Gorilla endoscopic sinus surgery: a life-saving collaboration between human and veterinary medicine

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Background: **Chronic rhinosinusitis is a common disease process in humans; however, in the primate population of gorillas, it has rarely been described. This case describes lifesaving sinus surgery on a critically ill gorilla performed by a human otolaryngology team in collaboration with the gorilla's veterinary medicine team.**

Methods: **The 35-year-old western silverback gorilla was treated for 3 months with aggressive medical therapy for a worsening sinus infection. When his condition became severe, a computed tomography (CT) scan was performed showing advanced chronic rhinosinusitis with nasal polyps vs other masses and some bone erosion. As his condition deteriorated further, a tertiary otolaryngology team performed sinus surgery using the latest technology available, including image guidance, steroid-eluting sinus stents, and balloon sinus dilation. The postoperative course was complicated by subcutaneous infection and eventual fistulization. Fortunately, with culture-directed antibiotic therapy his condition gradually improved. One year later he required revision sinus surgery. At that point allergy testing was performed followed by appropriate allergy medical therapy. Now, 3 years out from his initial surgery, he continues to do well and has fathered a young female gorilla.**

Results: **This case represents a unique collaboration between human physicians and veterinarians. The combined medical approach was critical to heal this ailing gorilla. This case discusses many of the challenges and offers recommendations for physicians who may be involved with similar care of animals in the future.**

Conclusion: **The success of the surgical and medical treatment of this gorilla's life-threatening sinus infection required many experts, careful planning, and corporate generosity. The interaction between human and animal medicine would not have been successful without the close and trusting collaborations between human and veterinary health providers. We encourage human healthcare providers to seek volunteer opportunities through their local zoos by engaging in discussions with their local veterinarians.**

Key Words:
endoscopic sinus surgery; chronic rhinosinusitis; allergic sinusitis; gorilla; primate; veterinary medicine; zoobiquity

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Chronic rhinosinusitis is a common disease in humans; however, in the primate gorillas, it has rarely been described. This case describes lifesaving sinus surgery on a critically ill gorilla performed by a human otolaryngology

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FIGURE 1. Purulent left nasal drainage seen on physical exam.

team in collaboration with the gorilla's veterinary medicine team.

Case description

The patient is a nearly 200-kg (435-pound) 35-year-old male silverback western lowland gorilla (*Gorilla gorilla gorilla)* living at the Woodland Park Zoo (Seattle, WA). In the spring of 2014, his keepers and Zoo veterinarians noted a remarkable decline in his overall health. He developed purulent nasal drainage from the left nostril, exhibited signs of headache by holding his head, and decreased consensual interactions with the female gorillas.

The Animal Health Care team at the Zoo interpreted these signs as suggestive of chronic rhinosinusitis. Despite 1 month of cephalexin followed by a second month of trimethoprim/sulfamethoxazole, the nasal purulence progressed to involve both nostrils and his health and behaviors continued to decline. Thus, after 3 months of symptoms without improvement, the Animal Health Care team reached out to the Department of Otolaryngology–Head and Neck Surgery at the University of Washington for consultation.

On visual examination of the gorilla by 2 otolaryngologists (G.E.D. and A.D.H.) in his enclosure while fully awake at the Zoo, he showed signs of chronic rhinosinusitis (Fig. 1). His nasal purulence was copious as well as presence of purulent drainage in his eyes. Given that gorillas are thought to have similar nasolacrimal anatomy to humans, the orbit purulence suggested more extensive disease than isolated chronic rhinosinusitis. A nasal culture obtained by the gorilla keepers showed *Enterobacter* species. Based on the antibiotic sensitivity profile, both enrofloxacin (a fluoroquinolone used in animals) and prednisone were administered. Adjuvant treatments such as nasal saline irrigations or nasal sprays could not be feasibly performed due to a lack of patient cooperation. Unfortunately, his condition dramatically worsened after only a few days, including increased lethargy, decreased appetite, and the interpretation by the gorilla keepers of increased physical discomfort.

The healthcare team of otolaryngologists and Zoo Animal Health providers decided to obtain a computed tomography (CT) scan of his sinuses to obtain more information to help decide if surgery was a realistic option. Though the Zoo has ultrasound and conventional digital radiograph capabilities, the Zoo relies on an offsite human imaging center when CT scans are needed (Center for Diagnostic Imaging, Seattle, WA). The CT images showed complete opacification of his bilateral frontal, sphenoid, ethmoid, and maxillary sinuses, and revealed bone erosion involving the lateral and anterior walls of both maxillary sinuses, his anterior skull base, and possibly his nasal septum (Fig. 2).

Discussion now centered on whether or not this represented a sinus neoplasm vs severe chronic rhinosinusitis. Review of the veterinary medical literature yielded no examples of successful medical treatment for chronic rhinosinusitis in gorillas. However, in the lay literature there was a case report of nasal abscesses being drained from Massa the gorilla at the Philadelphia Zoo in 1969.[1] More recently, there was a report of sinus surgery being performed on Vicki the orangutan in the United Kingdom at the Chester Zoo.[2] This engendered discussion of whether endoscopic sinus surgery could be performed. Unfortunately, his condition rapidly deteriorated to the point where he ceased to drink, eat, or move from a fetal position.

The dramatic decline in health prompted the lead veterinarian (D.C.) to convene an emergent discussion with the Gorilla Species Survival Plan (SSP) (http://gorillassp.org/). The Gorilla SSP is a group of dedicated professionals who oversee the welfare of the gorillas in the United States. They provide expertise in all matters of gorilla healthcare, such as developing breeding plans, directing research programs to improve gorilla health, and providing veterinary medical expertise. The Zoo Animal Health Care team and the lead author then discussed the options, including attempting sinus surgery vs euthanasia. In the wild, western lowland gorillas live 30 to 40 years, though in captivity they can live in to their 50s.[3] Together, the decision was made to proceed with surgery. The lead author reached out to industry representative to request emergent shipment of the necessary equipment needed to perform state-of-the-art endoscopic sinus surgery. This equipment included endoscopes, a high-definition video tower, image guidance, microdebrider, sinus instruments, hemostatic materials, dura repair materials, cautery, and mometasone-furoate steroid-eluting implants.

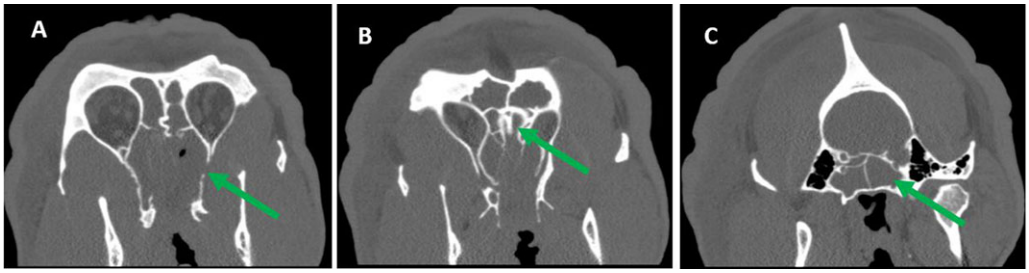

FIGURE 2. Coronal CT scan images showing complete opacification of (A) bilateral frontal and maxillary sinuