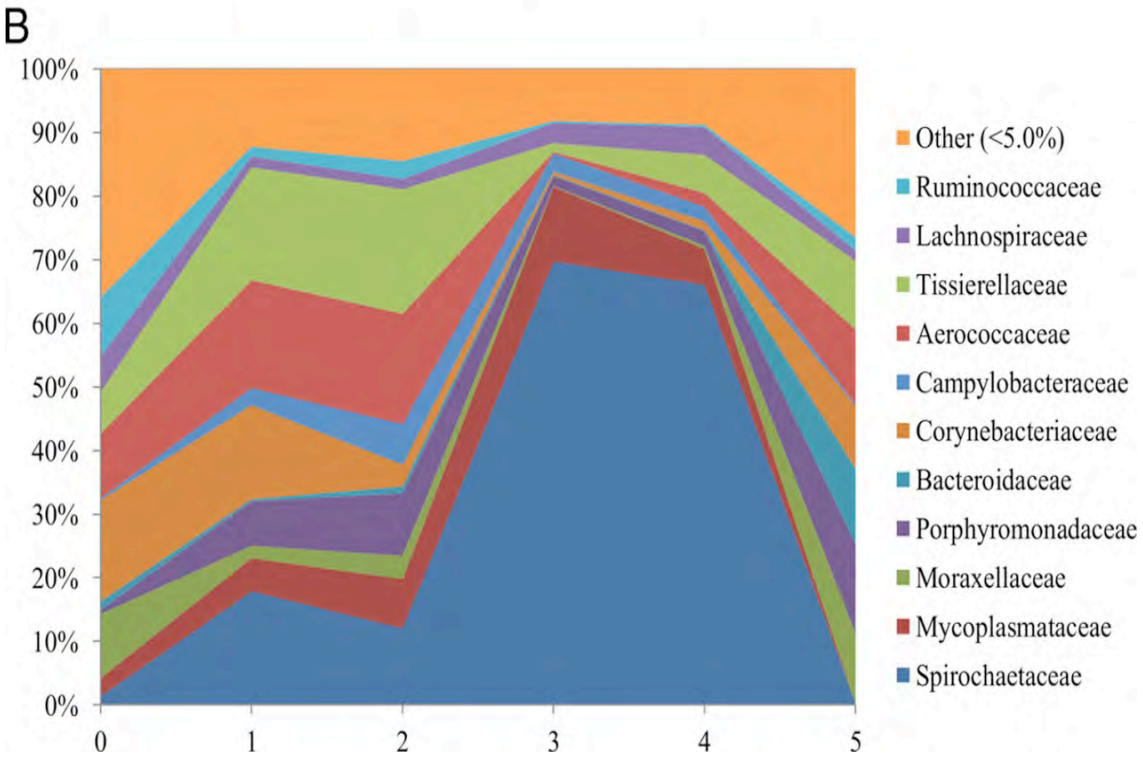
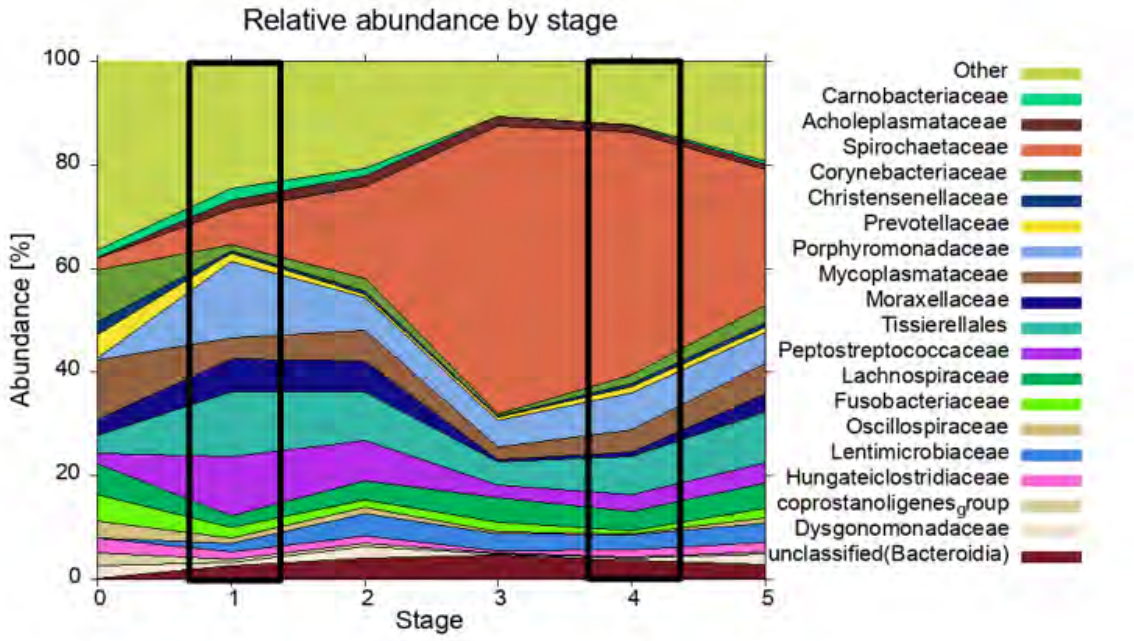
Figure 3. Relative abundance, by stage, of bacterial families that represent at least 5% of the bacterial reads acquired. (Top = Dairy Cattle; Bottom = Feedlot Cattle)



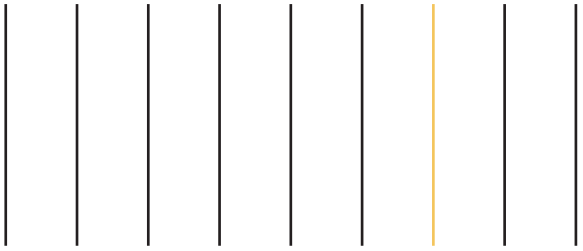
Krull AC et al. *Infection and Immunity* 82(8):3359-3373 (2104)



Engelken 2022 (*unpublished data*)

INFECTIOUS BOVINE KERATOCONJUNCTIVITIS – WHAT WE KNOW & DON'T KNOW ABOUT "PINKEYE"

TERRY ENGELKEN
DVM, MS



LARGE ANIMAL

Infectious Bovine Keratoconjunctivitis – What we Know and Don't Know about "Pinkeye"

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Infectious Bovine Keratoconjunctivitis (IBK) or "pinkeye" is the most common ocular disease of cattle, worldwide. Colorado researchers have identified IBK as the 3rd most important health concern among producers, falling behind only respiratory disease and flies. Clinical signs include excess lacrimation, photophobia and blepharospasm. This is followed by corneal edema and if the infection continues, ulceration. It is common for these corneal ulcers to heal with evidence of scarring in the center of the eye. Eye irritation from face flies, plant awns, or extreme UV light may damage the cornea and make it more susceptible to bacterial invasion. Economic losses associated with this disease include treatment costs, labor, decreased weaning weight, and discounts associated with blind calves. According to the 2017 NAHMS Cow-Calf Survey, nearly 20% of all cattle are vaccinated against IBK on an annual basis.

The exact etiology of IBK is currently being debated. There are multiple studies that have identified different potential bacterial pathogens and their associated clinical presentation. *Moraxella bovis* infection alone has been shown to cause the disease both experimentally and in field outbreaks. There are various other organisms isolated from both active lesions and normal eyes such as *Mycoplasma bovoculi, Moraxella bovoculi, Mycoplasma bovis,* and *Branhamella spp.* An Iowa State study using *M. bovoculi* inoculation alone on scarified corneas could not produce lesions of IBK. Researchers suspect that there is synergism between various organisms to produce IBK lesions, but the exact mechanism remains elusive. Multiple studies have shown the importance of maintaining the normal microbiome of the eye. Disruptions in the normal bacterial population of one eye may cause similar changes in the opposite eye as well and lead to bilateral disease.

Ocular immunity involves tear film, the mucosal epithelium, and diffuse lymphoid tissue. Tear film provides a physical barrier and contains secretory IgA. The epithelium produces antimicrobial proteins and dendritic cells while the lymphoid tissue around the eye secretes IgA and IgG. On the other hand, invading bacteria need two components to produce disease: Cytotoxin (RTX) and a pilus. The cytotoxin causes lysis of the corneal epithelium and migrating neutrophils and lymphocytes. This is the primary driver of corneal ulceration. The antigens of cytotoxin are highly conserved across different bacterial strains and animals will develop antibodies following cases of IBK. The invading bacteria need pili in order to adhere to the corneal surface and produce disease. There are seven distinct serogroups (A-G) and unfortunately, heterologous protection across the different subgroups does not occur. It has also been shown that adding too many of these pilus antigens to a single vaccine has a "dilution" effect that will prevent adequate immune response to any of the serogroups. This obviously complicates serogroup selection for vaccine production.

Studies have looked at the ability of serum antibody to protect against cases of IBK. An ELISA was developed to measure IgG specific antibody to the type IV pilus protein of *M. bovis*. These studies compared the relative antibody levels between calves that developed clinical IBK versus those that did not. While calves resistant to IBK had numerically higher ELISA titers, the differences were not significant. ISU data showed that antibody levels increase over the course of the summer (May through October), but there was no significant difference in titers between calves with clinical IBK and normal calves at any time point. Nebraska researchers showed that ELISA titers may increase following

vaccination with an autogenous or commercial product compared to sham vaccinated controls. However, there was no significant difference in disease outcomes between these three groups.

Vaccination against the organisms implicated in IBK has been controversial at best and ineffective at worst. Multiple studies using either autogenous or commercially available vaccines have failed to produce significantly less disease in well-designed studies. Factors such as strain selection, causal organisms present, and insufficient time between vaccination and pathogen colonization of the eye will all impact apparent vaccine efficacy. These results should not be totally surprising as we struggle to define the basic pathophysiology of how microbiome insult, pathogen interaction, and ocular immune system stimulation interact to produce disease. A better understanding of how the immune system of the calf interacts with ocular pathogens will be required to enhance vaccine efficacy.

Suggested Reading:

Ruminant Ophthalmology. Veterinary Clinics of North America: Food Animal Practice 37(2):237-380, July 2021. O'Connor AM, editor.

Hille MM, Spangler ML, Clawson ML et al. A five year randomized controlled trial to assess the efficacy and antibody responses to a commercial and autogenous vaccine for the prevention of infectious bovine keratoconjunctivitis. *Vaccines* 2022, 10, 916 https://doi.org/10.3390/vaccines10060916.

Angelos JA, Agulto RL, Mandzyuk B et al. Randomized controlled field trial to assess the efficacy of an intranasal *Moraxella bovis* cytotoxin vaccine against naturally occurring infectious bovine keratoconjunctivitis. *Vaccine: X* 15 (2023) 1003778 https://doi.org/ 10.1016/j.jvacx.2023.100378.

Garcia MD, Matukumalli L, Wheeler TL et al. Markers on bovine chromosome 20 associated with carcass quality and composition traits and incidence of contracting infectious bovine keratoconjunctivitis. *Animal Biotechnology* 21:188-202 (2010) https://doi.org/10.1080/10495398.2010.495012.

BALANCING BEEF COW DIETS: INTRODUCTION TO BRANDS

ROBERT LARSON
DVM, PHD, DACT, DACVPM (EPIDEMIOLOGY), ACAN

LARGE ANIMAL

BRANDS
Beef Ration and Nutrition Decisions Software

Balancing Beef Cow Diets: Introduction to BRANDS

Dr. Bob Larson

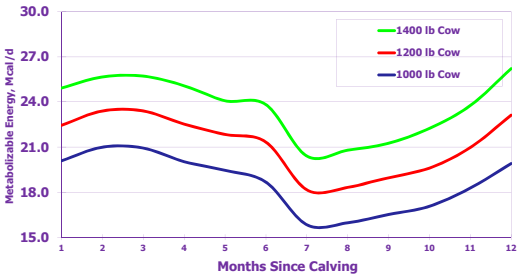
Step 1: Determine Diet Requirements

Energy and Protein Requirements

- **Requirements for Breeding Cattle are Dependent Upon:**
  - Body Size
  - Stage of Pregnancy
  - Body Condition and Compensation
  - Milking Ability
  - Breed Type

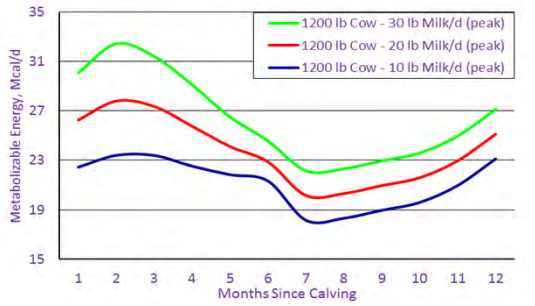
Animal Nutrient Requirements

Effect of Cow Size



Animal Nutrient Requirements

Effect of Milk Production Level and Pregnancy



Nutrient Requirements of Beef Cows

Dependent on Stage of Pregnancy

Nutrient	Period 1 80 days (post-calving)	Period 2 125 days (pregnant & lactating)	Period 3 110 days (mid-gestation)	Period 4 50 days (pre-calving)
TDN (lbs/day)	16.0	12.7	10.5	12.3
NEm Mcal/day	16.4	13.4	10.1	11.3
Protein (lbs/day)	2.5	2.1	1.5	1.8
Calcium (gm/day)	33	27	17	25
Phosphorus (gm/day)	25	22	17	20
Vitamin A (IU/day)	39,000	36,000	25,000	27,000

*NRC requirements plus 10%

Step 1: Determine Diet Requirements

Other Considerations:

- Temperature / Moisture
- Hair coat
- Acclimation
- Ionophores

Interpreting BCS of Beef Cows

Assumptions:

- BCS is a good estimate of fat stores, but not a good indication of current energy partitioning
- Low BCS at calving and the start of breeding is associated with poor reproductive efficiency
  - Low BCS at calving is associated with prolonged postpartum anestrus
  - Declining (or steady) BCS at breeding is associated with poor fertility
- Low BCS at calving of the dam is associated with increased neonatal calf health risk
- Extremely high BCS is an economic waste
- A range of BCS is compatible with optimum production based on timing within production cycle

BCS Association with Beef Cattle Reproduction

- Several publications document unfavorable measurements of reproductive success in thin cattle compared to cattle characterized as having moderate to good body condition
  - Longer interval to resumption of fertile cycles
  - Lower percentage pregnant
  - Lighter weaning weights of calves

Interpreting BCS of Beef Cows

My Current Thoughts:

- BCS is easily obtained (low technical, labor, and financial investment) and is appropriate for mature cow/bull evaluation
- BCS can be repeatable within and somewhat consistent between evaluators with training
- BCS at calving serves as a proxy for length of postpartum anestrus
- BCS change from calving to breeding serves as a proxy for onset of fertile cycles (PPA) and fertility

Interpreting BCS of Beef Cows

My Current Thoughts:

- BCS collected prior to calving, prior to breeding, and at the time of pregnancy diagnosis (mid-gestation) provide different information – but all three data collection times are important
- Good BCS prior to calving and breeding is indicative of good management from several perspectives (forage management, supplementation strategy, matching cows to the environment, access to feed, health, etc.)
- Manage cows and heifers as groups (populations) so that a herd-specific minimum percentage have BCS ≥ 5
- Individual cow BCS should be interpreted in relation to the group's BCS distribution

Relationship Between Body Condition and Reproductive Efficiency

Calving BCS	Number of Days to Resume Fertile Cycles
3	88.5
4	69.7
5	50.5
6	51.7

Adapted from Houghton 1990

Relationship Between Body Condition and Reproductive Efficiency

- Thin cows require special management during late pregnancy and early postpartum periods to maintain reproductive performance (Houghton et al., 1990)

BCS at Time of Examination	BCS Needed at Calving	Total Wt. Gain Needed	Days to Onset of Calving	Daily Weight Gain Needed (lbs./d)
Very Thin (3)	5	194 lbs.	60 (2 mo)	3.2
Thin (4)	5	97 lbs.	60 (2 mo)	1.6
Moderate (5-6)	5	0 lbs.	60 (2 mo)	0
Very Thin (3)	5	194 lbs.	90 (3 mo)	2.1
Thin (4)	5	97 lbs.	90 (3 mo)	1.0
Moderate (5-6)	5	0 lbs.	90 (3 mo)	0
Very Thin (3)	5	194 lbs.	120 (4 mo)	1.6
Thin (4)	5	97 lbs.	120 (4 mo)	0.8
Moderate (5-6)	5	0 lbs.	120 (4 mo)	0

Step 1: Determine Diet Requirements
Step 2: Estimate Forage Intake

Forage Quality	Percent Body Weight Intake
Excellent	3-3.8%
Average	2-2.5%
Crop residues	1.8-2.0%
Below average	1.8-2.0%
Extremely poor quality	1.4-1.8%

2%$^{+}$/– 0.5 (1.5-2.5%)

Step 1: Determine Diet Requirements
Step 2: Estimate Forage Intake
Step 3: Determine Forage Contribution

Requirement – Forage Contribution = Supplement Needed

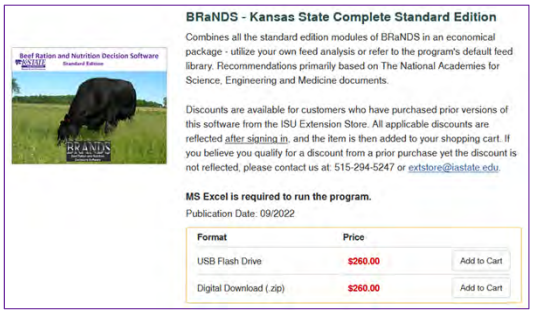
How energy-dense does the supplement need to be?

- Corn → CGF/DDG/SH/WM → high quality forage

https://www.iowabeefcenter.org/brands.html

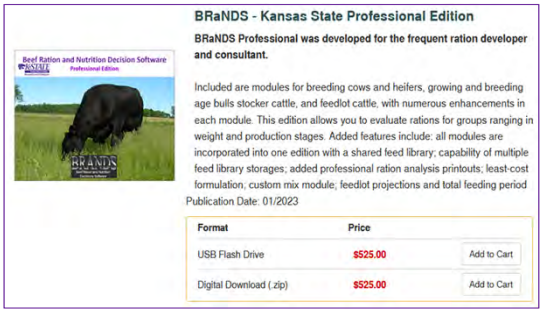
Kansas Standard Cow & Heifer Edition

https://store.extension.iastate.edu/product/14899



Kansas State Professional Edition

https://store.extension.iastate.edu/product/12888



Using BRANDS

Producer Setup

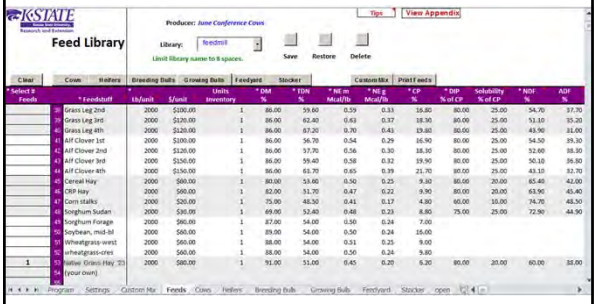
- Open Brands Software
- Enable MACROS
- Go to "Settings" Tab
- Click on New Producer, Enter producer Info, Click Save Button

Using BRANDS

Feeds Selection and Customization

- Go to Feeds Library - click on Feeds tab
- Enter Native Grass Hay (2023) manually

Dry Matter, %	91%
TDN	51%
NEm, mcal/lb.	0.45
NEg, mcal/lb.	0.20
Crude Protein, %	6.2%
DIP, % of CP	80%
Sol. Of CP, % of CP	20%
NDF, %	60%
ADF, %	38%
eNDF, % of NDF	90%
Calcium, %	0.81
Phosphorus, %	0.18



Using BRANDS

Feeds Selection and Customization

- Go to Feeds Library - click on Feeds tab
- Enter Native Grass Hay (2023) manually
- Select several potential feeds
  - 1 – Line 53 (manually added hay '23)
  - 2 – Line 94 (Soy hulls - $105/ton)
  - 3 – Line 95 (Wheat mids - $85/ton)
  - 4 – Line 100 (Corn Gluten Feed - $110/ton)
  - 5 – Line 104 (Dried Distillers Grains - $165/ton)
  - 6 – Line 138 (Corn - $3.63/bu…*$130/ton*)

Where To Find Feed Prices?

By-product feeds
http://agebb.missouri.edu/dairy/byprod/bplist.asp

Corn
https://www.ams.usda.gov/market-news/state-grain-reports

Hay
https://www.ams.usda.gov/market-news/hay-reports

Using BRANDS

Nutrient Requirements

- Go to Cow Module – click on Cow tab
- Enter Herd Parameters
  - Feeding Period – 1
  - 1/19/23 thru 3/25/23
  - Cow Size – Medium
  - Breed type - British
  - High - Milk
  - BCS - 5
  - BCS Desired - Maintenance

Using BRANDS

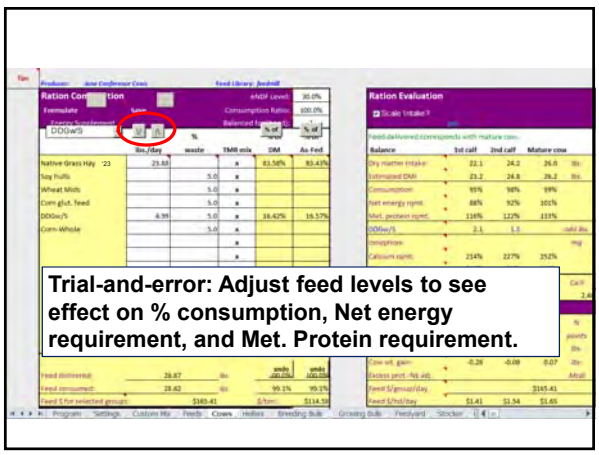
Nutrient Requirements

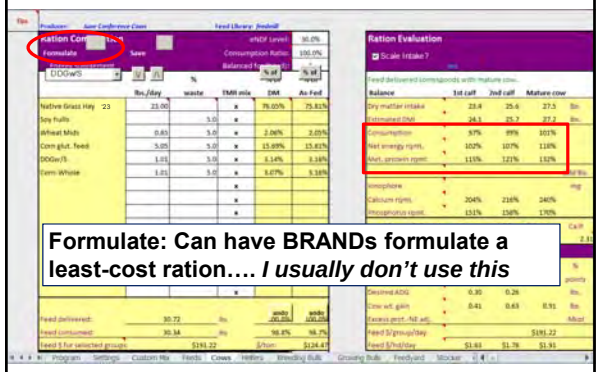
- Go to Cow Module – click on Cow tab
- Enter Herd Parameters
  - Prod. Stage - 3rd trimester
  - Calf Birth Weight - Moderate
  - Wind - Normal
  - Hair Condition – Clean & Dry
  - Hair coat - Winter
  - Temperature - Normal
  - Enter Data, Name File, AND PRESS SAVE

Using BRANDS

Ration Balancing Screen

- Determine amount of base forage to be consumed (usually 1.5 to 2.5% of BW)
- Determine amount of DDG needed to meet requirements
- Trial-and-Error method of ration balancing
- Use of ↓ ↑ buttons (next to Energy Supplement window)





Using BRANDS

Nutrient Requirements

- See what happens if you change BCS to "4" and BCS Desired to "+1/2 CS/mo" …

Ration Evaluation

☑ Scale Intake?

yes

Feed delivered corresponds with mature cow.

Balance	1st calf	2nd calf	Mature cow	
Dry matter intake	22.1	24.2	26.0	*lbs.*
Estimated DMI	23.2	24.8	26.2	*lbs.*
Consumption	95%	98%	99%	
Net energy rqmt.	69%	73%	80%	
Met. protein rqmt.	82%	87%	95%	
DDGw/S	6.2	5.6	4.1	*add lbs.*

Using BRANDS

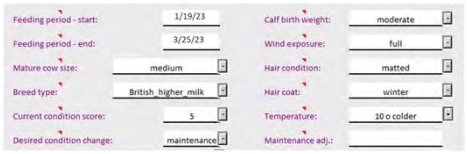
Nutrient Requirements

- Changes needed – increase DDG…

Using BRANDS

Nutrient Requirements

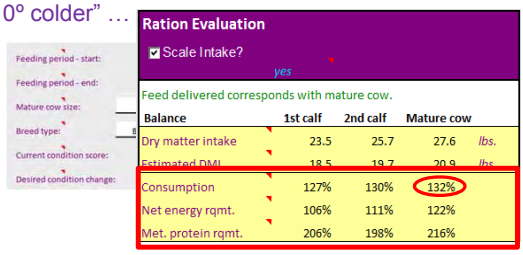
- See what happens if you change Wind exposure to "full", Hair condition to "Matted", and Temperature to "10º colder" …



Using BRANDS

Nutrient Requirements

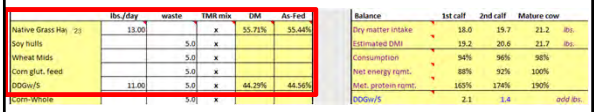
- See what happens if you change Wind exposure to "full", Hair condition to "Matted", and Temperature to "10º colder" …



Using BRANDS

Nutrient Requirements

- Changes needed – increase DDG…



Using BRANDS

Nutrient Requirements

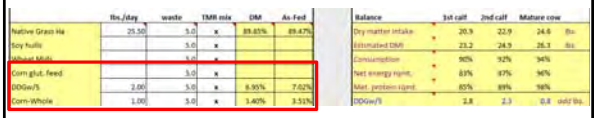
- See what happens if you started with a higher quality forage (good brome hay) …

Forage intake increases and need for supplement greatly decreases !

Using BRANDS

Nutrient Requirements

- Start by using corn and DDG

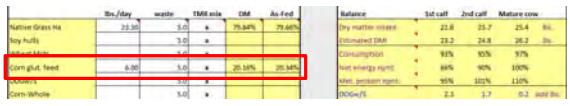


$0.93 / cow / day

Using BRANDS

Nutrient Requirements

- Try using Corn Gluten Feed

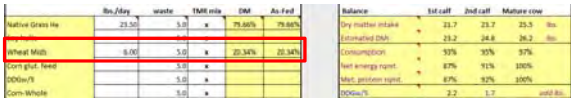


$0.98 / cow / day

Using BRANDS

Nutrient Requirements

- Try using Wheat Mids



$0.90/ cow / day

Using BRANDS

Nutrient Requirements

- The point is not that currently wheat mids are less expensive than distillers grains
- The point is that BRANDS can be used to compare options

Summary:

- Mature cows in moderate BCS (i.e. 5) that are not presented with weather stress and have average or better quality forage available will maintain or gain body weight on forage alone.
- All other situations (i.e. thin cows, cows consuming less than average quality forage, cows facing weather stress, heifers) require 3 to 15 lbs. of an energy-dense supplement (e.g. distillers grain, soy hulls, corn gluten feed, corn, etc.) to meet their caloric needs.

Heifers are not cows!!

Heifers' nutritional requirements from weaning to breeding are very different from mature cows' primarily because heifers are still growing (require NE partitioned toward growth in addition to maintenance)

Interpreting Target Weight for Puberty

What is the appropriate target weight?

- 50% - 55% - 60% - 65% of mature weight?
- Real question is…

  "What ration should I feed cohort of replacement heifers to result in the desired number reaching puberty and becoming pregnant at the desired date?"

  Need to know target weight in order to determine desired average daily gain from weaning to breeding

  ADG = (Target weight – Starting weight) / Number of days

  I would rather know yearling wt. (not % of mature wt) that meets the herd's goals

Interpreting Target Weight for Puberty

What is the appropriate target weight?

- How is target weight calculated?
- What is your goal?
  - Nearly all heifers in replacement pool reach puberty?
    - Set a high target weight (actual lbs. or 65% of mature wt.)
  - Only small-framed heifers (low mature wt.) or early maturing heifers reach puberty?
    - Use herd average mature weight – and set a low target weight (actual lbs. or 55% of mature wt.)

Interpreting Target Weight for Puberty

What is the appropriate target weight?

- How is target weight calculated?
- What is your goal?
- Answer: Monitor herd – what weight is needed to reach targeted number of pubertal heifers?
  - If I know – that is the target weight (assuming constant genetic potential for mature wt. and age-at-puberty)
  - If I don't know – base target weight on producer's goal

Summary (moderate wt. gain):

Situation (animal requirement / forage quality)	Outcome (Supplement Required)
BCS 5 cows with average quality forage	Maintain (or even gain) weight on forage alone
BCS 5 cows with poor quality forage	Lose weight on forage alone – need 3 lbs (as fed) DDG to maintain body wt.
BCS 3-4 cows (need to gain 1.7 lbs. daily) with average quality forage	Need ≈7 lbs (as fed) DDG to obtain BCS 5 w/n 90 days
BCS 3-4 cows (need to gain 1.7 lbs. daily) with poor quality forage	Need ≈11 lbs (as fed) DDG to obtain BCS 5 w/n 90 days
Heifers that need to gain 1.5 lbs. daily with good quality forage	Need ≈4.5 lbs (as fed) DDG to meet targeted gain
Heifers that need to gain 1.5 lbs. daily with average quality forage	Need ≈5.5-6.0 lbs (as fed) DDG to meet targeted gain
Heifers that need to gain 1.5 lbs. daily with poor quality forage	Need ≈7.5-8.0 lbs (as fed) DDG to meet targeted gain

Summary (rapid wt. gain):

Situation (animal requirement / forage quality)	Outcome (Supplement Required)
BCS 3-4 cows (need to gain 2.5 lbs. daily) with average quality forage	Need ≈12-12.5 lbs (as fed) DDG to obtain BCS 5 w/n 60 days
BCS 3-4 cows (need to gain 2.5 lbs. daily) with poor quality forage	Need ≈15-15.5 lbs (as fed) DDG to obtain BCS 5 w/n 60 days
Heifers that need to gain 2.5 lbs. daily with good quality forage	Need ≈11.0-11.5lbs (as fed) DDG to meet targeted gain (not much forage)
Heifers that need to gain 2.5 lbs. daily with average quality forage	Need ≈11.5-12.0 lbs (as fed) DDG to meet targeted gain (not much forage)
Heifers that need to gain 2.5 lbs. daily with poor quality forage	Need ≈12.5-13.0 lbs (as fed) DDG to meet targeted gain (not much forage)

EMPOWER YOUR WHOLE TEAM WITH PERFOR-MANCE-BASED COMPENSATIONYE

CHRISTINE STATEN
DVM, MBA

PRACTICE MANAGEMENT

Empower Your Whole Team with Performance-based Compensation.

Christine A. Staten, DVM MBA
Adobe Veterinary Center
Veterinary MBA
Tucson, AZ

Most veterinarians are paid based on their performance, so why don't we pay our non-doctor team members based on their competence and skills? I find that most practice owners struggle with pay scales, starting wages, raises, and promotions. How do practice owners and managers choose which team member has more "value" than another? What happens when they compare paychecks, and you must answer to the discrepancies? I've been there. The solution is a performance-based compensation model with tier-based levels. We have used this model successfully in our practice for over a decade, attracting, retaining, and motivating high-performing team members.

Implementing a team member compensation program will be transformational to your practice because you will:

- Empower your team.
- Eliminate the stress of raises and promotions.
- Maintain internal consistency and high-level skills/knowledge.
- Attract, retain, and motivate high performing team members.
- Encourage cooperation and mentoring.
- Recognize and reward self-motivation and performance.

How it Works

Each position in your practice needs to be defined and the duties divided into multiple levels. Each level or tier should have soft skills, hard skills, and knowledge. Some of the skills, like drawing blood from ten cats, can be logged by the team member. Knowledge can be assessed with tests, like medical math or vaccine schedules. The first tier is usually all the stuff that you expect them to be proficient in at the end of their orientation. And then each additional tier level has higher level skills and knowledge.

A team member works to become proficient in all areas of the next tier and then requests a review. Their tests and logs along with feedback from their peers determine if they truly are proficient and ready to move up. If they are, they are moved into the next tier which has additional responsibilities and a higher hourly wage attached to it. If they are not yet proficient in some things, we work to help support them and provide them with the tools necessary to get to the next tier.

You can set whatever criteria you would like for moving from one tier to the other. The top tiers in each area have advanced skills and knowledge that not everyone in that position needs to have. They also have additional responsibilities that not everyone in that position wants. For example, we have 5 tiers for our small animal technicians and most of them are happy staying at tier 3 or 4.

The biggest benefit is that each team member is empowered and provided the tools to control their career path and their compensation. A benefit to the practice owner/manager is that there is no more confusion around hiring wages and raises. If you want to work alongside self-motivated team members who actively pursue improvement in hard skills, soft skills, and knowledge and help their peers do the same, performance-based compensation may be just the thing for you and your practice.

Questions

Team member compensation programs

A. Empower your team.
B. Increase the stress of raises and promotions.
C. Maintain internal consistency and high-level skills/knowledge.
D. Encourage cooperation and mentoring.

Each level or tier should require advancements in

A. Soft Skills
B. Hard Skills
C. Knowledge
D. All the above

Ways to assess competency are

A. Logs
B. Tests
C. Gossip channels
D. Peer reviews

All technicians should reach the highest tier in

A. 1 year
B. 3 years
C. 5 years
D. Techs never need to reach the highest tier.

Performance-based compensation works well for all the following except

A. Technicians
B. Resort team members
C. Receptionists
D. It works for everyone.

WHAT THE HECK IS CULTURE & HOW DO I IMPROVE MINE?

CHRISTINE STATEN
DVM, MBA

PRACTICE MANAGEMENT

What the Heck is Culture & How do I improve mine?

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If you don't get this right, nothing else matters. Everybody's talking about team culture in veterinary practices. People are attracted to "good" ones, and they are quick to leave "bad" ones. We all want a positive one, but what does that even mean? Purposeful, strategic decisions by the leaders in the practice create and maintain positive cultures. This presentation will discuss what culture is, why focusing on it is so important and the key elements necessary to create and maintain your own positive culture.

Everybody's talking about culture in the veterinary workspace. A positive culture is one of the top reasons that people join a practice, and a negative culture is one of the top reasons people leave a practice. In today's veterinary employment landscape, a positive culture is critical for recruitment and retention.

We know that a positive work culture increases team member engagement. Employee engagement leads to less absenteeism, less turnover, more productivity, less work-related accidents, less stress, less burn out, and healthier people, both mentally and physically. You can't afford not to focus on your culture.

We all know we want one but what does that look like and how do you get it? And just as important, how do you keep it?

It all starts with a strategic plan. You need to know your vision. Where do you want to go? And then figure out how you're going to get there, which is your mission. And then your core values define your behavior. They are the guiding beliefs of your practice. You've got to lock these in and make sure they're active in your practice. Everyone is motivated by something. What is it? Is it serving the public? Is it caring for animals? Is it preventing disease spread? Is it saving lives? Your team values are core to your clinic but within that clinic there are a lot of different motivators, and you need to be making sure that you are empowering people and making them feel like they're making a difference in the ways that matter most of them. Without purpose, it's hard to get people all moving in the same direction.

Next, you must set and enforce practice standards based upon your vision, mission, and values. Put these in writing in the form of a policy manual, an employee handbook, standard operating procedures, behavioral expectations, or other documents. You need to define what a positive culture looks like in your practice. But it's not enough to put it in writing and have them sign it. You need to talk about it. You need to live it. You need to recognize and reward it. And you need to enforce it. How do you do all this? Ask them to describe their perfect work environment. Use that to create policies and behavioral expectations. To get buy-in from the team, they must understand the benefits to the patients, the clients, the practice, and themselves.

Make sure that you are hiring the right people and keeping the wrong people out. This is the single most important thing you can do for positive culture. Once you've got your dream team, make sure you have clear and open communication channels. Everyone should be empowered and have a voice. Mutual respect, Collaboration, trust, and support between everyone is not only desired, but necessary and it must be fostered.

You must be vigilant about rewarding positive behavior and addressing negative behavior. Nothing will erode a culture faster than allowing one person to behave in a way that is contrary to the culture you've defined. Believe me, I know. That one tech that is so proficient in her skills and so great with clients, but always seems to be speaking negatively about team members when they're not there. She needs to be held to the same standards as everyone else or she needs to leave. To ignore it will destroy the trust relationship you have with your team. It will destroy your culture.

To help encourage positive behaviors, it is critically important to provide training in empathy, teamwork, personality types, and communication. Make sure team building and culture are on the agenda of every meeting. Once you equip your team with the guidelines and tools they need to contribute to a positive culture, they will constantly build and reinforce it. In a culture that people desire, they will work to keep it alive.

Questions

Which of the following is NOT a benefit of a positive work culture in a veterinary practice?

A. Increased absenteeism
B. Higher productivity
C. Less stress
D. Healthier employees

Which of the following behaviors can erode a positive culture the fastest?

A. Addressing negative behavior promptly
B. Allowing one person to speak negatively about team members
C. Providing training in communication
D. Having too many meetings

What is the purpose of defining core values in a veterinary practice?

A. To set revenue targets
B. To dictate employee schedules
C. To guide behavior
D. To determine equipment purchases

Which aspect of training is NOT mentioned as important for encouraging positive behaviors?

A. Empathy
B. Communication
C. Teamwork
D. Technical skills

In a culture where people desire to work, what are employees likely to do?

A. Strive to undermine the culture
B. Work to maintain and reinforce it
C. Complain frequently about workplace conditions
D. Avoid participating in team-building activities

BUILDING YOUR DREAM TEAM: RECRUITING & RETAINING THE BEST

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PRACTICE MANAGEMENT

Building Your Dream Team – recruiting and retaining yours

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Close your eyes and imagine your dream team. What does it look like? How does it function? Now recognize that that can be your reality. This presentation will go over what you need in place before assembling your dream team. We will discuss how to attract the right people and identify the team members you really want (and those you don't) in the interview process. Effective onboarding and orientation are critical for establishing your new hire as a successful team member. And then, once you get them in the place, you need to be proactive about retention.

Preparing.

There are a few things you need to establish in your practice before you can effectively build your dream team. You must know and use your mission, your vision, and your core values. This is your purpose, and it defines your culture. You need to have a comprehensive policy manual that has been run by an attorney. This both defines how you want your practice to function, as well as offering you protection against frivolous complaints. In addition to the policy manual, I recommend a code of conduct that literally describes the behaviors you expect from your team members. In a perfect world, what positions would you like to have within your practice in the future? Don't assign people to them at this point, just identify the positions and then give them each a job description. If you have a small practice or you don't have any management structure in place, you may be the one doing everything in each of these job descriptions right now. The goal would be to outsource them strategically once you have them identified and described.

Recruiting.

Now that you have all the structure in place, how do you get that perfect team member to find you? You need to get the word out that you have a position available in multiple ways. Enlist your team members in the recruiting process. If they're a good fit at your practice, their friends may be too. They're also not going to refer someone to the practice that's not a hard worker because they recognize that would make their job harder. You should put a banner on your website, announce it on your social media platforms, and put a sign in front of your building. Reach out to schools in your area that educate veterinarians, veterinary technicians, and veterinary assistants. You can do paid advertisements on veterinary-specific and non-veterinary specific sites. I think of recruitment as an extension of marketing. Most people applying for a job will look at the social media and website accounts of that business. Make sure that your culture is reflected in those areas. You need a career page that is easy to find on your website and gives an applicant all the information they would need to know about being a team member in your practice. This allows you to keep any outgoing advertisements short into the point.

Interviewing.
Once you've got some applicants, enter the interview process. I recommend reviewing resumes and cover letters and then conducting quick 3-to-5-minute phone interviews. Candidates that move on from that stage move into a group or individual interview. Candidates that move through that phase then have a "skills assessment" at your practice. During this entire interview phase, you are looking for an individual that fits into your vision, mission, and core values. It doesn't matter how good their skill set is, if they are going to have a negative attitude and suck the energy out of your existing team, they will not be an asset to your practice. Once you're ready to make an offer to the perfect team member, discuss your detailed job description, policy manual and code of conduct. This is also where you would do any personality testing, drug screens, or background checks.

Onboarding, Orienting, and Retaining.
Congratulations, you found the right person and they've accepted your offer. Now the real work begins. You must have a structured and efficient onboarding and orientation process to establish that team member into the position swiftly. The trainee needs to understand the process and their role in it. They need a point of contact for check-ins and evaluations. Don't drop the ball in this phase. The last thing that you would want is for that perfect team member to leave your practice so regular check-ins or stay interviews are important for that person and everyone on your entire team. Team members want to be empowered and know their path to growth and wage increases so be transparent about those opportunities. Maintain your positive culture. This involves you holding everyone accountable for the code of conduct. Bottom line, work diligently and purposefully to retain your team.

That dream team that you're picturing is just around the corner. Focusing on creating a positive culture, attracting the right people, using the interview process to identify the team member you want, onboarding and orienting them effectively, and then giving them a reason to stay will make your dream a reality.

Questions

To help new techs onboard successfully into your practice, on day one

A. Buy them gifts
B. Assign them a point of contact
C. Have them take rooms by themselves
D. Keep them away from your other team members

The following are "green flags" during the interview process

A. They can follow directions
B. They are upbeat
C. They tell you all about their last horrible boss
D. They want to learn and grow

The process from receiving an application to an offer of employment should take

A. Less than 2 weeks
B. 2 or more weeks
C. 4-6 weeks
D. 3-4 months – Don't rush this stage.

Check-in meetings should be all except

A. Spontaneous and unscheduled
B. A time for goal-setting
C. A two-way conversation
D. A celebration of wins

It is important to know and understand this before hiring someone

A. Vision
B. Core Values
C. Purpose
D. All of the above

DVM GRADUATE EXPECTATIONS FOR SALARIES & CONTRACTS

JAMES ROUSH
DVM, MS, DACVS, ASSOCIATE DEAN OF ACADEMIC PROGRAMS AND STUDENT SUCCESS

PRACTICE MANAGEMENT

Student Expectations for Starting Contracts and Salaries ~Dr. James K. Roush, Associate Dean for Academic Programs and Student Success, Kansas State University

This seminar will present graduating student expectations regarding salary and other benefits based on the 2023 AVMA National and from our internal survey of 2024 Kansas State graduates. Actions taken by the K-State CVM has addressed student debt and the overall student debt:income ratio is now 1.77 to 1. The recent veterinary job market includes robust opportunities for new veterinary graduates with salary offers at an all-time high and contract offers that often include moving expenses, maternity leave (55% of jobs) retirement contributions (65% of employers match), full medical plans (74%) and signing bonuses (average $9885), as well as training and mentoring data. Salary offers should be commensurate with the type of position and work expected and graduate starting salaries rose last year relative to national averages. Overall average reported salary ranges are often misinterpreted and misleading due to inclusion of training program and other salaries in the data. Kansas veterinary starting salaries average 4th lowest among states, and even adjusting for cost-of-living leaves the state well below national average salaries.

Dr. Roush will also discuss Kansas applicant numbers and admissions in light of national numbers. K-State ranks highest per capita (2007 class) in numbers of Kansas students admitted annually compared to all states with veterinary colleges, yet the CVM is funded at the 3rd lowest state and tuition level of all veterinary colleges. The least number of Kansas residents go to out-of-state veterinary colleges compared to residents from all states with a veterinary college.

2024 K-State student salary data (averages) compared with 2023 AVMA Survey National Data

Position type	**2023 National Averages (AVMA)**	**2024 K-State Graduates**	**Jobs in Kansas**	**Jobs Out-of State**
Private Practice	$125464	$110514	$98577 (last $88190)	$113000 (last $113424)
Companion Animal (predominant)	$133876	$120471 (1 students)		
Companion Animal exclusive	$130610	$122967 (30 students)		
Food Animal (predominant)	$94078	$92000 (5 students)		
Mixed Practice	$104222	$89211 (19 students)		
Not-for-profit	$84019	$100000 (1 students)		
Student Debt	$161979	$184863[@]		

[@]Up substantially this year, but federal interest reinstated.

OSTEOARTHRITIS & OTHER CHRONIC PAIN SYNDROMES: RECOGNITION, ASSESSMENT, MANAGEMENT

MARK EPSTEIN
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SMALL ANIMAL

CANINE & FELINE OSTEOARTHRITIS & CHRONIC PAIN SYNDROMES
RECOGNITION, ASSESSMENT, AND MANAGEMENT
Kansas State Univ 2024

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It can be argued that chronic pain is the most ubiquitous disease process in all of medicine. All animals, whether human and veterinary should they live long enough, will probably experience it. And of all chronic pain syndromes, osteoarthritis (OA) remains the most predictable cause in both dogs and cats. Indeed, in dogs the pathophysiology of OA is commonly heritable and conformational, to include, joint incongruity, joint malalignment, and intrinsic cartilaginous defects. For these dogs, the disease process begins at a very young age and is progressive and lifelong. At least 30-40% of dogs may be affected clinically,[1] with a higher percentage (up to 60%) having radiographic changes associated with degenerative joint disease.[2] Other common causes include acquired conditions such as trauma, including not insignificantly chronic cranial cruciate ligament (CCL) injury and acute-on-chronic CCL rupture. Nearly half of musculoskeletal disorders identified during a 10-year span in 16 veterinary hospitals resulted from joint disease.[3] The etiology of OA in cats is uncertain, with less attributable to conformation (exception: hip dysplasia in Maine Coons[4]) than dogs. Cats, both young and old, appear to have a very high incidence of OA, with up to 60% of all cats have radiographic OA changes and 90% over 10 years old.[5] Although the pathophysiology of OA may be different in dogs and cats, this means that OA in both these species can initiate early in life, far earlier (relatively speaking) than routinely in humans, and how we intervene in OA may be quite different from one life stage to another.

Risk factors for OA begins with breed predisposition (see Table 1) and extend to breed dispositions for a variety of other painful orthopedic conditions, injuries, and inflammatory joint diseases (see Tables 2, 3).

For example the highest prevalence of canine hip dysplasia (CHD) is in those that tend to be stocky, round, and heavy. The lowest prevalence is in slender, trim, fleet-footed, and highly coordinated breeds (e.g. greyhound, whippet). However, one report failed to support the hypothesis that heavy, fast-growing dogs from four large-sized breeds were at increased risk for CHD, and other unknown risk factors and genetic variances within litters may have played a role in this cohort of dogs.[6]

Interestingly, CHD is not reported in wild, undomesticated carnivores, speculatively because they often mature slowly due to poor nutrition, although again other genetic variances may play important roles.[7] Nutrition clearly can play a role, evidenced by one study that limited feeding of domestic dogs at risk for CHD over a 5-year period, revealing minimal development of coxofemoral joint osteoarthritis.[8] [6]

Table 1: Heritable Conformational conditions resulting in OA:

		Common breeds with Highest Odds Ratio [9],[10] (Alphabetical)
Hip Dysplasia		Burnese Mtn Dog, Chow chow, German Shepherd, Kuvasz, Labrador retriever, Newfoundland, Rottweiler, St. Bernard
Legg-Calves-Perthes		Australian Shepherd, Chihuahua, Miniature Pinscher, Pug, Toy Poodle, West Highland white terrier, Yorkshire terrier

Elbow Dysplasia	Fragmented medial coronoid	Burnese Mtn Dog, Bullmastiff, German Shepherd, Irish Wolfhound, Labrador retriever, Rottweiler, St. Bernard.
	United anconeal process	Burnese Mtn Dog, Mastiff, Rottweiler
OCD	Shoulder	Burnese Mtn Dog, Great Dane, Great Pyrenees, Irish Wolfhound, Labrador large breed especially German Shepherd, Rottweiler; sporting breeds
	Elbow	Chow, Golden Retriever, Great Dane, Labrador Retriever, Newfoundland, Rottweiler
	Stifle	Boxer, Bulldog, Great Dane, Irish Wolfhound, Mastiff, Rottweiler
	hock	Bullmastiff, Labrador Retriever, Rottweiler
Medial shoulder instability/subluxation[11]	Congenital	Dachshund, Chihuahua, Pekinese, Shetland sheepdog, toy poodle
Angular limb deformity (premature growth plate closure)[12]	Pes varus	Dachshund
	Pes valgus	Collies, Shetland sheepdogs, Newfoundland, Rottweiler
	Genu valgum (knock knee)	Small breeds[13]
	Genu varum (bow-leg)	Large breeds[14]
Luxating Patella[15]	Medial	Maltese, Pomeranian, Toy Poodle, Yorkshire Terrier
	Lateral	Akita, Bulldog, Cavalier King Charles Spaniel, Chihuahua, Chinese Sharpei, Great Pyrenees
Poor tibial plateau angle resulting in Cranial Cruciate injury/rupture		Newfoundland, Rottweiler, Labrador retriever, Boxer, Chow chow, American Staffordshire terrier, St. Bernard, Alaskan malamute, Airedale terrier. Sexually altered and females predisposed.[16] Akita, Mastiff, and Chesapeake Bay retriever were also predisposed, and obesity a significant risk factor.[17]

Other historical, environmental factors will also impact the development of CHD. One report of 501 dogs found increased risk of development of a dysplastic phenotype in puppies allowed to take stairs at or before 3 months of age, and diminished radiographic CHD in puppies that were allowed off-leash before 3 months of age; those born on a farm, and in the spring or summer.[18]

OA is typically envisioned as a disease of bone and cartilage. And of course, physical examination – or even just movement - often will easily elicit the crepitace attributable to osteophytes and bone-on-bone grating. But it is instructive to point out that the pain of OA is not felt at the articular surfaces or what is left of them. Rather, the pain is felt in the peri-articular structures, from an inflamed synovium, when tension is placed on a fibrotic joint capsule, and when patients are asked to exert (even if just by standing or walking) weakened ligaments, tendons, and muscle. Thus OA is a disease of the entire joint organ, including dramatic synovitis, fibrosis, and atrophy…and the result is not just pain but progressive disability. Physical examination and clinical measurement instruments (CMIs) can be designed to illuminate and document these findings.

Several validated CMIs are available and can be use to semi-quantify patient comfort, mobility, and abilities, e.g.

a. CODI: Cincinnati Orthopedic Disability Index:[19] Includes a client-specific outcome measure (CSOM), whereby the pet owners are asked not only standard questions but also to volunteer specific activities of daily living that have become difficult for their dog, the degree of impairment, and the final score is normalized to a 0-100 scale. Based on the human MACTAR (McMaster-Toronto Arthritis) and WOMAC (Western Ontario McMaster) arthritis index in humans, variations of CSOMs have been applied to a number of OA pain studies in dogs.

b. CBPI: Canine Brief Pain Inventory.[20] Derived from the human Brief Pain Inventory, the CBPI questionnaire asks owners to place their dogs on a 0 best-10 worst scale in 3 domains, a Pain Severity Score (4 subdomains of pain its present and least, worst, and average over the previous week), a Pain Interference Score (7 subdomains of general life enjoyment plus ability of general activity, to rise, walk, run, climb stairs), with a combined overall best score of 0 and worst of 100; and an Overall quality of life impression Poor to Excellent).

c. LOAD: Liverpool Osteoarthritis in Dogs.[21] The questionnaire asks owners to scale (0 best-5 worst) 5 areas of mobility Generally (general, lameness disability, activity, affect of cold/damp weather on lameness, stiffness after lying down) and 8 areas of mobility at Exercise (how active in exercise, how keen, ability, affect on lameness, how often stopping/resting, effect of cold/damp weather, stiffness after lying down, effect of lameness). The maximum best score is 0, maximum worst/most affect score is 65).

d. COAST: Canine Osteoarthritis Staging Tool.[22] This novel CMI not only gives an OA "score" but defines the stages of OA for assessment and monitoring of dogs either 'at risk' or with clinical signs of the disease. It consists of two key steps (grading and staging), performed by both owner and veterinarian, which are repeated at monitoring intervals tailored to the requirements of the individual dog. Unique to COAST, it has a key focus on "at risk" dogs (e.g. breed, conformation, body condition score predispositions, history of joint injury, etc.) and not merely symptomatic patients, which minimizes the risk of underdiagnosing OA, and allows for prospectively earlier diagnosis of OA. A two-pronged approach to grading ('grade the dog' and then 'grade the joint') ensures that the impact of OA on the joints and on the dog as a whole is evaluated. The resulting grades are consolidated to provide an overall measure of disease severity. This correlates with the stage of OA which is useful for guiding treatment and monitoring disease progression. The individual grades may also provide useful supplementary information.

And in cats:

a. FMPLI: Feline Musculoskeletal Pain Index[23] www.painfreecats.org
b. MICAT: Montreal Instrument for Cat Arthritis Testing[24]

Owners may recognize orthopedic pain only when the gait is asymetric (only 1 limb affected, or far worse than a contralateral limb, thus "lameness"), but bilateral disease (e.g. osteoarthritis) may not reveal a single limb being favored (i.e. no lameness reported). Instead the patient may merely shift weight forward or back w/ resultant muscle atrophy and hypertrophy accordingly. Changing the rise from lying down, a shortened stride, stiff gait, or improving gait when "warmed out" also points to osteoarthritis pain. Decreased range of motion (ROM) may indicate joint capsule fibrosis and/or osteophytes.

An orthopedic exam can be both brisk and thorough when part of a routine wellness visit. It begins and can be halfway completed upon knowing signalment e.g. age, breed (see Table 1), gender (males over-represented), lifestyle (agility & sporting vs. sedentary) dispositions, history (previous trauma or h/o lameness?), and first walking in the room, chatting with the owner, and watching/interacting with the pet.

- Visible conformation: Body condition score; kyphosis of back, diminished angle to stifle & hock, obvious muscle atrophy (denotes a patient that has been shifting weight forward for considerable time); cow-hock, base narrow or wide, chondrodyplasia – all evident at a glance.
- Dog sitting "square", or cheating on one hip?
- When stands from a laying position, should be all 4 legs simultaneously; vs. rising up first on forelimbs and fololwed by hoisting up the rear quarters.
- Gait if possible – stilted or fluid? Lameness: look for a "quick step" and it is the contralateral limb affected; look for classic 'wiggle' of rear quarters seen as the dog rotates its pelvis to reduce painful extension of the hip.
- Jumping up or standing on back legs easily, partially, or unable/unwilling?

In the cooperative patient, the hands-on orthopedic exam can be completed in less than two minutes and of course can be incorporated to the rest of the physical exam as hands are run over the body. If there is a reported lameness or disability then more time may need to be spent on the affected area to fully characterize.

Focusing on the orthopedic aspect of the PE:[25] A consistent routine back to front or vece versa, with attention "lame" leg last if reported. Although not required, an assistant is recommended to aid with maneuvering, restraint if necessary, and identification of painful response (body shift, change of facial expression). The clinician can focus mindfulness towards: symmetry (atrophy or thickening relative to contralateral limb), ROM (full or limited/resistance; crepitation), and pain (hyperalgesia upon palpation). Individual regions and maneuvers:

Scapula: prominent scapular spine suggests disuse atrophy; abducted limb may suggest infraspinatus contracture;

Shoulder: Flexion, extension, adduction, abduction, internal/external rotation, drawer maneuver. Pain at cranial aspect shoulder and in extension consistent w/ supraspinatus tendonopathy (*note: avoid placing forelimb into extension w/ hand placed caudal/behind or distal to elbow join*t during should extension which also forces elbow into extension and a painful response could be shoulder OR elbow). Instead place hand above elbow which is held in neutral position. Bicipital tenosynovitis: pain upon deep palpation, or palpation during simultaneous flexion of shoulder then elbow (max stretch on bicipital tendon). Medial glenohumeral laxity (excessive shoulder abduction and pain at end of maneuver).

Elbow: ROM including extension/flexion and varus/valgus; thumb & forefinger caudal to humeral condyle in front of olecranon: effusion will cause a distension rather than concave depression; pain upon digital pressure on medial as indicates r/o ununited anconeal process, Fragmented coronoid process

Long bone: pain on digital pressure? (puppies/young large breed dogs r/o panosteitis, hypertrophic osteodystrophy; older large breed dogs primary r/o osteosarcoma, metastatic bone neoplasia)

Carpus: ROM including varus/valgus and extension/flexion (pad should touch or nearly touch caudal antebrachium).

Spine: deep palpation (hyperalgesia?), symmetry, atrophy? Cervical gentle ROM, any resistance? Digital pressure at lumbosacral w/ and without extension of tail (best if hind limbs somewhat elevated (pain elicited r/o LS stenosis)

Hip: Puppy: Ortolani: hand on flexed stifle and femur is forced in a dorsal/axial direction with other hand on hip/pelvis → abducted: clunk when subluxated femoral head moves "up and over" the acetabular rim. Adult: Should be able to elicit comfortable 3 second hold in extension (via pulling back on hock or stifle).

Stifle: cupping from behind; medial buttress consistent with chronic cranial cruciate ligament injury and instability; luxating patella through extension and flexion (Grade IVs hardest to detect due to false impression of proper seating since cannot be displaced; follow patellar ligament from tibial tuberosity, will be ectopic for luxating patella and puffy if any effusion). Clicking or popping in ROM (meniscus); tibial thrust and cranial drawer for CCL.

Tarsus: popping during ROM may be displacement of superficial digital tendon post-retinaculum tear (→hyperflexion of tarsus, digits; also calcaneal tendon damage can lead to hyperextension); joint capsule distension, palpable on dorsal as well as caudomedial, caudolateral joint surfaces (suggests OCD).

Early Management (COAST Stage 1-2): REDO the PARAGRAPHS

Several Systematic Reviews reveal the most predictably effective, evidence-based means of canine OA management[26],[27],[28],[29] and are summarized in industry guidelines such as the Global Pain Council[30] and AAHA Pain Management Guidelines.[31] However the most cogent consensus of treatment guidelines are based on COAST Stages.[32],[33]

1. Weight Optimization: keep the patient lean! The evidence is clear that #1 preventative measure to slow the progression of OA in at-risk dogs is to maintain a lean body condition score.[34],[35],[36],[37],[38] The role of adipose tissue as a mediator of systemic inflammation, the contribution of central obesity to chronic pain in humans (doubling the risk for it[39]), and the primacy of weight loss to diminish chronic pain signs and symptoms- is now a settled matter. In dogs with osteoarthritis, several studies illuminate the benefit of improving pain scores, mobility, and NSAID reduction with weight loss alone (even modest, i.e. only 6%[40]). Indeed, it is probably not an overstatement to say that in an overweight patient, both the clinician and pet owner are wasting time and money on other interventions until and unless weight optimization is achieved.
2. NSAID (including EP4 receptor antagonists): for the early OA patient may be in an intermittent or pulse dose fashion – several weeks on, several weeks off. Multiple systematic reviews describe safety of efficacy of NSAID use in dogs and their highest and wisest use.[41],[42],[43] See the separate discussion on NSAID in dogs and cats.
3. Chondroprotectants: The evidence for glucosamine and chondroitin in OA remains mixed at best, although some other ingredients of oral neutraceuticals such as Bosswelia, egg shell membrane, avocado soybean unsuponafiables, MSM, green-lipped mussel, microlactin, and others offer suggestions for varying degrees of immunomodulating, chondroprotective, and pain-modifying effect (with one combination product in an well-designed but unpublished study revealing statistical improvement in biomarkers and LOAD[44]). A recent review of nutritional supplements for canine OA concludes that even if additional investigation is needed, dietary supplements should be considered in OA management.[45],[46] It can be argued that these neutraceuticals, due to their ease, relative safety, low cost, and easy acceptance by pet owners, should be deployed with earliest onset of OA signs, or even in at-risk patients before symptomatic. Parenteral polysulfated glycosaminoglycans (PSGAG), in particular Adequan® which is FDA-approved "Disease-modifying osteoarthritis agent" (DMOAD) for dogs with bioavailability and efficacy supported by independent studies.[47] One abstract in cats demonstrates bioavailability and distribution to joints with SC administration.[48] Another injectable glycosaminoglycan for horses, pentosan polysulfate (PPS, Cartrophen®), also has some evidence for benefit in canine OA[49] although not available in the U.S.
4. Eicosapentaenoic acid (EPA)-rich diets in dogs,[50] Docosahexaenoic acid (DHA)-rich diet in cats.[51] There is an emerging body of evidence to support other nutritional supplements such as eggshell membrane and many others.
5. Exercise, especially controlled. Therapeutic exercise is hypoalgesic[52] and considered to play a crucial role in the management of osteoarthritis in dogs.[53],[54]

Note: The AAHA/AAFP Pain Management Guidelines[55] strongly emphasizes the role of low-stress handling and fear-free environment (especially in the clinic setting). For dogs and cats, a superior resource is Dr. Sophia Yin's *Low Stress Handling, Restraint and Behavior Modification of Dogs and Cats: Techniques for Developing Patients Who Love Their Visits* and website, www.drsophiayin.com. For cats in particular, the *AAFP/ISFM Feline-Friendly Handling Guidelines*[56] is an excellent place to begin, and the manuscript is accompanied by video demonstrations: http://www.catvets.com/guidelines/practice-guidelines/handling-guidelines. In

addition, pheromones are increasingly recognized for their integral role in diminishing stress, with its attendant contribution to pain. All of this is globally part of the Fear-Free experience for cats, www.fearfreepets.com.

Additional modalities for more advanced OA (COAST Stages 2-4):

1. Pain-modifying analgesic drugs: PMAD – one or more
    a. amantadine: exerts a pain-modifying effect as an NMDA receptor antagonist[57] and remains an interest in humans with chronic and neuropathic pain (but not specifically osteoarthritis) in humans, with mixed results.[58],[59] One study at 3 mg/kg once daily does demonstrate utility as an adjunct to NSAID in dogs with refractory osteoarthritis within 3 weeks,[60] and there is one case report of using amantadine to treat neuropathic pain in a dog.[61] More recent pharmacokinetic studies suggest that 3-5 mg/kg every 12 hours may be more appropriate.[62] Toxicity and kinetic studies have been performed in humans[63] and cats[64] but not in dogs. In dogs, anecdotal reports of amantadine-induced ADE's include agitation and other behavioral changes, and GI signs especially diarrhea. In humans QT-syndrome is reported, and in dogs a recent study demonstrated a moderate risk of arrhythmia and decreased cardiac output in halothane-anesthetized dogs receiving IV amantadine.[65] The clinical significance of this finding in awake dogs receiving PO amantadine remains unknown.
    b. gabapentin or pregabalin: anti-convulsant that analgesic properties predominantly by down-regulating pre-synaptic voltage-dependent calcium channels in the dorsal horn of the spinal cord[66] but other mechanisms probably exist as well (while structurally similar to GABA, it is not a direct agonist, although it may have indirect effects on GABA metabolism such as increasing intracellular stores). Because of its effectiveness and tolerability, it is approved for post-herpetic neuralgia and is in widespread use for humans with a variety of neuropathic and other maladaptive pain conditions,[67],[68],[69],[70],[71] and this suggests, along with published veterinary case reports,[72],[73],[74] a strong rationale for the utilization of gabapentin in analogous conditions experienced by dogs and cats. The utility of gabapentin for osteoarthritis in demonstrable in rodent models,[75],[76] one canine study suggests a disease-modifying effect (not a pain study) in experimental osteoarthritis,[77] but no clinical studies have been published investigating gabapentin canine OA. However, case reports exist of successful use in treating non-OA neuropathic pain conditions in both dogs[78],[79],[80] and cats.[81] In cats, one study demonstrated a benefit of gabapentin in naturally-occurring osteoarthritis,[82] in addition to a case series of chronic musculoskeletal pain.[83] Pharmacokinetics of gabapentin are well established in dogs[84],[85],[86] and cats,[87] with a half-life suggesting TID administration schedule, although anecdotally BID appears to be useful. The primary adverse effect in dogs appears to be somnolescence (as in humans) which usually will spontaneously resolve over a few days' acclimation time. For chronic pain dosing, a general consensus is that doses are initiated at 3-5 mg/kg and gradually tapered upwards as the patient can tolerate to a target dose range of 20+ mg/kg. Pregabalin is a gabapentin-like analogue and is thought to have a similar mechanism of action for both its pain-modifying (the labeled indication) and anticonvulsant (down-regulates calcium channels, diminishing action potential propagation) activity. In the U.S. it is available as Lyrica® labeled in humans for pain associated with diabetic neuropathy, fibromyalgia, and post-herpetic neuralgia (Shingles) and is a scheduled Class IV drug. It appears to have a superior kinetic profile relative to gabapentin: higher oral bioavailability, longer T ½, and with a linear GI absorption profile suggesting a dose of 4 mg/kg twice daily in the dog.[88] A case series describes its use in canine syringomyelia,[89] but its expense may currently limit its use in veterinary medicine.
    c. note: tramadol has been shown to be ineffective in modifying OA-related pain[90]
    d. SS(N)RI's: These compounds exert their effect by increasing serotonin +/- norepinephrine in the synaptic cleft. At least one popular SSNRI, duloxetine, has a chronic pain label in humans (including osteoarthritis and low back pain, in addition to fibromyalgia and diabetic neuropathy); one evaluation in dogs revealed poor bioavailability (4%),[91] but another study appears to reveal a dose-dependent effect with more favorable plasma levels at high doses (30 & 60 mg to laboratory beagles, equivalent to 100 & 200 mg in humans respectively which 2-4x customary dosing), but with a much shorter plasma T1/2 (2.5 H in dogs, vs. 10-12 H in humans).[92] Another SSNRI, venlafaxine (which has evidence for efficacy in human OA[93]), is reported to have bioavailability approaching 50% of that of humans and T ½ of 3 hours with a suggested dose of 4 mg/kg PO Q 8-12H.[94] Evidence of a clinical pain-modifying effect for either molecule is currently lacking in animals, and there are no dosed-titration data for either

drug. Note: many drugs and compounds enhance monoamines and/or serotonin and caution should be undertaken when or if used in combination. Examples include: tramadol, TCA's including amitriptyline and clomipramine, SS(N)RI's, amantadine, metoclopramide, selegiline, amitraz, mirtazapine.

2. Biologic therapies:
    a. Anti-Nerve Growth Factor Monoclonal Antibodies (monthly SC injection).[95],[96] The feline version is available as Solensia™, and Librela™ in the dog
    b. Intra-articular injections – some commercially available, others investigational
        i. Stem Cells (autologous mesenchymal vs. allogeneic)[97],[98]
        ii. Platelet-rich Plasma (PRP)[99],[100]
        iii. Stromal-vascular fraction[101]
        iv. Autologous Protein Solution[102]
        v. Tn-117 – under investigation as anti-synovitis medical device (Synovetin OA™)
        vi. Resiniferotxin – TRPV1 agonist under investigation[103] ("molecular neurosurgery")

3. Physical Modalities
    a. Physical Therapy – beyond therapeutic exercise as described above, referral for more advanced modalities e.g. hydrotherapy[104]
    b. Energy-based modalities – Embraced by many but most evidence is molecular, cellular, tissue; clinical evidence limited and conflicting, and outcome measures not always pain.
    c. Low-Level Laser
    d. TENS
    e. Extracorporeal Shock Wave Therapy
    f. Pulsed Electromagnetic Field Therapy[105]
    g. Acupuncture
    h. Myofascial Trigger Point Therapy

Table 2: Other heritable non-joint but painful orthopedic disorders:[106]

panosteitis	Basset Hound, Burnese Mtn Dog, Chinese Sharpei, Dalmatian, English Springer Spaniel, Giant Schnauzer, German Shepherd, Great Dane, Great Pyrenees, Irish Wolfhound, Mastiff, St Bernard. Males are affected four times more often than females. Age: 6 mos – 2 years.
Hypertrophic Osteodystrophy	Boxer, Great Dane, Irish Setter, Weimaraner

Table 3: Other Acquired painful orthopedic conditions with breed dispositions:

Tendonopathy, mineralization, myopathy/contractures	Supraspinatus tendonopathy/ mineralization[107]	Performance, sporting dogs, almost 60% agility dogs; median age 6.5 years.
	Infraspinatus contracture[108]	Working and sporting dogs, e.g. "bird" dogs (pointers, setters) in US, Elkhound in Europe
	Bicipital tenosynovitis[109]	No breed or gender disposition but trend mean wt 33 kg, mean age 4.6y.
	Gracilis, semitendinosus myopathy/contracture[110]	German shepherd
	Achilles tendon injury[111]	Doberman, Labrador, Border collie
	Iliopsoas injury[112]	Sporting, working breeds

Medial shoulder instability/subluxation[113]	Congenital		Dachshund, Chihuahua, Pekinese, Shetland sheepdog, and toy poodle
	Acquired		Sporting, agility breeds
Intervertebral Disc	Hansen 1[114]		Chondrodysplastic breeds
	Hansen 2[115]		Non-chondrodysplastic breeds
Lumbosacral stenosis[116]			German shepherd dog, Airedale terrier, Boxer, English Springer spaniel, Golden retriever, Great Dane, Irish setter, Labrador retriever.
Osteosarcoma[117]			Bernese Mountain dog, Doberman pinscher, German shepherd, Golden retriever, Great Dane, Greyhound, Irish setter, Labrador retriever, Rottweiler Saint Bernard, other large and giant breeds
Inflammatory Polyarthritis	Infectious, especially vector-borne		No breed predisposition but outdoor (vector-exposed) dogs at higher risk
	Immune-mediated[118]	Erosive (Rheumatoid Arthritis)	Small, toy breeds; Sheltie
		Non-erosive (Idiopathic)	Labrador Retriever, Golden Retriever, German Shepherd, Cocker Spaniels, Akita, American Eskimo, Shar Pei, other Sporting and large-breed dogs; age 2-5 years.

Note: Odds ratios reflect the likelihood of a particular dog within a breed being affected by a given condition; it does not necessarily predict the most common breeds to walk through the door with that condition, since some breeds are far more popular (e.g. Labradors) than others (e.g. Kuvasz, Irish Wolfhound). An informal survey among 5 veterinary rehab professionals identified the following breeds as the most commonly encountered with orthopedic conditions in their practices, in order of frequency cited: Labrador retriever, German shepherd, Rottweiler, Golden Retriever, Newfoundland, St. Bernard, Great Dane, Burnese Mtn Dog, Border Collie, Doberman pinscher.[119]

Management of non-OA, non-OSA pain

- Adjunctive Pain-modifying analgesic drugs, including but not limited to:
  - gabapentinoids, amantadine, amitriptyline, SSRI/SSNRI, acetaminophen? (dog only), maropitant, ketamine,, cannabinoid?, low-dose naltrexone?
- NSAID
- opioids (oral bioavailability low; be aware of potential diversion)
- weight optimization
- Biophysical modalities
  - Therapeutic Laser, PEMF, etc.
  - Acupuncture
  - Myofasical Trigger Point

Osteosarcoma (and potentially other neoplasms) :To the above,

- Bisphosophonate infusion: zoledronate[120] 0.1 - 0.15 mg/kg IV in 60 ml (or 10ml/kg) saline over 15min q 4wks. Monitor renal values
- Palliative radiation therapy

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CPR BASIC LIFE SUPPORT (BLS) GUIDELINES BASED ON THE RECOVER (REASSESSMENT CAMPAIGN ON VETERINARY RESUSCITATION) INITIATIVE

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PATHOPHYSIOLOGY OF PAIN AND MALADAPTIVE PAIN SYNDROMES

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Pathophysiology of Pain and Maladaptive Pain Syndromes
Kansas State Univ 2024

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In the last 10 years, the veterinary profession has undergone what can only be described as a sea change in perspectives about animal pain and pain control. In many ways the issue of pain management in animals closely parallels that in human pediatrics, whereby the patient is non-verbal and the clinician must rely on personal/staff observations and the reports of the patient's advocate (in some ways this parallel extends to human geriatrics, whereby the patients may be once again non-verbal and a caregiver is the patient's advocate). Thus it is that physicians have also long struggled with the critique of under-managing pain in children[1],[2] the cognitively impaired,[3] and the elderly.[4],[5]

Under- (or un-) managed pain elicits a cascade of debilitating neuro-hormonal effects that result in hypertension, catabolism, immunosuppression, and in what can be a terminal event, bacterial translocation and sepsis. This is called the "stress response." With under- (or un-) managed pain, patients at best recover more slowly from their condition, and at worst, may develop severe, even life-threatening complications.

However, the effect is not limited to pain of an acute nature. In addition to discomfort and physical disability, the capacity of chronic pain to impair cognition is becoming increasingly recognized in humans. A global summary of statistically significant findings in 42 studies of patients with chronic musculoskeletal pain revealed that deficits of memory, attention, psychomotor speed, and mental flexibility all can be attributed as a consequence of chronic pain, independent of other causes.[6] In animals, for all of these reasons, under-attended, under-managed pain can become a criterion for euthanasia.

Pain itself is normal, and when physiologic it is protective. But undermanaged pain, as it becomes extended in time and intensity, becomes maladaptive and debilitating. And the younger the patient, the more long-term consequences of undermanaged pain because of the enhanced plasticity of the spinal cord: hypersensitivity to thermal stimuli can be documented years after the initial sets of painful experiences in both animals and humans.[7] Thus for clinicians in a veterinary practice, their staff, and their clients, the first step to developing an aggressive, integrative pain management system is to internalize how dangerous and damaging undermanaged pain is to their patients. In fact, until so convinced, stocking drugs on a shelf and writing down protocols stands little chance of successful hospital-wide implementation.

The neuro-anatomic, physiologic, and molecular basis of nociception is a rapidly evolving field of study. Once-simple models are now understood to be highly complex and supremely inter-related sets of dynamics. The "Gate Control Theory", offered in 1965 by Melzak and Wall, proposes a feedback mechanism that controls activation of pain fibers by allowing or inhibiting impulses through the "gate."[8] Nothing that we now understand about nociception challenges the basic operational premise of the Gate Theory. What is new and growing is the illumination of its details.

Nociceptors are specialized nerve fibers that have their dendritic endings in peripheral tissue, with several different subtypes identified. These nerve fibers have receptors that respond to mechanical and chemical stimuli but may be polymodal for touch, pressure, heat, cold, itch, and other sensations. When activated by the appropriate stimulus, a signal is said to be *transducted*, and the nerve endings depolarize. The signal is then conducted, or *transmitted*, electrobiochemically in an afferent direction, that is, towards the spinal cord. There, in the dorsal horn, the signal is *modulated*, that is either enhanced or dampened. Synapses are made with secondary neurons which ascend up the spinothalamic tract of the spinal cord to the thalamus, where another synapse occurs with tertiary neurons, which then project to the

cerebral cortex where *perception* occurs. However, in addition to these ascending pathways to the brain are descending, inhibitory pathways; and under the proper conditions conduction can occur from the spinal cord down the peripheral nerve fibers in an anti-dromic fashion to the site of original transduction.

The fastest of the nerve fibers are the small but fully-myelinated A-beta sensory fibers which involve the sensations of touch, pressure, vibration, and proprioception. Somewhat slower are the thinly-myelinated A-delta fibers which stem from mechano-, thermo-, and nociceptors involved in sharp physiologic and acute pain. C-fibers are large and unmyelinated and hence very slow conductors of mechanoreceptors and nociceptors involved in dull, aching chronic pain. From somatic sites the cell bodies of these nerve fibers are located in the dorsal root ganglia, and from visceral sites, the sympathetic ganglia. The terminal endings of these fibers are highly tropic in the dorsal horn, with somatic A-delta and C fibers occurring in the most dorso-lateral aspect (Laminae I and II), somatic A-beta fibers terminating in the deeper Laminae II, IV, and V, and visceral A-delta and C fibers scattered throughout each of these Laminae.[9] However, the tropism, inter-connectivity, and even phenotype of these various neurons is not static, rather the dorsal horn can exhibit dramatic plasticity, changing and altering form and function depending on a wide variety of factors: age (the younger the more plasticity), type and duration of stimulus, gender (or sexual status i.e. presence or absence of androgenic hormones), and others.

At the peripheral site of transduction, stimulus comes in the form of heat (transient vanilloid receptor 1, TRPV1), cold (cold- and menthol receptor 1, CMR1), membrane distortion, or cell damage releasing fatty acids and free ions from cell membranes. Each of these stimuli open non-specific cation channels on the peripheral endings of A-delta and C-fibers, which allows an inward Na+, K+, or Ca+ current. When a critical threshold of intracellular Na+ and/or Ca+ is reached, then activation and opening of voltage-gated cation channels occurs, which propagates depolarization afferently along the nerve fiber membrane.[10] In addition, the free fatty acids are catalyzed by phospholipase-A2 into arachadonic acid, providing the substrate for cyclo-oxygenase metabolism and the initiation of the inflammatory cascade through a number of mediators e.g. prostaglandins, H+ ions, cholecystikinin, histamines, Substance P, bradykinins, leukotrienes, and many more,[11] all highly noxious stimuli that bind to their own receptors on the nociceptor nerve ending, exacerbating or continuing the cation influx. The peripheral nerve fiber transmits its signal to the spinal cord, terminating in the dorsal horn.

In the dorsal horn, the nociceptors terminate and release various highly bioactive molecules across synapses to interneurons (also called *second-order* neurons). Chief among many of these in the classic model is the excitatory amino acid glutamate, which binds to AMPA receptors on the interneuron. This binding causes a sodium/potassium channel to open, allowing Na+ to flow freely through the cell membrane into cytoplasm (and K+ out into the extracellular space), which elicits an action potential: the interneuron depolarizes and the impulse is transmitted afferently to the brain. However, as quickly as it opens, an AMPA receptor will close, unless the stimulus is sustained. If the stimulus is in fact sustained, not only will the AMPA receptor remain open, but the accumulation of intracellular Na+, will phosphorylate adjacent NMDA receptors, releasing a magnesium “plug.” The NMDA receptor is now open and free to allow calcium to inflow into the neuron, further depolarizing it for an extended period of time.[12] NMDA activation is now well-established in its role of potentiating hypersensitization and neuropathic pain.[13]

The second-order, or projection neurons, upon which the peripheral A- and C-fibers synapse, are characterized as wide dynamic range (WDR, sensitive to a variety of sensations, including pain) and nociceptive-specific (NS, pain-only) neurons. They ascend the spino-thalamic tract to terminate in the thalamus, with projections (via third-order neurons) to the reticular, limbic, homeostatic-control, and cortical somatosensory regions of the brain[14]. Here the spatial and temporal qualities of pain become more than an unpleasant sensation, but transcends to a physical and emotional experience as well.

Inhibitory neurons, some intraspinal and some descending from the brain, synapse on the second-order neurons as well. Here the neurotransmitters are inhibitory in nature and include gamma amino butyric acid (GABA), norepinephrine (NE), certain serotonins (5-HT3), B-endosyn, and others[15]. Furthermore, circulating endogenous opioids bind to kappa and delta (less so mu) receptors (closing Ca+ channels, and opening K+ channels, respectively), hyperpolarizing the cell. A basal level of interconnectivity occurs between afferent A-beta, A-delta, C-fibers, interneurons, and intra- and descending inhibitory neurons.[16] Lastly, the supporting glial cells (astrocytes, microglia, oligodendrocytes) in the spinal cord, whose purpose was once thought to be merely structural in nature (providing synaptic architecture, host defense, and myelin, respectively), are now thought to be highly integrated into the pain process, particularly with regards to chronic pain.[17] Recently described is the tetrapartite synapse, which includes an astrocyte, microglial cell, and pre- and post-synaptic neuronal terminal.[18] A recently isolated chemokine, fractalkine, appears to be a neuron-glial cell signal, activating glially-dependent pain facilitation (in a recent rat model, blocking the one known fractalkine receptor in rats diminished the development of neuropathic pain).[19] Indeed, the glia may play a primary role with regards to synaptic strength, plasticity, and sensitization in the spinal cord, which does exhibit substantial change under the influence of chronic pain.[20]

Sustained nociception begins to alter the dynamic considerably, and pain can quickly move from its physiologic, protective nature to a maladaptive one. The constant presence of inflammatory and bioactive mediators at a peripheral site forms a “sensitizing soup” that creates a constant barrage of excitatory neurotransmitters in the dorsal horn. The opening of the calcium channel begins a cascade of events that in some cases becomes irreversible. An influx of calcium ion causes activation of Protein Kinase C (PKC), which in turn elicits production of nitrous oxide (NO), which then diffuses back across the synapse and through the terminal ending of the afferent nociceptor. This causes K+ channels to close and also the production of Substance P, a profoundly excitatory bioactive molecule, which then flows back across the synapse once more to bind on neurokinase (NK-1) receptors of the interneuron[21] (expression of the NK-1 receptor appears to also contribute to opioid-induced hyperalgesia and tolerance[22]). Not only does the interneuron stay depolarized, but a phenotypic change may be induced where it may not reset. Expression of *c-fos*, *c-jun*, and *Knox-24* genes transcribe new (probably aberrant) proteins that produce permanent microstructural changes of the neuron that result in reduced firing threshold, upregulation of central neuronal activity, downregulation of inhibitory activity, expansion of the receptive field, peripheral hypersensitivity and intensified pain responses to further stimulation.[23]

Furthermore, the afferent nociceptor will conduct a signal efferently, in an anti-dromic fashion. There, at the peripheral site of original stimulus, it releases Substance P and calcitonin gene-related peptide (CGRP), another highly bioactive excitatory compound, which elicits further release of inflammatory mediators and recruiting and activating other previously innocent-bystanding nociceptors, further bombarding the dorsal horn with impulses.[24] As the feedback loop persists, more and more cells express *c-fos* and other genes, Nerve Growth Factor is stimulated into production (suspected to be from glial cells), and more interconnections are made between types and locations of neurons in the spinal cord.[25] These interconnections are not isolated to somatosensory neurons, for they have been shown to newly express adrenoceptors which are activated by catecholamines. Sympathetic stimulation may then result in nociception,[26],[27] and may in fact be central to the pathophysiology of neuropathic pain. Moreover, neuropathic pain is associated with alterations in receptor location (more places on more axons) and sensitivity to excitatory amino acids (greater) throughout the nervous system.[28] Eventually, when the process of pain is located centrally (in the spinal cord) rather than at the site of the original stimulus, the pain is said to be “neuropathic” in origin. Once neural pathways are thus sensitized, the physiologic (and physical) responses to pain may persist, even when the peripheral nerves themselves are blocked (or even transected).[29] Clearly, at this point, pain has become a disease unto itself.

Summary of terminology used to describe this sensitized state:
Peripheral hypersensitization: generation of an ever-present "sensitizing soup" of inflammatory mediators (prostaglandins, bradykinin, cytokines, neuropeptides), activation of quiescent (silent/sleeping) bystanding nociceptors from non-injured tissue, reduction of threshold in normally-high threshold nociceptors.

Central hypersensitization: increase in the excitability of neurons in dorsal horn of spinal cord, cumulative depolarization ("wind up") amplifying the neuronal activity in dorsal horn, generation of Nerve Growth Factor which promotes interconnections between formerly segregated types and locations of neurons, expression of new receptors, and phenotypic modification of nerve function.

Neuropathic pain: the extension of hypersensitization which is the initiation of transmitting a pain impulse (spontaneous depolarization) in the absence of noxious stimuli, or out of proportion to it.

In both acute and chronic pain, other non-neural peripheral tissues are not exempt from physical changes as well. Reflex muscular spasms are not only themselves painful, they may compromise vascular supply, and the resulting ischemia can result in release hydrogen ions and ATP, which are also highly sensitizing agents. This can result in altered, maladaptive conformation and gait, leading to abnormal stresses on ligament, tendon, cartilage, as well as and hyperirritable bands of contracted muscle (myofascial trigger points, TrP).[30]

Glial cells (astrocytes, microglia, oligodendrocytes) in the spinal cord, whose purpose was once thought to be merely structural and macrophage-like in nature (providing synaptic architecture, host defense, and myelin, respectively), are now thought to be highly integrated into the pain process, particularly with regards to chronic pain.[31] Recently described is the tetrapartite synapse, which includes an astrocyte, microglial cell, and pre- and post-synaptic neuronal terminal.[32] A recently isolated chemokine, fractalkine, appears to be a neuron-glial cell signal, activating glially-dependent pain facilitation (in a recent rat model, blocking the one known fractalkine receptor in rats diminished the development of neuropathic pain).[33] Indeed, the glia may play a primary role with regards to synaptic strength, plasticity, and sensitization in the spinal cord, which does exhibit substantial change under the influence of chronic pain.[34] There is no one moment when pain is transformed from physiologic to "acute" to "chronic" to "hyperesthetic" to "allodynic" to "neuropathic". Rather it exists on a continuum with a high degree of biologic variation from patient to patient. There is also recent evidence that anxiety in the acute setting, mediated by cholecystikinin rather than mobilization of the hypothalamic-pituitary-adrenal axis, plays a major role in creating a chronic, hyperalgesic state.[35]

Historically, the focus of analgesia has been to diminish transduction (e.g. local anesthesia, anti-inflammatories) and perception (e.g. opioids), and indeed these remain crucial components of a multi modal approach to pain management. The most exciting area of attention today however is in the dorsal horn, by enhancement of inhibitory modulation of nociception and interrupting the feedback loop that results in exaggerated pain responses and perception. As greater understandings emerge of the molecular and physiologic bases of pain emerges, new opportunities for intervention also emerge.[36]

Clinical Features and definitions of Neuropathic Pain state:

- Hyperesthesia: exaggerated pain out of proportion to a noxious stimulus
- Allodynia: pain from a non-noxious stimulus (e.g. touch, pressure)
- Extended duration: pain persisting past the time of expected tissue inflammation and healing
- Expanded field: pain at site(s) distant to the damaged tissue
- Spontaneous pain: in the absence of known tissue injury

- Dysesthesias: pain with other sensations including itch, tingling, even numbness
- Exaggerated character of pain: stabbing, "lancinating" (cutting, piercing), radiating, pulsing, burning
- Sympathetic signs: pain that worsens with stress, or the painful site exhibits autonomic signs (vasodilation, edema, vasoconstriction, etc.)

What might this look like in a dog or cat?

Think of the cat that:

- no longer wishes to be stroked or petted, or have feet touched
- grooms less
- conversely, abruptly grooms, perhaps down to extremity, or chronically overgrooms a region
- dislikes being held, objects to restraint
- spontaneously rubs its mouth
- reacts to (runs from) an invisible stimulus
- spontaneous panniculus

And dog or cat that:

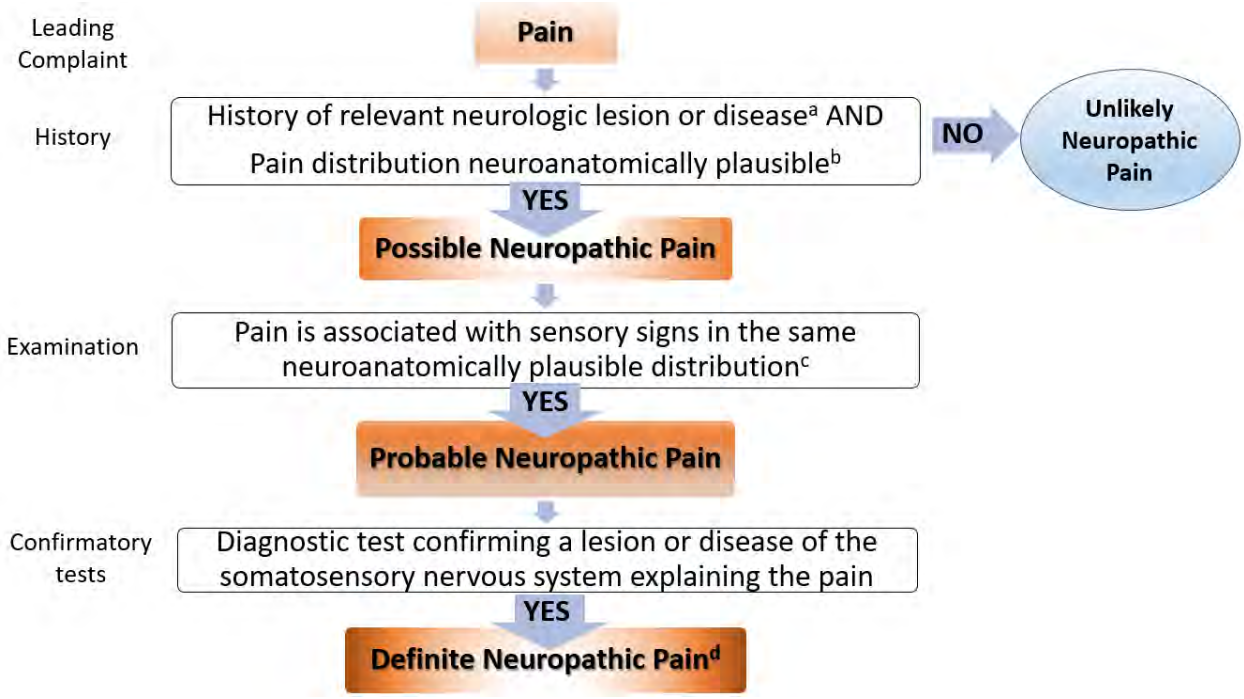
- exhibits avoidance behavior
- increasingly objects to nail trims and/or venipuncture
- progressively interacts less with owners
- or becomes increasingly grouchy/self-defensive

Diagnosis in Humans, Diagnosis in Animals

Confirming neuropathic pain in humans involves validated self-reporting questionnaires and Quantitative Sensory Testing (QST). Some patients may be assumed to have neuropathic pain if they are diagnosed with a known such condition e.g. post-herpetic neuralgia (Shingles) or diabetic neuropathy. Intermediary criteria have been established, wherein a patient showing some of 8 criteria is described as having "possible," "probable," or (if 5 of 8 are present) "definite" neuropathic pain.[37] Since it exists along a spectrum, another descriptor is that a patient may have "pain with a neuropathic component" (PNC).

A grading system in humans defines criteria for neuropathic pain on a probability spectrum (Figure 1).[38] In this schema, history and clinical observations are enough to speculate that a patient has "possible" neuropathic pain. Additional examination may reveal signs consistent with "probable" neuropathic pain, and confirmatory testing (often advanced diagnostics not available to the clinical generalist) can lend a diagnosis of "definite" neuropathic pain; however (and importantly), *known direct nerve damage qualifies as a confirmatory test.*

Figure 1



From: Finnerup NB, Haroutounian S, Kamerman P, et al. Neuropathic pain: an updated grading system for research and clinical practice. Pain. 2016;157(8):1599-606.

In dogs and cats, validated Clinical Metrology Instruments (CMIs) exist for post-operative and chronic osteoarthritis-related pain (See Chapter XX Steagall, or Chapter XX Monteiro). However, none of these specifically address the presence or absence of a neuropathic pain component. A semi-objective sensory testing rubric for hyperalgesia and allodynia in dogs and cats has been proposed (Table 1).

Table 1: Semi-objective sensory testing in dogs and cats[39]	
Hyperalgesia: Produces exaggerated response in affected area compared to unaffected	Allodynia: Normally non-painful but elicits pain in affected area compared to unaffected
Manual pinprick w/ needle	Manual light pressure
Thermal cold (acetone, cold metal 0°C)	Light manual prick (sharpened wooden stick, stiff von Frey hair)
Thermal heat (object at 46°C)	Stroking (brush, gauze, cotton applicator)
Algometry: lowered threshold and tolerance	Thermal cool (objects at 20°C)
	Thermal warm (objects at 40°C)

QST, although not a "pain measurement" per se, evaluates sensory changes (gain or loss of function) elicited in and contributing to a pain state with central and/or peripheral sensitization. QST modalities include mechanical and thermal threshold analyses among others. Current work with QST is beset by a lack of standardization of instruments, modalities, methods, and outcome measures used. Such standardization in veterinary patients must be established before QST can become a clinical cage-side tool.

Prevalence of Neuropathic Pain in Dogs & Cats

One study in a teaching hospital evaluated cats for the presence of pain with neuropathic features. Among outpatients, 92 of 652 (14%) cats and 20% of dogs exhibited pain, with 1/3 – ½ of these (7-8%%) exhibiting a neuropathic component for 1 to 12 months (1% experienced pain >1 year) [40]

This represents a somewhat similar prevalence as found in the human general population (6.9-10%)[41] although some specific sub-populations have much higher rates. In the emergency setting, 23% of both cats and dogs experienced a combination of inflammatory and neuropathic pain.[42]

Recognized or Suspect Neuropathic Pain Conditions in Dogs and Cats[10]

- Feline Orofacial Pain Syndrome (FOPS)[43] – characterized by episodic, spontaneous unilateral pawing at the mouth, excessive and exaggerated licking movements, growling when eating, drinking, or grooming, and food aversion anorexia. More severe cases will involve self-mutilation of tongue, lips, and buccal mucosa. In the UK there appears to be genetic disposition (Burmese cats, < 1year old). In the USA it has been observed in many breeds (excluding Burmese cats, the median age of onset is 9 years old), and a majority (63%) were associated with erupting teeth or oral pathology such as odontoclastic resorptive lesions, periodontal disease, lymphoplasmacytic gingivitis/stomatitis, and post-extraction surgery. Environmental stress may precipitate episodes. Understanding at the present time suggests a neuropathic pain condition analogous to trigeminal neuralgia and/or glossodynia in humans, with involvement from the sympathetic nervous system (SNS).

- Feline Hyperesthesia Syndrome (FHS)[44] - characterized by skin twitching and muscle spasm in the lumbar area, licking of lumbar, flank, tail regions, tail-chasing, exaggerated response to a non-noxious stimulus (e.g., stroking), and reactive (including vocalization) avoidance behavior to a non-apparent stimulus. In extreme cases, a non-noxious stimulus can elicit a seizure-like tetany response or self-mutilation (especially of the tail). Affected cats are generally younger (median age 1 year, range 1-7years) and male cats (both intact and altered) may be overrepresented. Episodes are intermittent, ranging from several times per day or per week. Proposed etiologies include an idiopathic focal epilepsy, primary (and idiopathic) neuropathic pain disorders,

- Feline Idiopathic/Interstitial/Sterile Cystitis (FIC, FSC)[45] - under various names, including Pandora Syndrome for its complex (and evil) nature,[46] this condition mirrors an analogous syndrome in women (Interstitial Cystitis, IC) more broadly called Bladder or Pelvic Pain Syndrome (BPS, PPS). Indeed the term “cystitis” is inappropriate, since significant inflammation is not a feature of the condition in cats or humans.[23] In both species there are similar clinical signs and abnormalities of afferent sensory neurons (lowered firing threshold, recruitment of otherwise “silent” mechanoreceptors; and increased norepinephrine (NE) content and activity in bladder wall,[47] increased peripheral nerve and CNS excitability[48], enhanced sympathetic efferent neuronal function, upregulation of bladder mucosal Substance P and NK-1 receptors.[49] The result of this cascade represents peripheral and central hypersensitization along with disrupted epithelial excretion of glycosaminoglycan (GAG). Several subtypes of lower urinary tract disease are described in both cats and women, but both species almost always express a Type 1, non-ulcerative form that is considered neuropathic in origin.[50] The complex etiology appears to include early-life (both pre- and postnatal) stressors, presumptively due to a strong sympathetic

response on the developing pituitary-adrenal axis and high plasticity of the developing CNS. Later in life, chronic activation of the central threat response system (CTRS), the condition becomes a clinical entity and can involve other extra-bladder comorbidities in addition to their LUT signs.[51] Fundamentally, FIC and IC appear to represent a neuropathic phenomenon whereby the SNS gets wired into nociceptive pathways.

- Feline herpesvirus[52] - Post-herpetic neuralgia (PHN, Shingles) is an extremely common and painful neuropathic pain condition in humans. Herpes zoster virus infects and damages peripheral nerve endings creating the cascade of sensitization events characteristic of peripheral nerve injury. Viral activation elicits painful erupting skin lesions most often on the back, neck, and face; however, the hyperalgesia and allodynia of PHN can be present without the dermatologic lesions. Cats are infected by a different virus, FHV-1, but it shares similarities including permanency of infection, propensity to re-activation, and dermatoses. These lesions are often mistaken for a variety of other dermatologic conditions including military dermatitis, eosinophilic granuloma complex, pemphigus, dermatophytosis, and squamous cell carcinoma. Biopsy, dermatohistopathology and PCR can correctly identify lesions that are herpetic in origin.[53] Treatment focuses on antiviral therapy and managing secondary bacterial infection. Although the degree of discomfort cannot be known with certainty, it is most likely not minor and analgesic strategies should be considered.

- Feline gingivostomatitis (FGS) - FGS is a common, often severe and refractory disorder of uncertain etiology but thought to involve an immune-mediated response to dental plaque and correlated with a variety of organisms with indeterminate causality.[54] FGS can be exquisitely painful, and it is plausible, if not likely, that peripheral and central sensitization processes are involved (to include an anti-dromic, efferent neurogenic component, contributing to a self-perpetuating viscous cycle of inflammation causing pain, and pain worsening inflammation).

- Osteoarthritis (OA) - Many experimental models demonstrate that OA can be accompanied by peripheral[55] and central[56] sensitization consistent with a neuropathic component. In humans with OA, approximately 25% have a neuropathic component to their pain.[57] A study of cats with *hip* OA identified temporal summation and a lower mechanical threshold in the *feet* of 25% of the patients.[58] This study illustrates two classic features of peripheral and central sensitization: increased tactile sensitivity, and expanded field (distant from the affected site).

- Syringomyelia (Chiari-like Malformation)[59] – a congenital condition especially affecting the Cavalier King Charles Spaniel, the CNS maldevelopment is essentially “punched out” lesions in the spinal cord (especially cervical) and brain, eliciting exquisite neuropathic pain symptoms.

- Inflammatory Bowel Disease (IBD)[60] - The chronic inflammatory state of IBD produces an ongoing afferent barrage of visceral nociceptors producing changes in the dorsal horn of the spinal cord consistent with central sensitization. Furthermore, intestinal high- and low-threshold mechanoreceptors can undergo a phenotypic alteration into nociceptive function, with normal motility eliciting visceral pain. Chronicity may also elicit a neurogenic component to the pathophysiology: neurons begin to carry efferent signals from the dorsal horn back to the intestine, enhancing inflammation. In humans, IBDs are characterized by debilitating painful flare-ups (presumably from cross-innervation with the SNS), and are comorbid with other hyperalgesic syndromes such as Interstitial Cystitis (now more accurately called Urologic Pelvic

Pain syndrome).[61] The extent to which cats and dogs with IBD experience visceral pain, "cramping," and/or hyperalgesia may be difficult to discern.

- Pancreatitis (acute and chronic[62]) - Abdominal pain is a classic feature of acute and chronic pancreatitis in humans; it is less well appreciated in cats. In humans the "neuro-immune" response is especially robust in pancreatitis (and pancreatic cancer) leading to remarkable visceral discomfort. Inflammatory cells and a unique brew of local neurotrophins and neuropeptides active pancreatic afferent nociceptors leading to central changes consistent with hypersensitization and somatic neuropathic pain disorders. Due to the diffuse projections of afferent nociceptors in the spinal cord, pain may not be confined to the upper/cranial right quadrant where the pancreas is located; humans with pancreatitis (and cholecystitis; perhaps similar to feline "triaditis") report pain in the back and even the shoulder. Additionally, as with other inflammatory states, a neurogenic component may additionally contribute to the pathophysiology of pancreatitis.

- Diabetic Neuropathy (DN) - In humans with diabetes mellitus (DM), DN is so common and debilitating that several drugs are labeled specifically for this indication. Reported sensations include walking on glass shards or barbed wire, and spontaneous tingling and itch without evoked stimulus; these signs are also reported in the hands (i.e., "Diabetic Hand and Foot Syndrome"). In cats (less so in dogs, but may be under-appreciated), DM is associated with motor neuropathy and a classic plantigrade stance in the rear legs (less often in the forelimbs) and a posture and gait associated with generalized weakness. However, classic sensory neuropathic changes in peripheral nociceptors and along the entire length to the spinal cord dorsal horn, have been found in cats like those in humans,[63] including endoneural microvascular pathology.[64] This likely accounts for anecdotal observations of diabetic cats and dogs objecting to handling of paws, being held or stroked, and/or objecting increasingly to their insulin injections.

- Gross nerve injury: entrapment, transection - Nerve injury so reliably produces central and peripheral sensitization that ligation of major nerve bundles is a prime neuropathic pain model. One case report describes neuropathic pain in a cat whose sciatic nerve had inadvertently been ligated during rear limb amputation.[65] This patient experienced both hyperalgesia and hypoesthesia (numbness) in different aspects of the surgical region. Any amputation requires severing of major nerves, and in humans, post-amputation neuropathic pain signs occur in a high proportion (45-85%) of patients, medically managed or resolved in most cases but remaining persistent in 5-10% of patients.[66] Manifestations of post-amputation neuropathic pain in dogs and cats may also include persistent tactile sensitivity and constant grooming at the stump site (it is possible that a subset are experiencing dysesthesia – tingling or itch). Cats experiencing chronic lameness months or years post-onychectomy may be experiencing neuropathic pain in their feet.[67] Pathophysiology of post-amputation neuropathic pain, including phantom limb pain, may include micro- or macroscopic neuroma formation, the sprouting of nerve endings at the transaction site into a bundle of hyperexcitable, cross-linking neurons classic of peripheral sensitization. Changes are also detectable in peripheral axons, dorsal root ganglia, spinal cord, and even the cerebral cortex. Similarly, nerve root compression or injury from intervertebral disc disease and/or lumbosacral stenosis are likely confer a neuropathic pain component to these conditions

- Spinal cord injury (SCI) - Damage or compression to the spinal cord is known to create a neuropathic pain component with hyperalgesia and tactile allodynia in a majority of human post-SCI patients. Etiologies in the cat may include blunt force trauma, forced sacrococcygeal tail avulsion, intervertebral disc disease/herniation (IVDD, although much less common in cats, affecting <0.3%, both cervical and thoracolumbar (TL) are reported, with a possible pure-bred breed disposition [Persians, British Shorthairs] in the latter[68]) , lumbosacral stenosis (LSS), neoplasia, congenital malformations, infectious disease, and iatrogenic injury from epidural injection. Radiographic changes suggesting LSS may be more common than clinically relevant, but affected dogs and cats present with signs such as low tail carriage, hyperalgesia of the lumbosacral region and/or upon dorsoflexion of the tail, reluctance to jump and/or ambulate, elimination outside the litter box, pelvic-limb paresis, urinary incontinence, constipation, and in the exam room, raising of tail and taking a rectal temperature.[69] Pudendal nerve entrapment with neuropathic pain is described in humans with LSS, with chronic disabling perineal discomfort (anorectal, urogenital) especially upon sitting or urgency to urinate or defecate; in cats this may be shown as or newly objecting to insertion of a rectal thermometer.[70] Advanced imaging, specifically MRI, is more likely to pick up lesions not apparent radiographically, and the condition may be more common in cats than currently appreciated. The presence of transitional lumbosacral vertebrae is a risk factor for LSS, with affected cats having a 9-fold increased risk of developing the condition over cats without transitional vertebrae (54% vs. 6% in the general population).[71]

- CNS infection and neoplasia - Any disease of cerebral cortex, meninges, or spinal cord involving inflammation, vascular changes, ischemia, or necrosis can potentially induce pain with a neuropathic component. This may include profound headache with migraine-like features. Migraines themselves, whether primary idiopathic or comorbid to another disorder, are essentially a neuropathic pain condition that happens to involve blood vessels in addition to afferent and efferent neurons[72]. Head pressing associated with intra-cranial disease, including brain tumor, may be in part from severe debilitating headache. Infectious agents known to cause encephalitis and/or myelitis in cats include viruses (Feline Infectious Peritonitis (FIP), rabies, Feline Leukemia Virus (FeLV), and Feline Immunodeficiency Virus (FIV)), protozoa (toxoplasmosis), systemic fungi (most commonly *Cryptococcus neoformans)*, and parasites (*Cuterebra* myiasis*)*. Granulomatous Meningoencephalitis, Pug Encephalitis are idiopathic immune-mediated conditions, and Feline nonsuppurative meningoencephalomyelitis and eosinophilic meningoencephalitis (EME) are idiopathic but likely involve an as-yet-unidentified infectious agents.[73],[74]

- Vascular disorders: - Aortic thromboembolism elicits sudden, massive ischemic myopathy and neuropathy and can be considered chief among feline vascular disorders to induce neuropathic pain.[75] Cerebrovascular disease (including “ministroke”) and other vascular ischemic events may be under-appreciated in dogs and cats. Migraine is considered a neuropathic pain disorder (with similar pathophysiology that simply includes a blood vessel involved at the interface between primary and second-order neurons.[76] One case report of suspected migraine treated in a dog appears in the literature.[77]

- Persistent Post-Surgical Pain (PPSP) - PPSP is a significant and well-described neuropathic phenomenon in humans, with up to half of patients developing chronic pain after surgery (even common outpatient procedures), and signs of neuropathic pain present in 35 to 57%. 11.8% of

patients still experienced moderate to severe pain 12 months post-operatively.[78] Veterinary metrics are not available but if PPSP exists in even a fraction of cats and dogs as reported in humans, it would represent a potentially significant unrecognized clinical problem. In humans, the degree of trauma[79] (surgical and otherwise) and the degree of acute postoperative pain[80] are predictive factors for chronic pain with neuropathic components. In humans every 10% increase in the time spent in severe postoperative pain was associated with a 30% increase in chronic pain 12 months after surgery.[80]

- Bone Disease - Trabecular bone and periosteum are richly innervated. Upon fracture, infection, or neoplasia, periosteal and intrinsic mechanosensitive neurons are damaged, followed by massive release of excitatory neuropeptides which activate and sensitize neurons and promote ectopic nerve sprouting (including sympathetic fibers) at the callous. With proper healing these factors return to baseline and pain subsides, but if proper healing does not occur, chronic bone pain results.[81] Complex Regional Pain Syndrome (CRPS) is a poorly understood *sympathomimetic* neuropathic pain syndrome reported as a complication of fracture (and other trauma) in humans and several animal species including a dog.[82] Pelvic fractures are especially prone to severe and chronic maladaptive pain complications.[83] A case series describes idiopathic musculoskeletal pain in 3 dogs.[84] Osteosarcoma and any metastatic cancer to bone elicits neuropathic pain through classic mechanisms but also includes massive central glial hypertrophy, peripheral upregulation of cyclooxygenase, and a unique proalgesic neurochemical signature from osteoclastic activity.[85] The effect of such changes has been detected via QST in canine OSA.[86]

- Allergic inflammation - Allergic inflammation has been established as potential cause of neuropathic pain in mice,[87] and implications for this in dogs and cats (as established in mice) include well-recognized syndromes such as flea allergy dermatitis, atopic and flood allergy dermatitis, possibly eosinophilic granuloma complex, feline asthma, and canine eosinophilic pneumopathy. In the extreme, the phenomenon of "neuropathic itch" is well described in humans and animal models.[88]

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PAIN MANAGEMENT FOR THE LOW-SURGICAL DOSE PATIENTS

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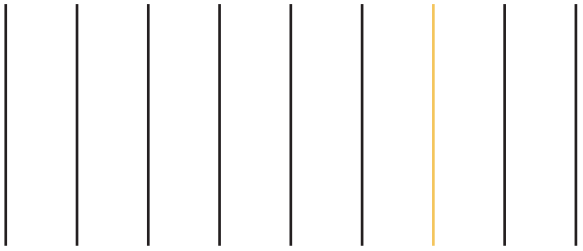

SMALL ANIMAL

Trans Operative Pain Management for The Low-Surgical Dose Patient
Kansas State 2024

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The robust advances in pain management for companion animals underlie the decision of AAHA and AAFP to expand on the information provided in the 2007 AAHA/AAFP Pain Management Guidelines for Dogs and Cats.The 2015 Guidelines can be found at these URL's: (https://www.aaha.org/public_documents/professional/guidelines/2015_aaha_aafp_pain_management_guidelines_for_dogs_and_cats.pdf and http://jfm.sagepub.com/content/17/3/251.full.pdf+html), and the 2022 AAHA Guidelines can be found at 2022 AAHA Pain Management Guidelines for Dogs and Cats

The Guidelines continue the trend in all branches of medicine toward evidence-based consensus statements that address key issues in clinical practice. Although not a review article, the Guidelines represent a force multiplier for the busy practitioner, consolidating in a single place current recommendations and insights from experts in pain management. The recommendations of the guidelines Task Force are evidence based insofar as possible and otherwise represent a consensus of expert opinion. These notes contain the key applied principals for veterinary clinicians.

Devising an evidence-based top-tier trans-operative pain management strategy is within the scope of any practice to achieve. The framework of effective pain management systems rests solidly on the foundation of recognition/assessment, pre-emption, and using multiple modalities. Multiple modalities allow for intervention at several different places of the nociceptive pathway, increasing effectiveness and minimizing the need for high or protracted doses of any one particular drug (including, perhaps especially, opioids), and minimizes the likelihood or severity of peripheral and central sensitization which contributes to maladaptive (exaggerated) pain. Veterinary medicine would do well to emulate a recent trend in human transpoerative care called ERAS – Enhanced Recovery After Surgery,[a] which aims for evidence-based measures to 1. Reduce Surgical stress, 2. Maintain physiologic functions, and 3. Enhance mobilization after Sx; outcomes measured include: 1. Reduced morbidity rates, 2. Faster recovery, 3. Shorter hospital stays. Chief among the strategies to achieve the ERAS goals is to minimize the minimization of opioid use.[1]

The basic construct for low-surgical dose patients is a 4-legged stool:

1. ANXIOLYTICS

Anxiety contributes directly to the hyperalgesic state through cholecystikinin-mediated "nocebo" effect.2 A number of studies in humans support the idea that patients who are highly anxious or stressed pre-operatively experience higher pain scores post-operatively. These observations are also found in many animals studies, where restraint, social defeat, rotation – all things veterinary patients experience in the normal pre-surgical setting in order to draw blood, place catheters, etc. – contribute to hyperalgesia.[3] Thus the first leg of a strong transoperative pain management protocol does not involve the use of analgesics in and of themselves, but anxiolytics and not just pharmacologic ones i.e. low-stress handling techniques,[b] the Fear Free™,[c] experience to include (but not limited to) pheromones and addition to tranquilizers/sedatives such as trazodone (8-10mg/kg) or gabapentin (15 mg/kg) for the owner to administer at home pre-visit. In hospital, clinicians may choose between phenothiazines (e.g. acepromazine), benzodiazepines (midazolam or diazepam), or alpha2 agonists (dex/medetomidine).

2. OPIOIDS

[a] https://erassociety.org/
[b] http://drsophiayin.com/lowstress, http://www.catvets.com/guidelines/practice-guidelines/handling-guidelines
[c] https://fearfreepets.com/

Opioid receptors are distributed ubiquitously throughout the body and can be found in most central and peripheral tissues. Several opioid different receptor types and subtypes have been isolated, each with a variant effect; activation of an opioid receptor inhibits presynaptic release and postsynaptic response to excitatory neurotransmitters. The proposed mechanism includes opioid receptor coupling with the membrane-associated G protein; this leads to decreased intracellular formation of cAMP which diminishes calcium channel phosphorylation (closing off the channel) and opens potassium channels enhancing potassium influx. The resulting effect is hyperpolarization of the neuron and blockade of Substance P release. Nociceptive transmission is thus greatly impeded. Opioids in combination with anxiolytics discussed above can induce a profound sedating neurolopetanalgesic effect to the patient's benefit. However, recent efforts to reduce the frequency, duration, and dosing of full mu agonists (e.g. morphine, hydromorphone, fentanyl) in favor (while still maintaining patient comfort) of partial mu agonists (buprenorphine) and mu-antagonist/kappa agonist (butorphanol) in human medicine are being mirrored in the veterinary profession https://ivapm.org/wp-content/uploads/2018/12/Op-Sparring-Task-Force-WP.pdf.

Different opioid drugs are available which vary in their relative potency and receptor affinity, and a complete discussion of their similarities and differences are available in a number of resources. Full-mu agonists have the most significant analgesic punch, but in low-surgical dose patients it can be argued should be used only short-term (e.g. hydromorphone as a pre-medication). Full mu agonists do not have a ceiling effect which means higher doses can achieve more profound analgesic but with accompanying increases in adverse effects (dysphoria, suppressed appetite and in the extreme constipation, hyperalgesia, and potentially fatal respiratory suppression however uncommon this might be in animals). Recognizing and having strategies for counteracting their signs will minimize the complications that they present.[4]

Buprenorphine is a partial mu agonist so less potent an analgesic than full mu agonists and can be considered suitable for low-surgical dose patients. It has a ceiling effect, meaning higher doses elicit neither additional analgesia nor much more in the way of adverse effect. Buprenorphine does have a higher affinity for the mu receptor than full mu agonists and will displace those molecules if both are present. Buprenorphine also has the unique feature of taking significant time to achieve maximum effect (1 hour IM, 30 min IV); and it is the least sedating of commonly used opioids in veterinary medicine.

Butorphanol is a mu agonist and a kappa antagonist; like buprenorphine it has a ceiling effect. However its short duration of action in the dog (approx. 30-40 min) generally makes it a poor choice for surgical analgesia in this species, although co-administered with alpha-2 agonists (e.g. dexmedtomidine) it will act syngergistically for both pain and sedation and this combination can be appropriate for low-surgical dose procedures.

Tramadol, in contradistinction to humans, does has negligible opioid activity in the dog, but cats have opioid (and serotonin, norepinephrine) metabolites similar to humans.

3. NSAID

The primary mode of action is to inhibit cyclooxygenase 2 (COX2), the enzyme that is expressed at site of inflammation and results in the production of pro-inflammatory and vasoactive prostaglandins. Also, through poorly understood mechanisms, likely by modulating multiple gene expression pathways,5 it may inhibit central perception of pain. Several superior products are now labeled for use in dogs and cats (meloxicam and robenacoxib are metabolized through oxidative rather than glucuronidase pathways), making them among the most popular of pain management medications in veterinary medicine. Pre-operative use of NSAID appears to be safe in healthy dogs (even in the face of modest hypotension; but hypotension should be avoided with the use of IV fluids and careful blood pressure monitoring); robenacoxib is specifically labeled for pre-op use. However it is satisfactory to administer post-operatively should that be the clinician's preference. The adverse event profile however is well-established and results from metabolites of COX1 metabolism (especially in the GI tract), and also PGE2 from COX2 metabolism (especially in the renal tubules) do have normal homeostatic, tissue-protective, and tissue-healing effects. However, the frequency and severity of NSAID ADE can be minimized through well-established means. The GI and renal adverse effects can be expected to occur most commonly in higher

risk patients, e.g.: hypovolemia, hypotension (including anesthetic procedures especially those not supported by intravenous fluids), pre-existing GI or renal disease, overusage, and the inappropriate combination with other NSAID's or corticosteroids. Notable in this last category is client use of aspirin in their pets, which may be unbeknownst to the clinician unless specifically queried in a thorough history (uniquely, this NSAID produces a cyto-protective lipoxin through the COX pathway;[6] thus when COX is inhibited through the use of another, concurrently-given NSAID, the potential for GI toxicity is considerably enhanced). The very rare hepatic issues are idiosyncratic reactions of that dog to that molecule, and can not be prevented or predicted based on liver enzymes (do avoid in liver dysfunction however).

Grapiprant is not COX-inhibiting but rather antagonizes just the EP4-receptor of PGE2 (responsible for activating nociceptors), sparing the EP1, EP2, EP3 subunits largely concerned with normal tissue function and repair. Galliprant™ is labeled for osteoarthritis in dogs, and its use in acute, post-surgical pain remains to be determined (conflicting data as of this writing).

Robenacoxib (Onsior™, Elanco) has been approved for 3 days of post-operative pain relief in cats. It is COX2-selective with the unique feature of having a very short plasma elimination half life of 1.7 hours (compared to meloxicam at approx. 20 hours), yet (because it like all NSAID is highly protein-bound) stays at the site inflammation/effusion for >24 hours. It is presumed that this novel PK profile lends itself to impressive safety data including up to 5 & 10X labeled dose.[7]

4. LOCOREGIONAL ANESTHESIA

Local anesthetics were once a mainstay of pain management in veterinary medicine, and may now be one of the most under-utilized modalities. Administered locally or regionally, they are the only modality that renders complete anesthesia to a site, i.e. no transmission of nociceptive impulses as long as the drug exerts its effect. Initially used as a means of desensitizing tissues in order to "invade" tissues with scalpels; local anesthetics are enjoying a rebirth as powerful tools to prevent or reduce perioperative pain (as well as procedural and even chronic pain) and to reduce general anesthetic and concurrent analgesic (especially systemic opioid) requirements. There is no longer a reason to hold an "either-or" position; "for surgery either I use local anesthetics *or* I use general anesthesia", in fact, there are many reasons to combine general and local anesthetic for surgical pain relief.[8] Simple techniques for the low-surgical dose patients include: topical/dermal/epidermal local anesthetics for IV catheter placement (e.g. EMLA®, LMX4®, or their generic equivalents), incisional line blocks, field blocks for lumpectomies or laceration repairs, intra-abdominal (peritoneal) blocks before laparotomy closure, orofacial blocks for extractions and mesovarium and intra-testicular blocks for spay and neuter respectively, are well described in the literature.

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PAIN MANAGEMENT FOR THE HIGH-SURGICAL DOSE PATIENTS

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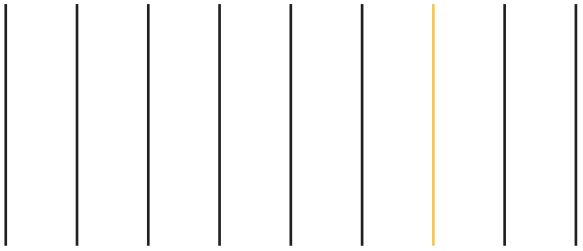

SMALL ANIMAL

Trans Operative Pain Management for The High-Surgical Dose Patient
Kansas State Univ 2024

Mark E. Epstein, DVM, Dipl. ABVP (C/F), CVPP
TotalBond Veterinary Hospitals, PC
Gastonia, Charlotte NC, Lake Wylie SC

Industry Pain Management Guidelines include:
2014 & 2022 WSAVA Global Pain Council: https://wsava.org/Global-Guidelines/Global-Pain-Council-Guidelines/
2015 & 2022 AAHA

- https://www.aaha.org/public_documents/professional/guidelines/2015_aaha_aafp_pain_management_guidelines_for_dogs_and_cats.pdf
- https://www.aaha.org/aaha-guidelines/2022-aaha-pain-management-guidelines-for-dogs-and-cats/home/

The Guidelines continue the trend in all branches of medicine toward evidence-based consensus statements that address key issues in clinical practice, and represent a force multiplier for the busy practitioner, consolidating in a single place current recommendations and insights from experts in pain management. The recommendations of the guidelines Task Force are evidence based insofar as possible and otherwise represent a consensus of expert opinion. These notes contain the key applied principals for veterinary clinicians.

Devising an evidence-based top-tier trans-operative pain management strategy is within the scope of any practice to achieve. The framework of effective pain management systems rests solidly on the foundation of recognition/assessment, pre-emption, and using multiple modalities. Multiple modalities allow for intervention at several different places of the nociceptive pathway, increasing effectiveness and minimizing the need for high or protracted doses of any one particular drug (including, perhaps especially, opioids), and minimizes the likelihood or severity of peripheral and central sensitization which contributes to maladaptive (exaggerated) pain. Veterinary medicine would do well to emulate a recent trend in human transpoerative care called ERAS – Enhanced Recovery After Surgery,[a] which aims for evidence-based measures to 1. Reduce Surgical stress, 2. Maintain physiologic functions, and 3. Enhance mobilization after Sx; outcomes measured include: 1. Reduced morbidity rates, 2. Faster recovery, 3. Shorter hospital stays. Chief among the strategies to achieve the ERAS goals is to minimize the minimization of opioid use.[1]

The basic construct is a 4-legged stool even for Low-Surgical Dose Patients (covered in that session) include

- **ANXIOLYTICS** (pharmacologic, non-pharmacologic)
- **OPIOIDS** (short action, duration)
- **NSAID**
- **LOCOREGIONAL ANESTHESIA**

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High-Surgical Dose Patients can be defined as those undergoing procedures with existing evidence of, or significant risk factors for, hypersensitization, i.e. for post-surgical pain that includes pain exaggerated in scope, severity, duration, character, and field. This maladaptive pain experience can be said to be “Pain with a Neuropathic Component” and contribute significant to patient morbidity, delayed recovery, and in the extreme with patients on the edge, post-op mortality.

Patients with or at risk for maladaptive pain processing include but are not limited to those with:

1. Significant tissue trauma (orthopedic or soft-tissue; pre-existing, surgical, or both)
2. Pre-existing chronic inflammation
3. Nerve injury (pre-existing, surgical i.e. amputation, or both)

[a] https://erassociety.org/

4. Any pre-existing chronic pain syndrome or having risk factors for peripheral neuropathy e.g. diabetes mellitus, vinca alkaloid chemotherapy

Such High Surgical Dose Patients require the same components, albeit somewhat amended, as Low Surgical Dose Patients, but also several more i.e. a 5-, 6-, sometimes 7- or 8-legged stool. These interventions may include one or more of the following:

Alpha-2 agonist: Medetomidine and dexmedetomidine binds opioid-like receptors on C- and A-delta fibers, especially in the central nervous system. Binding pre-synaptically, NE production is reduced and sedation occurs; binding post-synaptically, analgesia is produced, and is profoundly synergistic with opioids. It also blocks NE receptors on blood vessels, resulting in vasoconstriction; the resulting hypertension parasympathetically induces bradycardia, which is extended by a subsequent direct decrease in sympathetic tone. However, central perfusion is maintained and the author has found a wide use for these alpha-2 agonists in acute and peri-operative setting, though only in combination with opioids and at doses much lower than suggested by the manufacturer. One particularly novel and user-friendly utility is IV micro-doses intra- and post-operatively, 0.25 – 1.0 mcg/kg. This may result in intravenous volumes of only 0.01 – 0.03 ml in even the largest of dogs. Alpha-2 agonists can be administered safely in appropriate patients at a Constant Rate Infusion of 1.0 mcg/kg/hr (1.0 ml = 0.5 mg)/L administered at maintenance rate of 2 ml/kg/hr.[2]

Zenalpha® is a new product that combines medetomidine + the peripheral alpha-2 antagonist vatinoxan. The product is labeled for IM sedation as a solo agent in dogs only, and attenuates medetomidine's peripheral vasoconstriction which in turn attenuates the rise in peripheral vascular resistance, reflex bradycardia and drop in cardiac output. Extralabel usage over lower doses in combination with opioids, and administered intraveneously, have been explored but ideal dosing has not been determined. It appears that atipamezole can be safely administered to further reverse the effects of Zenalpha® (but unlike the vatinoxan it includes, will also reverse the central (sedation, analgesic) effects as well.[3]

Sub-anesthetic Ketamine CRI: A phencyclidine dissociative anesthetic, the evidence is building for its pre-emptive and preventive effects when given at subanesthetic doses in an intravenous constant rate infusion. Ketamine binds to a phencyclidine receptor inside the NMDA receptor, i.e. the calcium channel would already have to be open and active for ketamine to exert its effect. However, once bound, it decreases the channel's opening time and frequency, thus reducing Ca+ ion influx and dampening secondary intracellular signaling cascades. Hence it is unlikely (and has not been shown) to be truly analgesic in nature. Rather, it appears to be protective against hyperalgesia and central hypersensitization in the post-operative setting,4 including in the dog.5 Ideal sub-anesthetic ketamine plasma concentrations – eliciting the most benefit with the least adverse effect – has been reported at 2-3 mcg/ml, which can be achieved by administering ketamine IV CRI at 10 mcg/kg/min.[6] This can be accomplished by placing 60 mg (0.6 ml of 100 mg/ml stock) ketamine in 1 L of fluids and administered at customary intra-operative rates of 10 ml/kg/hr. Post-operatively, the rate can be reduced to customary maintenance rates of 2 ml/kg/hr, which administers the ketamine CRI at 2 mcg/kg/min. A loading dose of 0.25 – 0.5 mg/kg ketamine IV is recommended prior to the initiation of the CRI in order to rapidly achieve plasma levels (can be achieved through ketamine itself, a "ketofol" mixture with reduced doses of propofol, ketamine/valium or Telazol™ induction). Human consensus guidelines advise that sub-anesthetic ketamine CRI should be deployed in patients undergoing more painful procedures, guidance that can be extrapolated to both dogs and cats; additionally clinicians should consider utilizing this modality in patients with pre-existing chronic inflammation and known or suspected nerve injury.

Lidocaine CRI: The mechanisms behind a pain-modifying effect of systemic lidocaine remain an area of investigation but appear to include its ability to enter the nociceptor cell body in the dorsal root ganglion. In humans the evidence is strong for safety and the beneficial effects of intravenous lidocaine (IVL) on pain after abdominal surgery in humans (especially for the 1st 24 hours, and less so for other surgeries eliciting somatic pain)[7],[8],[9],[10] and possibly horses, including both pain and return of bowel function. Systemic, intravenous infusion of lidocaine has also been shown to elicit a sustained effect on neuropathic pain in humans.[11] Several systemic lidocaine CRI protocols are described, some combined with other pain-modifying agents. A customary one is described[12]: 300 mg lidocaine 2% (15 ml) is placed in a liter of

crystalloids, and administered at a surgical rate of 5-10 ml/kg/hr, delivering 25-50 mcg/kg/min. Post-operatively the rate may be reduced to maintenance rate of 2 ml/kg/hr, delivering 10 mcg/kg/min. Note: for accurate dosing, 15 ml of the crystalloid should be removed prior to the addition of the lidocaine. Lidocaine should be used with caution in hypovolemic states, and is advised for use in dogs only.

NSAID: Special Considerations.
Suppressing COX enzymes suppresses production of PGE2 and its pro-nociceptive, pro-inflammatory properties, but this molecule also promotes tissue healing through vasodilation and other means.

Fracture repair: Rodent and canine models reveal that NSAIDs elicit a time- and dose-dependent delay in fracture healing.[13] However the effect is reversible upon withdrawal of NSAID[14] and a human Meta-analysis (and FDA FOI data for veterinary-approved NSAIDs) do not support a clinically-relevant affect of delayed- or non-union fracture repair with judicious use of NSAIDs. It is generally considered not only safe, but appropriate to use NSAIDs post-fracture repair (including TPLO), but for a time period of days to weeks rather than months. One canine study showed no difference in radiographic healing between dogs without carprofen and those with 2-week administration of carprofen.[15]

GI surgery: data in humans undergoing intestinal resection/anastomosis reveal a higher rate of leakage from the anastomotic site in cohorts receiving NSAID than those that do not.[16] There is not a clear consensus in veterinary medicine about NSAIDs use post-GI surgery is appropriate in dogs and cats. The author supports the use of NSAIDs in GI surgery as long as the bowel is healthy and patient not otherwise compromised, for the 1st 24-48 hours post-op.

Opioid: Use of extended-duration formulations:
In cats, Simbadol™ (Zoetis) is a 1.8 mg/ml buprenorpine FDA-approved product labeled for 24 hours of post-surgical analgesia in cats labeled for use at 0.24 mg/kg SC; the author utilizes a reduced dose of 0.12 mg/kg to minimize the modest adverse effects of lethargy and diminished appetite (and supported by more recent PK data although with wider range variability than the labeled dose[17]). One recent study in dogs found the off-label use of Simbadol™ in this species at 0.02 mg/kg to be non-inferior to a 0.3 mg/ml product administered SC.[18]

Newer on the market just in 2022 is Zorbium™ (Elanco), a transdermal buprenorphine product for cats. Placed on the skin between the shoulder blades, the product enters into the stratum corneum of the skin, resides there and slowly releases into systemic circulation from there providing 4 days of post-operative analgesia.

Enhanced-duration local anesthetic: Liposome-Encapsulated Bupivacaine
In 2016, an extended-release, LE-encapsulated bupivacaine product was FDA-approved for dogs undergoing stifle surgery (Nocita™, Aratana, since purchased by Elanco), eliciting 3-days of analgesic effect; in 2018 the label was extended to nerve block for digit surgery (onychectomy) in cats. The product has been available for several years in humans under the trade name Experel™. As the liposomes degrade, bupivacaine is released into the surrounding tissue, rendering its local anesthetic effect. The product itself is viscous and does not readily diffuse, therefore the label calls for utilizing an “advancing needle” technique whereby the product is deposited by repeat injections into the affected tissue, at each layer upon closure. A number of extralabel uses have been described. A post-launch study revealed that post-breach, the product has 4 days of stability and 5 days of sterility.[19]

Maropitant (Cerenia®) is a central antiemetic through blockade of Substance-P to the NK-1 receptor, which is also involved in pain processing especially involving central sensitization. The true pain-modifying effect in dogs remains uncertain. A 2020 Systematic Review of its use in dogs and cats revealed that the available evidence supports that it significantly reduces the minimum alveolar concentrations for gas anesthetic for many different surgical procedures, but that it had no clearly proven effect on inflammation and pain.[20] However, these were almost exclusively on ovariohysterectomy models which would generally not be expected to elicit central sensitization. Indeed one study in a population of dogs with risk factors for hypersensitization (undergoing large soft tissue resection i.e. mastectomies), coadministration of maropitantI V (bolus followed by CRI) maropitant with ketamine and lidocaine CRIs had an adjuvant effect with minimal cardiorespiratory effects and effective analgesia,

improving pain management and patient comfort.[21] Maropitant performed poorly in development as pain-modifying agent in humans and was withdrawn as a study target. However the prospect remains it may provide benefit in a subset of patients (e.g. for visceral pain, with central sensitization) or with improved delivery systems (e.g. in a nanoparticle formulation).[22]

Adjunctive drugs:

Tramadol: In humans, tramadol is described as a synthetic opioid with 1/100th of the affinity for the mu receptor as morphine but a much better analgesic effect than this would predict. This is likely due to the combined effect of a highly active M1 metabolite and serotonin- and norepinephrine (inhibitory neurotransmitters) agonism. However, recent work demonstrates that it appears to have a very short half-life (1.7 hours) in the dog,[23] and it appears that dogs produce very little of the M1 opioid metabolite.[24] The unfavorable PK profile of oral tramadol in dogs, and in a Systematic Review and Meta-Analysis the lack of evidence to support a post-surgical pain-modifying effect[25] should lend skepticism about its use as an analgesic in this species. Cats do make the M1 metabolite in similar quantities and PK as humans,[26] and there are data to support its use for post-surgical pain in this species[27]. Its bitter taste may limit its use in cats, but there are case reports and anecdotes of finding palatable versions in beef and marshmallow flavoring.

Gabapentin is labeled for use as an anti-convulsant drug but is in widespread human use for its analgesic properties. While structurally similar to GABA, it is not a direct agonist, although it may have indirect effects on GABA metabolism such as increasing intracellular stores. Another leading hypothesis is that it exerts effect through interaction with the alpha-2-delta subunit of the voltage gated calcium channel.[28] Its utility in chronic, neuropathic pain states is well-established in humans,[29] but more recently its utility in the transoperative setting is supported by a number of systematic reviews.[30],[31],[32],[33],[34],[35] Pharmacokinetic studies in dogs reveal that it may have a half-life of 3-4 hours in the dog[36], suggesting a TID administration schedule. Based on experience in humans, pre-operative doses are recommended in the 10-15mg/kg mg/kg range and post-op 7-10 mg/kg[37]. The primary adverse effect in dogs appears to be somnolescence (as in humans) which usually will spontaneously resolve over a few days acclimation time, but this AE not been a frequent occurrence in the author's experience.

Acetaminophen (paracetamol, APAP) has an unidentified certain mechanism of action although may be predominantly by inhibiting a variant of COX1 in the brain, and bind to cannabinoid receptors. Although anecdotes and older studies may imply a pain-modifying effect, newer studies demonstrate that in the dog, oral (or suppository) APAP does not achieve serum levels generally associated with a pain-modifying effect.[38] However, acceptance of acetaminophen's safety and potential analgesic and anti-pyretic in dogs effect appears to be growing.[39] The clinical benefit of administering a combined acetaminophen + oral opioid in dogs appears to be mixed at best with treatment failures high post-TPLO utilizing APAP+ hydrocodone,[40] and an inferior effect of APAP + codeine to standard NSAD in an model of acute inflammation.[41] This is likely due at least in part to the large first pass effect oral opioid in dogs compared to humans (therefore limiting its bioavailability).
Note that prescribing oral opioid in any formulation puts these tablets into the public sphere, at risk for diversion and thus contributing to the opioid epidemic.

Non-pharmacologic interventions:

Cold-compression: Long known for its pain-modifying effect in humans, recent studies affirm a similar effect in dogs.[42],[43]

Therapeutic Laser: Two studies demonstrate a positive pain-modifying effect pre[44]- and post[45]-operatively, with one not improving better than placebo.[46]

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INTRODUCTION TO THE USE OF SGLT2 INHIBITORS IN CATS WITH DIABETES

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SMALL ANIMAL

Introduction to the use of SGLT2 Inhibitors in Cats with Diabetes

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SGLT2 inhibitors are new drugs used to treat hyperglycemia due to diabetes mellitus. Two veterinary products have been recently approved for use in diabetic cats. SGLT2 inhibitors are promising new tools for effective management of feline diabetes. The current label indication for these drugs allows use in newly diagnosed diabetic cats that have not previously received insulin.

The sodium glucose co-transporter (SGLT) proteins family is widely expressed in tissues. These proteins transport sodium and glucose across cell membranes and serve as a cellular uptake mechanism for these substances. Two SGLT proteins, SGLT-1 and SGLT-2, expressed in intestine and renal tubules, have special relevance for glucose homeostasis in health and disease.[1] The intestinal brush border cells express SGLT-1 but not SGLT-2, while the renal proximal tubules express both SGLT-1 and SGLT-2, where both exert important functions. Within the proximal renal tubules, SGLT-2 is expressed exclusively on the apical membrane of epithelial cells lining the S1 and S2 segments while SGLT-1 is expressed only along the S3 segment. Both SGLT-1 and SGLT-2 have similar molecular actions: sodium and glucose in the luminal fluid bind to the SGLT protein located on the epithelial membrane and are co-transported across the membrane and released into the intracellular compartment.

The kidney has an important role in maintaining glucose homeostasis in health but may contribute to persistent hyperglycemia in diabetic individuals. Glucose is freely filtered at the renal glomerulus and is present in high concentration in the glomerular filtrate. In healthy individuals, re-uptake of the filtered glucose load is essentially 100% and effective glucose uptake requires SGLT activity. SGLT-2 activity accounts for 90% of glucose uptake from urine with the remaining uptake mediated by SGLT-1 activity. The importance of SGLT-2 for normal renal glucose handling is illustrated by familial renal glucosuria, a benign condition characterized by persistent and marked glucosuria, that is caused by genetic mutations that inactivate SGLT-2. The activity of SGLTs (primarily SGLT-2) establishes the renal 'threshold' for glucose. In diabetic individuals, hyperglycemia develops when insulin needs are not met and blood glucose may exceed the renal capacity for glucose absorption. When the physiologic threshold is exceeded (i.e. the filtered glucose load exceeds maximal SGLT activity) glucosuria results.

SGLT inhibitors are a family of drugs derived from phlorizin, a non-selective blocker of SGLT-1 and SGLT-2, that interferes with intestinal glucose uptake and produces glucosuria. Newer drugs, such as canagliflozin, dapagliflozin, empagliflozin, ertugliflozin, and bexagliflozin are highly selective SGLT-2 inhibitors (SGLT-2i) and allow renal glucose handling to be specifically targeted. In diabetics, SGLT-2 inhibitors improve blood glucose and other measures of glycemia and are associated with a very low risk for hypoglycemia. Improved renal and cardiovascular outcomes in patients receiving SGLT-2 inhibitors have expanded the clinical indications for

these drugs.[1] Two SGLT2 inhibitors, bexagliflozin (Bexacat®) and velagliflozin (Senvelgo®. recently received FDA approval for veterinary use in cats as a treatment for newly diagnosed diabetes mellitus. Like other modern SGLT2i drugs, these veterinary SGLT2 inhibitors selectively produce renal glucosuria with minimal SGLT1-mediated gastrointestinal effects.

Initial experience with SGLT2 inhibitors for feline diabetes treatment has been very positive. Several US clinical studies have been reported on recently. [2,3] The SENSATION study included over 250 cats with naturally-occurring diabetes treated for 6 months using velagliflozin as the sole medical therapy (no concurrent insulin was given). The study examined the effect of treatment on relevant clinical and glycemic endpoints, such as improvement, respectively, in diabetes-associate clinical signs and laboratory parameters (fructosamine and mean blood glucose). [3] Velagliflozin treatment successfully lowered blood glucose and reduced clinical signs caused by diabetes in nearly 90% of study cats. The most serious adverse effect associated with velagliflozin use was EDKA[3]. EDKA is similar to the more familiar ketoacidosis of diabetes except the blood glucose is less than 250 mg/dl and may often be near or within the reference range[4,5]. EDKA treatment is identical to that for DKA with one exception. Along with administration of short-acting insulin to inhibit ketone formation, it is necessary to supplement glucose to prevent development of hypoglycemia during insulin treatment. EDKA, like DKA, develops when there is insulin deficiency. For this reason, a cat that develops EDKA while receiving an SGLT2i drug should be immediately taken off the drug and the drug permanently discontinued. After appropriate supportive care to resolve EDKA, the cat should be transitioned to a long-acting insulin and managed as an insulin-treated diabetic.

Overview of SGLT2 inhibitor use in diabetic cats

Indication and patient selection – SGLT2 inhibitors are labeled for once-daily use in diabetic cats that have not been treated with insulin. Contraindications include diabetic cats that have been previously treated with insulin, that have substantial systemic illness (vomiting, diarrhea, dehydration, concurrent morbidities), that have diabetic ketoacidosis (DKA) or signs consistent with DKA should not receive an SGLT2 inhibitor.

Formulations and dose information – Senvelgo (velagliflozin) is an flavored oral solution (15 mg/ml) and is dosed at 1 mg/kg given once daily. Bexacat (bexagliflozin) is a flavored tablet (15 mg) and is dosed at 15 mg (1 tablet) given once daily.

Monitoring – SGLT2 inhibitors are very effective for controlling glycemia in treated patients, so traditional monitoring used for diabetic cats may not provide helpful information. For example, data from bexagliflozin and velagliflozin studies suggests that glucose curves are not helpful for monitoring. Likewise, tests such as fructosamine or hemoglobin A1c, that reflect average glucose concentrations over time are less helpful in SGLT2 treated cats. Ketone monitoring is important since DKA/EDKA is the most serious diabetic complication that develops during SGLT2 use. Recommendations for ketone monitoring vary but regardless of the method used (blood ketometer or urine ketone dipstick) or testing protocol (frequency of testing, at-home vs clinic testing, etc) the goal is to detect significant ketosis as soon as possible to prevent onset of

clinical DKA/EDKA. Ketone testing prior to starting an SGLT2 inhibitor and follow-up testing after several days on the drug is important. Frequent monitoring of overall health, body weight, and ketones is important for the first several weeks after starting an SGLT2 inhibitor. In clinical trials, DKA/EDKA occurred most frequently in the 2 weeks following the initial dose of drug, although DKA/EDKA may occur at anytime during treatment. Like an insulin-treated diabetic, any cat receiving an SGLT2 inhibitor that becomes ill, cannot take oral medication should consult with or be evaluated by a veterinarian.

Summary

Velagliflozin and other SGLT2 inhibitors represent the first significant addition to the feline diabetes toolbox since veterinarians began using insulin to treat the condition decades ago. The introduction of SGLT2 inhibitors to the feline diabetes arena has ushered in exciting days. As we accrue valuable clinical experience with these drugs, we expect to gain additional insights into the biology and management of feline diabetes and envision new applications for these drugs in renal and cardiovascular in our veterinary patients.

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TRANSFUSION MEDICINE: PREPARING PRODUCT & TESTING FOR ADMINISTRATION

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Transfusion medicine: Preparing product and testing for administration

2024 86th Annual Kansas State College of Veterinary Medicine Conference

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Objectives

1. Attendees will be able to describe what some options are for in clinic blood collection of small animals
2. Attendees will be able to justify the use of various blood product selection depending on the disease that is being treated
3. Attendees will be able to develop a transfusion plan including pre-testing, product volumes and monitoring for reactions

Transfusions can be a lifesaving treatment in emergency medicine. However, if done infrequently it can be a daunting task. There are many factors that you must consider when doing a transfusion including acquisition of the product, what product to give, pre-transfusion testing, monitoring during transfusion and identifying transfusion reactions.

While blood products can be purchased, it might not make financial sense to keep blood product on hand due to frequency you administer transfusion. However, often when blood products are needed, they are needed quickly and the patient cannot wait until the product can arrive (depending on your geographical location.

Collection can be done in house through volunteer (clients and the donor) who are ideally screened appropriately. Screening may vary depending on geographical location but recommend you follow the ACVIM consensus statement (Wardrop et al., 2016).

Dog anticoagulant collection reference (non-leukoreduced):

Anticoagulant	Ratio	Additive solution	PRBC shelf life	Whole blood shelf life
CPD	1ml : 7 ml blood	SAGM	42 days	
CPD	1ml : 7 ml blood	AS-1 or AS-5	35 days	
CP2D	1ml : 7 ml blood	AS-3	35 days	
CPDA-1	1ml : 7 ml blood			28 days
CPD	1ml : 7 ml blood			21 days
ACD	1 ml: 7-9 ml blood			21 days
Heparin	5-12.5 U/ml blood			Immediate

Modified from Manual of Veterinary Transfusion and blood banking

Sometimes, the donors require sedation. The use of trazodone and/or gabapentin is fine to use. I generally follow the Canadian Blood Bank for what humans can be on and extrapolate to animals for medications (https://www.blood.ca/en/blood/am-i-eligible-donate-blood/abcs-eligibility#medication). Also see the Red Cross list (https://www.redcrossblood.org/faq.html#eligibility-medications). In general we want them to be overall healthy but there are some medications that are ok. Sometimes dogs need some

butorphanol to lay still for the sedation but ideally the dogs are happy to lay on their sides for the donation.

Cats often need sedation. Again the use of gabapentin is fine to decrease the stress. There are a variety of sedation protocols that have been deemed safe in cats with donation including

- 2 mg/kg alfaxalone + 0.2 mg/kg butorphanol IM
- 2 mg/kg alfaxalone + 0.2 mg/kg butorphanol + 0.2 mg/kg midazolam
- 2-5 mg/kg ketamine + 0.2 mg/kg midazolam IM

See (Taylor S, Spada E, Callan MB, et al. 2021 ISFM Consensus Guidelines on the Collection and Administration of Blood and Blood Products in Cats. Journal of Feline Medicine and Surgery. 2021;23(5):410-432. doi:10.1177/1098612X211007071) for more information.

Component therapy is the separation of whole blood before storage. This is now commonplace in human medicine and very common in veterinary medicine. Whole blood can be separated into several components including plasma, packed red blood cells, cryoprecipitate and platelets to name a few. These can also be further classified depending on the way the product is handled. Component therapy allows us to give the constituents that the patient needs. Below is a chart that includes various blood products, what is in it and how it is stored.

Table 1: Blood products, content and storage

	Content	**Storage conditions**
Fresh whole blood		Room temperature for up to 8 hours
Stored whole blood	Lacking in viable platelets and labile factors (5 and 8)	Refrigerated at 1-6ºC for up to 28 days (pending preservative)
Packed red blood cells	Contains RBC, WBC, non-viable platelets, and small amount of plasma	Refrigerated at 1-6ºC for up to 42 days (pending preservative)
Fresh frozen plasma	All coagulation factors, albumin, globulin	Frozen at ≤–18 ∘C for up to 12 months
Frozen plasma	All coagulation factors (lower concentrations of factor 5, 8 and vWF), albumin, globulin	Frozen at ≤–18 ∘C for up to 5 years
Liquid plasma	All coagulation factors, albumin, globulin	Refrigerated at 1–6 ∘C for up to 14 days
Cryoprecipitate	Factors 8, 13, vWF, fibrinogen and fibronectin	Frozen at≤–18 ∘C for up to 12 months
Lyophilized cryoprecipitate	Factors 8, 13, vWF, fibrinogen and fibronectin	Refrigerated at 1–6 ∘C for up to 18 months
Platelet rich plasma	Platelets, all coagulation factors, albumin, globulin	Room temperature storage under constant gentle agitation for up to 5 days

Platelet concentrate	Platelets, low volume of fresh plasma	Room temperature storage under constant gentle agitation for up to 5 days
DMSO preserved frozen platelet concentrate	Platelets, small volume of plasma, 6% dimethyl sulfoxide	Frozen at≤–18 ∘C for up to 6 months
Lyophilized platelets		Refrigerated at 1–6 ∘C for up to 24 months

Modified from Walker, J. (2016) Component therapy, In Manual of Veterinary Transfusion medicine and blood banking (ed. M. Holowaychuk, K. Yagi) John Wiley & Soms, Inc., Ames, Iowa

Once you determine which product is needed, it is important to know which testing is required before giving the transfusion. Dogs have a universal donor which is DEA 1 negative. Because of this, if you have a canine recipient who is receiving blood and you only stock or have access to DEA 1 negative blood, no testing is required. If you have access to positive and negative blood, the recipient should be blood typed first. No testing is required before giving a plasma transfusion to dogs.

Cats do not have a universal donor. Cats must be typed before receiving ANY blood product (red blood cells or plasma). It is controversial in the literature whether cats should be cross matched before receiving their first transfusion however the one prospective study suggests that it doesn't make a difference. Current recommendations are recommending cross matching.

Cross matches should be performed if the recipient has received a red blood cell transfusion greater than 4 days earlier; if you are within that window from their first transfusion, you do not need to crossmatch. Cross matching should also be considered if the patient is within that window but has had evidence of a reaction on a previous transfusion or if the transfusion history is unknown (a rescue dog). Pregnancy does not appear to cause the formation of alloantibodies.

For more information on cross matching look at (Davidow et al., 2021) and associated open access articles

There have been a variety of calculations that have been used in the past to estimate the amount of blood product to give. Generally you want to increase the PCV by ~10% but this can vary depending on the case. The current recommendations are:

Whole blood: 2 ml/kg to increase the PCV by 1%

Packed red blood cells: 1.5 ml/kg to increase the PCV by 1%

Plasma: 10-20 ml/kg to start

Note: in a study done with cat transfusions, no calculation appeared to work well. Generally an adult cat will get 1 unit (60 ml depending on who is providing the product)(Davidow et al., 2021) *and then reassess to see if more is needed (author's opinion).*

Generally when giving a transfusion we start at a slow rate and slowly increase the rate over the first hour to our maximum rate. The maximum rate is then continued over the next 3 hours to get the blood product into the patient in under 4 hours. The author generally starts at 0.5-1 ml/kg/hr for the starting rate. To determine the final rate the author divides the total volume by 3 hours, as not much product is being delivered over the first hour. During the first hour the rate is slowly increased to get from the starting rate to the maximum rate.

Transfusion reactions can be divided into immunologic and non-immunologic reactions. Non-immunologic reactions can include hypothermia, hypocalcemia (citrate toxicity), sepsis, transfusion associated circulatory overload and embolism. Immunologic reactions can include hemolysis, nonhemolytic febrile reaction, an acute hypersensitivity reaction and transfusion related acute lung injury. Monitoring the patient during the transfusion can lead to early detection of these reactions so they can be addressed quickly. There is no consensus for the ideal monitoring however the author recommends checking temperature, pulse and respiration every 15 minutes for the first hour then hourly during the transfusion. The recipient should also be monitored for facial swelling, tachypnea, vomiting and hives. If there are any concerns for a reaction, the transfusion should first be stopped and the patient should be assessed. For some of the reactions, the transfusion rate is just slowed, however some require treatment. Remember that an acute type one allergic reaction (urticaria, angioedema) is the only IgE mediated reaction and is the only one that will respond to diphenhydramine. Other transfusion reactions require that we treat the symptoms that are seen. For example, if the patient has citrate toxicity from having multiple transfusions and are hypocalcemic, they should receive a 10% calcium bolus over 10-20 minutes IV while monitoring an ECG and possibly a CRI. If the patient has evidence of transfusion associated circulatory overload, the transfusion should be discontinued, and they should be given oxygen therapy and possibly furosemide depending on other comorbidities.

The use of component therapy decreases the amount of antigen that we are giving to the recipient and in theory decreases the risk of a transfusion reaction. Understanding what the recipient needs can help guide the product that you chose to give the patient. Once you know the component, the pretesting can be determined and volume to be administered can be easily calculated. Being familiar with the various reactions can help you monitor for them and intervene if needed.

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A LITTLE SWEET, A LITTLE SOUR: APPROACH TO DIABETIC KETOACIDOSIS

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A little sweet, a little sour: Diabetic Ketoacidosis Management

2024 86th Annual Kansas State College of Veterinary Medicine Conference

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Objectives

1. Attendees will be able to list predisposing causes for DKA
2. Attendees will be able to discuss the benefits and limitations of diagnostic tests to recommend to clients.
3. Attendees will be able to develop a treatment plan for DKA including electrolyte monitoring and management and insulin protocols.

Diabetic ketoacidosis should be considered as a differential in any sick patient with a pre-existing diagnosis of diabetes. DKA is also diagnosed in a lot of patients at the time of diagnosis of their diabetes mellitus and quick bed side testing of emergency cases that include a BG can help assist in this.

An important thing to remember in the treatment of patients of DKA, is that not only does the DKA need to be managed but ideally a work up is performed for an underlying cause for the DKA. Some listed causes for pushing a dog or cat with controlled DM into a DKA crisis include:

Dogs	Cats
• Pancreatitis • Cushings • Neoplasia • UTI/pyelonephritis • Hypothyroid • Pneumonia	• Hepatic lipidosis • Cholangiohepatitis • UTI/pyelonephritis • Neoplasia • Pancreatitis

*Note your physical exam may also assist in narrowing down these options

Some specific tests to consider when working up a sick diabetic include:

1. Measurement of Ketones
    a. Urine dipstick
        i. Both serum/plasma or urine can be used
            1. Serum/plasma is more sensitive
        ii. Is most sensitive to measuring **acetoacetate** (less so acetate and doesn't measure Beta Hydroxybutyrate) (Gal & Odunayo, 2023)
    b. Ketometer
        i. Uses whole blood
        ii. Measures **Beta hydroxybutyrate**
            1. Dogs > 3.5 mmol/L (unlikely if < 2.8 mmol/L)
            2. Cats > 2.55 mmol/L
2. Measurement of Acid/base
    a. Evaluation of pH on a blood gas/istat

   b. Evaluation of HCO3- or bicarb
3. Additional tests pending the differentials on the list
   a. CBC/CHEM/UA/URINE CULTURE
   b. Abdominal ultrasound
   c. Chest radiographs

Usually the most important initial treatments for patients in DKA is fluid therapy and correction of electrolytes. While insulin is important, it is not an emergency to start it. Ensuring that the patient is hemodynamically stable should be done first. If the patient is believed to be hypovolemic on PE assessment- fluid boluses should be initiated. This is generally done with a balanced, buffered, isotonic, replacement crystalloid (Plasmalyte, Norm-R, LRS etc). The total shock dose in dogs is 90 ml/kg and the total shock dose in a cat is 60 ml/kg. Shock boluses are typically administered in ¼ shock alliquots (20 ml/kg in dog, 15 ml/kg in cat over 10-15 minutes) unless reason to give less or slower- murmur, history of heart disease for example.

The three main electrolytes that we consider and need to address are:

1. Potassium
   a. Usually the body is deplete of potassium but due to shifting in acidosis, this may not be reflected in the bloodwork (remember potassium is predominantly located inside of the cell) – but monitor closely for it because **once the pH is corrected and the insulin is started it may drop quickly**. I personally prefer a chart similar to the one on the right where the rate is considered rather than choosing the amount to add based on mEq/L because that doesn't take the fluid rate into account. (see below for the equation to use and an example)
   b. Note shouldn't exceed 80 mEq/L in a peripheral vessel

Scott's sliding scale → helpful in a hurry
but not as accurate as it doesn't take fluid rate into account

K concentration (mmol/L)	Potassium supplementation (mEq/ L)
<2	80
2-2.4	60
2.5-2.9	40
3-3.4	30
3.5-5	20

K concentration (mmol/L)	Rate of K+ potassium supplementation (mEq/kg/hr)
<2	0.5
2-2.4	0.3-0.4
2.5-2.9	0.2-0.3
3-3.4	0.1-0.2
3.5-5	0.05-0.1

Don't exceed 0.5 mEq/kg/hr

'- Note if the potassium seems resistant to supplementation- the patient may be deplete in magnesium

2. Phosphorus
   a. Phosphorus can start all over the place depending on additional underlying disease (such as an acute kidney injury due to a pyelonephritis). However,

once insulin therapy is started, it can decrease quickly and require supplementation. Red blood cells are particularly susceptible to hypophosphatemia due to their dependence on ATP and can lyse (phos < 1.5 mg/dL). At time of insulin starting- if the phosphorus is normal, many suggest starting to supplement.

i. Suggested rates of supplementation: 0.03 mmol/kg/hr – 0.12 mmol/kg/hr
    1. Note for author- if phos is mildly low, start at least at 0.06 mmol/kg/hr

3. Sodium
    a. Patients with DKA are often hyponatremic. Not because they are actually deplete of sodium but because the extra glucose is causing osmotic shifts and diluting out the sodium. You can correct for this with
        i. Corrected Sodium= measured sodium +[1.6 (glucose-100)/100]

Fluid math equations

Body weight (kg)x rate of supplementation(mEq/kg.hr) x 1/fluid rate(ml/hr) x final volume(ml/L) = mEq/bag (usually mEq/L)

Note this is written for units for potassium but can be used for other supplements such as CRIs of phosphorus, or medications (pain medications, metoclopramide, lidocaine etc).

Example: Body weight: 10 kg, K+ on bloodwork: 2.8 , fluid rate: 30 ml/hr

Body weight	Rate or supp	Inverted fluid rate	Final bag size		
10 kg	0.2 mEq	hr	1000 ml	=	66.7 mEq
	kg.hr	30 ml	L		L

10 kg x 0.2 mEq/kg/hr x hr/30 ml x 1000 ml/ L = 66.7 mEq/L

Cheat method of calculating Phosphorus and potassium (because phosphorus comes as Potassium Phosphorus)

1) Determine amount of K+ needed (mEq/L)

2) If potassium and phos relatively normal or low normal at starting Insulin → targeting 0.1-0.2 mEq/kg/hr K+

Using the higher end of K+ supplementation compared to a normal patient because going to be adding insulin

3) Do ½ potassium from KCl and ½ from Kphos

Example: if need 66 mEq/L of K → 33 mEq of K from KCl and 33 mEq of K from KPhos

Insulin protocols

Initiation of insulin remains controversial but it appears that it can be started fairly quickly. You should correct electrolytes (Potassium and phosphorus) first to avoid later complications as they will continue to drop with insulin therapy.

IV Humulin R protocol

Blood glucose concentration	Fluid type (250 ml bag)	Rate of admin of insulin solution	*Rate of insulin*
>250 mg/dL	0.9% NaCl	10 ml/hr	*0.09 U/kg/hr*
200-250 mg/dL	0.9% NaCl +2.5% dextrose	7 ml/hr	*0.064 U/kg/hr*
150-199 mg/dL	0.9% NaCl + 2.5% dextrose	5 ml/hr	*0.045 U/kg/hr*
100-149 mg/dL	0.9% NaCl + 5% dextrose	5 ml/hr	*0.045 U/kg/hr*
<100 mg/dL	----	Stop insulin infusion	*0*

Add 2.2 U/kg of Humulin R to 250 ml bag of saline

Note- Author uses the same dose for dogs and cats

The bag is good for 24 hours and you need to run the solution through the fluid bag because it binds to plastic

IM protocol- administered every 2-4 hours

Blood glucose concentration	IM dose of Humulin R	Dextrose supplementation
>250 mg/dL	0.2 U/kg	none
200-250 mg/dL	0.1 U/kg	2.5% administered at maintenance rate
150-199 mg/dL	0.1 U/kg	5% administered at maintenance rate
100-149 mg/dL	----	5% administered at maintenance rate
<100 mg/dL	----	5% administered at maintenance rate

Other protocols

1. Glargine alone protocol(Marshall et al., 2013)
    a. Initial injection: 1-2 U/cat IM + 1-3 U/cat SQ
        i. IM repeated at dose of 1-2 U/cat IM q 2 hours or more often
        ii. SQ repeated at dose of 1-2 U SQ q 12 hours
2. Glargine SQ + Humulin R IM
    a. 0.25 U/kg glargine SQ q 12 hours
    +
    b. 1 U/cat of regular insulin IM q 6 hours if BG > 250 mg/dL
3. Lispro
    a. IV in dogs and cats- Same as the IV Humulin R protocol but used 2.2 U/kg of Lispro into a 250 ml bag of 0.9% NaCl(Sears et al., 2012)
    b. IM in dogs: 0.25 U/kg IM q 1 hour until BG < 10% then 0.125 U/kg IM q 3 hours (Malerba et al., 2020)

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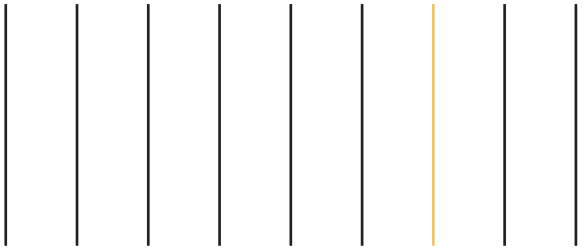
PAWING THROUGH POISONS: MANAGEMENT OF SMALL ANIMAL TOXICITY

JENIFER LOEWEN
DVM, DACVECC



SMALL ANIMAL

Toxicity Management in Small Animals

2024 86th Annual Kansas State College of Veterinary Medicine Conference

Jen Loewen, DVM, DACVECC

Objectives

1. Attendees will be able to describe the general approach to intoxications
2. Attendees will be able to describe common decontamination strategies
3. Attendees will be able to develop treatment plans (including antidotes when possible) for several common toxicities

Dogs and cats will eat some bizarre toxins. Some of these toxins we see frequently, and we don't need additional information, but sometimes the toxins are ones we rarely deal with or haven't heard of/dealt with before. Having a systematic approach to small animal toxins can be very helpful. The general approach to an intoxication is:

- Gather information about exposure and patient
- Learn about the toxin
- Decontamination
- Provide toxin antidote when possible
- Decrease toxin absorption
- Enhance toxin elimination
- General supportive therapy

There are a lot of resources available to help with toxicities. I have listed some that I have found helpful but there are likely a lot more than this (note I have no affiliation with any of these resources and I like to support my information on a toxin from more than one resource)

- ASPCA pet poison line or Pet poison hotline (note fees apply*)
- Blackwell's 5 minute veterinary consult- Small animal toxicology 2nd edition
- Pet poison app VetCPD 
- American College of Veterinary pharmacists- https://vetmeds.org/pet-poison-control/#
- Plant identification Facebook group: https://www.facebook.com/groups/144798092849300/
- Veterinary Information Network

For most toxins, when it is safe to do so, we want to decontaminate. For the gastrointestinal tract, this could mean inducing emesis and potentially being as aggressive as gastric lavage or endoscopy. In dogs, the dose of apomorphine that I use is 0.03 mg/kg IV or 0.04 IM (can be repeated if needed). In cats I generally use 8 mcg/kg of dexmedetomidine or 0.05 mg/kg hydromorphone SQ. Xylazine can be used in cats, but studies suggest that it doesn't work as well. Hydrogen peroxide should not be used in cats due to the risk of severe hemorrhagic gastroenteritis. Somethings we want to consider before decontaminating include:

- Is the animal alert enough to have a protected airway?

- Could the toxin cause harm being vomited up?
- When was the toxin ingested and do the benefits outweigh the risk on inducing emesis?
- Does the toxin bind to charcoal?

Other areas that we may need to decontaminate are the skin (consider putting an e-collar on to prevent continued grooming and ingestion) or ocular.

Some toxins we can treat with antidotes that either have a direct reaction with the toxicant, interact with the toxicants receptor or alter its metabolism.

To decrease absorption, charcoal can be given. Additionally, some toxins like methylxanthines can be reabsorbed from the bladder and allowing for frequent urination may decrease this risk.

Enhancing elimination decreases the time allowed for absorption. This could include the use of sorbitol in the first dose of charcoal, IV fluids to flush toxins out of the kidneys (may be dogma) may help. Hemodialysis may also be an option but goes beyond the scope of this lecture. Intravenous lipid emulsion can help with if the toxicant if lipid soluble. With the assistance of google, you can often find if the logP of a toxicant is > 1 → this means that lipid emulsion may work. The exact dosing isn't known but often includes 1.5 ml/kg bolus over 1-3 minutes and/or a CRI of 0.25 mg/kg/min over 30-60 minutes. This dose can be repeated in several hours if the serum or plasma is no longer lipemic.

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HIGH VOLUME HIGH QUALITY SPAY NEUTER TECHNIQUES

RON ORCHARD
DVM, MPH, CAWA, PHD STUDENT LEADERSHIP COMMUNICATIONS

SMALL ANIMAL

High Volume High Quality Spay Neuter Techniques

Ron Orchard DVM, MPH, CAWA

Ron Orchard

KSU CVM Clinical Instructor - Community Outreach
KSU SSLS PhD Student - Leadership Communication
Professional Interests
- Shelter Medicine/Outreach (Limited Resource Medicine)
- Community Engagement Scholarship of Teaching and Learning

Agenda

6.3.24

- Set Goal
- Why Implement Change?
- Importance of Team
- Resources
- Canine Spay
- Feline Spay
- Canine Castration

Goal

One Technique for Each Procedure

In-depth, hands on training takes 100+ hours.
This is the first step.

Why Implement Change?

Business-side

- Cheaper
- Faster
- Fewer Materials
- Can Serve More Clients

Medicine-side

- Less Time Under Anesthesia
- Fewer Complications
- Overpopulation
- Always Have a Reason

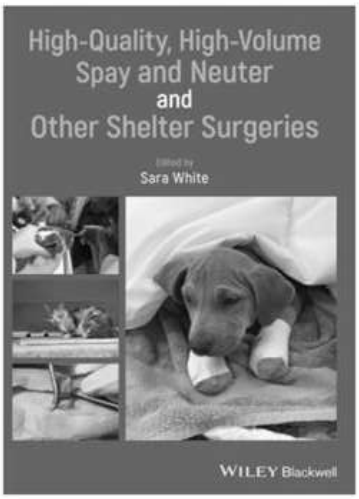
Always Have a Reason

Importance of Team

Veterinarians often not the most important member of that team

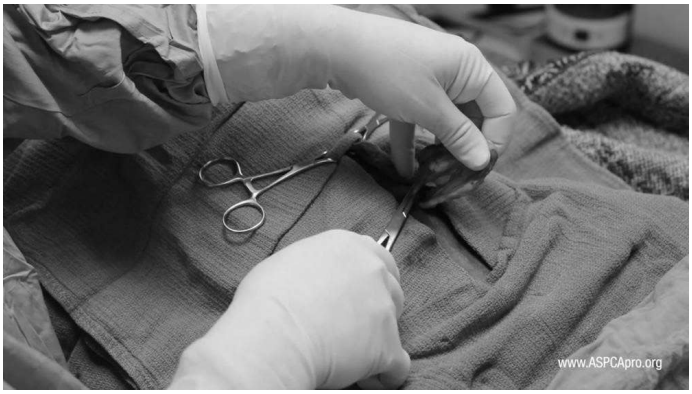
- Scheduling
- Prep
- Drug protocol
- Timing
- Recovery
- Etc.

Resources



Canine Spay - Ovarian Cutaway

After ovary exteriorized and clamps placed but *before* ligature placement.
Transect distal to carmalt to allow greater visualization.



Canine Spay - Ovarian Cutaway Reasons

Pros

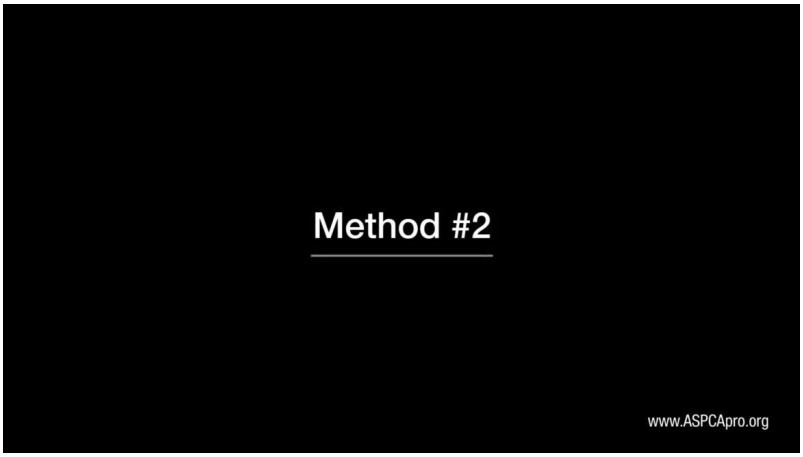
- Ligature can be placed with less manipulation of the tissue.
- Visibility is increased compared to ligating prior to transecting ovary.
- Greater technical efficiency tying over a transected end.

Cons

- Technique
  - Only clamp pedicle, not drape, skin, other tissue
- Instruments
  - Touchy clamp
- Verify all ovarian tissue excised

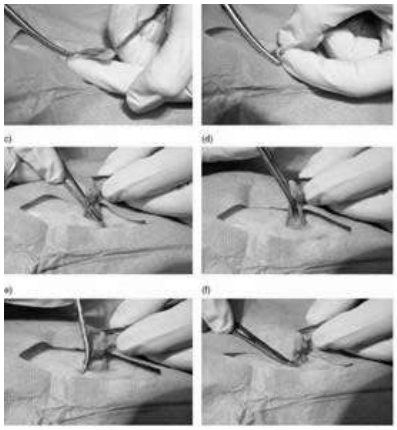
Feline Spay - Ovarian Pedicle Autoligation

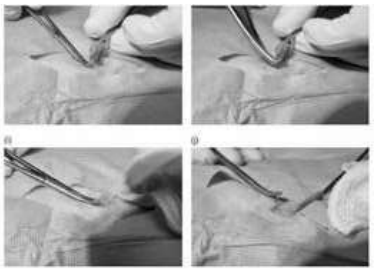
After suspensory ligament ruptured and window in broad ligament but *before* ligature placement. Can use same technique as autoligating feline spermatic cord.



Feline Feline Spay - Ovarian Pedicle Autoligation

Uterine horn and ovary pulled toward surgeon.
With hemostat closed, cross over the vessels and place into the window in the broad ligament behind the ovarian vessels.
With tip of hemostats facing away from surgeon, rotate instrument counterclockwise until tip faces surgeon.
Open hemostat and clamp ovarian vessels.
Transect and gently push the knot off the end of the instrument.





Feline Spay - Pedicle Tie Reasons

Pros

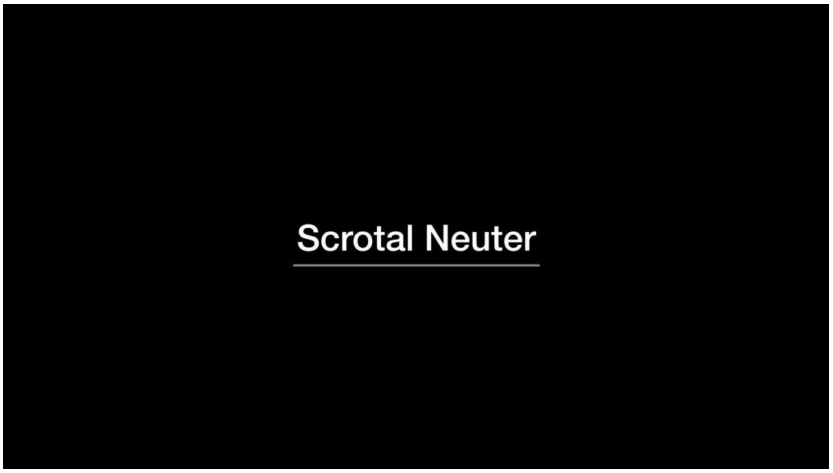
- Efficiency
  - Fast; No instruments impeding view and hands
- Technique
  - As safe as suture ligatures
- Less material
  - No suture needed at this step

Cons

- Technique
  - Inappropriate tension most common complication for new surgeons
- Muscle memory
  - There are other approaches
- Can’t use for every single patient
  - Vascular plexus

Canine Scrotal Castration

Surgical approach on ventral most aspect of scrotum, as opposed to pre-scrotal.
Once testicle is exteriorized, ligation can be surgeon's preference.
Surgeon’s preference on closure; Technically left open
- Single interrupted vs. none



Canine Scrotal Castration

Pros

- Efficiency
  - Fast
- Decreased Complication Rate
  - No instruments impeding view and hands
- Less Material
  - Fewer instruments and less suture needed.

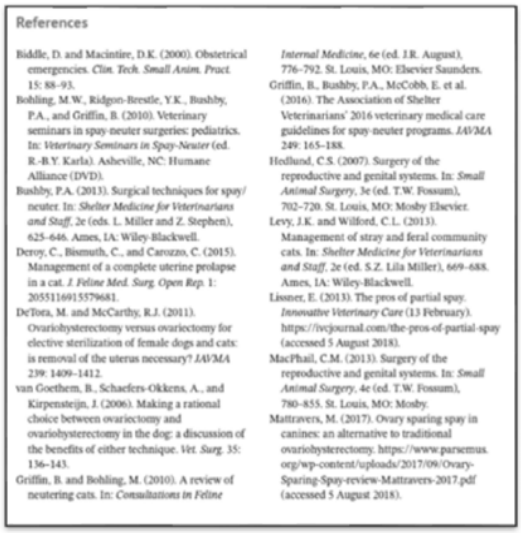
Cons

- Communication
  - Owners must know and consent
- Post-op Drip
  - A feature and a bug
- Colleagues
  - Established practitioners unaware of the evidence

Takeaways

Have a reason for why you do something
These and other HVHQSN techniques can save money and time while reducing complications.
Find quality resources to further evolve your practice.
Making the most out of HVHQSN practices requires the whole team.

References



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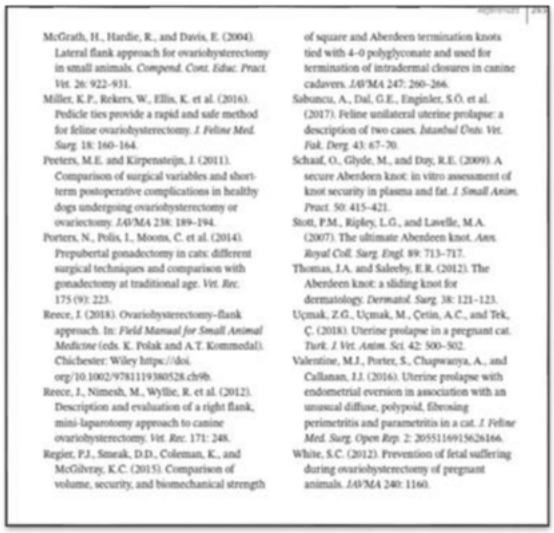

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Questions

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POINT-OF-CARE ULTRASONOGRAPHY

MACKENZIE HALLMAN
DVM, DACVR

SMALL ANIMAL

Point-of-Care Veterinary Ultrasonography

Kansas State University Annual Conference for Veterinarians

June 3, 2024

Manhattan, Kansas

Speaker: Mackenzie Hallman, DVM, DACVR. Assistant Clinical Professor of diagnostic imaging at Kansas State University.

Lecture Hours: 2

Reference: The format of this session is based on proceedings provided by Dr. Søren Boysen, DVM, DACVECC, Faculty of Veterinary Medicine, University of Calgary (srboysen@ucalgary.ca, https://vet.ucalgary.ca/vcds/podcasts). Additional references are provided to attendees upon request.

Introduction:

Ultrasonography (US) has become a widely available diagnostic tool in most small animal veterinary practices. US provides rapid information, is non-invasive especially in unstable patients, and can be learned by all levels of staff. However, a full systematic ultrasound examination can be daunting for the general practice clinician, or unfeasible in the emergency setting. In these instances, Point-of-Care Ultrasound (POCUS) can provide focused information to support and guide the clinical decision-making process.

Point-of-Care Ultrasound, also referred to as bedside/cageside ultrasound, focused ultrasound, or FAST scanning, is most useful in the following situations:

- **Triage** of the traumatized or unstable patient in the emergency setting
- **Monitoring** of the unstable patient in the hospitalized setting
- **Therapeutic** guidance or intervention in both these scenarios

The key to successful POCUS examination is for the scan to be guided by specific clinical questions (most helpfully binary YES/NO questions) and not an unguided perusal to see what 'shows up'. Most importantly, POCUS cannot replace physical exam and auscultation, and in fact these important findings will often guide the binary clinical questions that POCUS hopes to answer.

For example, instead of asking "Why is this cat dyspneic?" we instead ask YES/NO questions such as "Does this dyspneic cat have pleural fluid?" "Does this dyspneic cat have a big left atrium?"

It is also important to remember that ultrasonography cannot replace radiography in every scenario (especially GI, the thorax, and musculoskeletal), and should instead guide and be guided by these additional imaging options.

Basic machine settings, imaging planes, and transducer movements:

Every ultrasound machine available has a large array and slightly different arrangement of buttons, knobs, and settings. When encountering a new piece of equipment, the following five buttons/settings should be identified and manipulated first:

1. Depth: the region of interest should be centered in the screen.
2. Frequency: this may be a number or a range, and should be adjusted after the depth is set. If the image is too dark in the far field, the frequency should be reduced.
3. Focal zone: this allows the computer to maximize your image resolution at a particular level, and should be adjusted to just deep to the region of interest
4. Time-Gain Compensation: this automated setting has different names on different pieces of equipment, and creates a uniform 'grayness' to the image from top to bottom
5. Gain: this artificially increases or decreases the overall brightness on the screen.

Other settings (such as dynamic range/power, frame rate, precision, harmonics, etc) are more difficult to adjust 'on the fly' and should be adjusted as part of 'Presets' that can be set up by your sales rep or applications tech.

Options to freeze, label, and store images and videos are available on most machines.

In order to achieve efficient muscle memory, the imager and patient should be positioned in a standard set up each time. To achieve uniform images and aid in pattern recognition, ultrasound images should be obtained in two standard planes: sagittal/long-axis, and transverse/short-axis. Images should always be oriented with cranial toward the left of the screen while in sagittal plane, and with the patient's right toward the left of the screen while in transverse plane. This allows standardized image acquisition and prevents 'getting lost.'

Transducer or probe movements are described as a combination of: sliding, fanning, rotating, and rocking. Movements should be slow, and coordinated to obtain as many 'slices' or views of the area of interest, with the area of interest squared and centered and in the middle of the screen.

POCUS Abdomen

Indications: Triage and Monitoring POCUS scans are indicated in patients with a history of trauma, systemically unstable or critical patients, and in post-surgical patients with complications or lack of clinical improvement.

Positioning and Quadrants:

POCUS exams of the abdomen are generally performed in lateral recumbency. Hair can be clipped if thick, or a large amount of alcohol can be used to contact the skin.

Images should be obtained at each of the four quadrants of the abdomen:

1. Cranial/xyphoid/hepatic
2. Non-dependent kidney region
3. Bladder

4. Central and dependent region

YES/NO questions:

- Is there free fluid? Where? How much?
- Is there free gas?
- Is there SI ileus?
- Is there renal pelvic dilation?
- Is the patient producing urine?
- Is there a large mass lesion?

Potential pitfalls of abdominal POCUS:

Large amounts of GI gas may inhibit imaging or may mimic free gas. In large patients, a lack of depth may hide significant findings. Important artifacts may mimic clinically serious findings, such as mirror artifact mimicking diaphragmatic hernia, or edge shadowing mimicking free fluid or gas.

POCUS Thorax part 1- Pleural space and lungs

Indications: Triage and Monitoring POCUS exams can be performed on all patients that present with respiratory distress, tachypnea, or muffled or crackling lung sounds.

POCUS exam of the pleural space and lungs can help differentiate pulmonary vs cardiac sources of respiratory distress.

Positioning and Quadrants: As these patients usually present with respiratory difficulty, exams are often performed in sternal recumbency or standing, and can be performed while the patient receives supplemental oxygen therapy.

Hair can be clipped if thick, or a large amount of alcohol can be used to contact the skin. Images should be obtained at four general quadrants of the thorax, on both the left and right side:

1. Craniodorsal (caudal to scapula)
2. Caudodorsal
3. Cranioventral (level of heart)
4. Caudoventral (level of xyphoid)

YES/NO questions:

- Is there pleural space fluid?
- Is there pleural space gas?
- Are there normal lung surface A lines?
- Is there normal lung surface glide sign?
- Are there abnormal lung surface B lines? Where? How many?
- Is there lung consolidation?

The location of free pleural gas and free pleural fluid will shift with gravity depending on how the patient is positioned.

B-lines are referred to by several names including ring down, lung rockets, and comet tails. These are a type of reverberation artifact created by an irregular pleural surface and increased density/loss of aeration of the lung periphery. These are non-specific findings that are created by any pathology that results in loss of aeration (such as atelectasis), and/or infiltration of normally-aerated lung with any type of fluid or cells (ie cardiogenic or non-cardiogenic edema, hemorrhage, infection, neoplasia, fibrosis, other interstitial lung disease, etc).

Potential pitfalls of thoracic POCUS:

Glide sign can be difficult to identify in normal patients, especially in patients who are panting or not taking deep breaths, making identification of pneumothorax challenging. A gas-filled stomach may mimic free gas near the diaphragm.

B-lines are non-specific and can be identified with many diseases; B-lines are also present in small numbers in healthy animals, in older animals, and can be due to atelectasis caused by sedation, anesthesia, or recumbency.

Disease deep within the lung parenchyma that does not affect the subpleural tissue will not create visible changes on ultrasound.

Consolidated lung can look like liver, and mirror-image artifacts at the diaphragm can mimic diaphragmatic hernia.

POCUS Thorax part 2- Heart

Indications: Triage and Monitoring POCUS exams can be performed on all patients that present systemically unstable or in respiratory distress, especially those with a history of heart disease, an ausculted heart murmur, muffled heart sounds, pulse deficits, or pale mucus membranes.

POCUS exam of the heart can help differentiate pulmonary vs cardiac sources of respiratory distress.

Positioning and Quadrants: As these patients may present with respiratory difficulty, exams are often performed in sternal recumbency or standing, and can be performed while the patient receives supplemental oxygen therapy. Better views of the heart may be obtained with the patient in lateral recumbency, either from the 'up' side of the thorax, or from the 'down'/recumbent side.

Hair can be clipped if thick, or a large amount of alcohol can be used to contact the skin. Images should be obtained at four planes of the heart, from either the left and right side:

1. Apical view (level of the xyphoid)
2. Short axis at the base
3. Short axis at the apex
4. Long axis of the ventricles

YES/NO questions:

- Is there pericardial effusion?
- Is there decreased contractility?

- Is the ventricle wall thickened?
- Is there decreased ventricle volume?
- Is there increased ventricle and atrial volume?
- Is the left atrium significantly larger than the aortic root?

Potential pitfalls of cardiac POCUS:

Patient positioning and thoracic conformation (particularly deep chested and brachycephalic-breed conformations), and tachycardia can make standard views of the heart challenging to obtain.

Animals with normally-aerated lungs and no pericardial or cardiac enlargement may not allow visualization of the heart without a table designed for cardiac imaging from underneath the patient.

Heart wall thickness and lumen volumes will be influenced by fluid administration and volume overloading, or conversely by severe dehydration/hypovolemia.

Specific cardiac measurements should be repeated multiple times and averaged, and patient sedation, heart rate, hydration status, and body weight should all be taken into consideration when comparing measurements to normal. Coordinated timing with ECG tracings should be performed to ensure measurements are taken at systole vs diastole.

Ultrasound-guided Diagnostic and Therapeutic techniques:

Ultrasound can be used to guide a variety of both diagnostic and therapeutic interventions, including:

- Sampling of fluids for cytology and culture, and needle sampling (for cytology) or core biopsy sampling (for histopathology) of tissues.
- Removal of fluid or free gas for therapeutic stabilization of the patient.
- Placement of intravenous catheters, chest tubes, and urinary catheters.

CONFERENCE EVALUATION

Thank you for joining us!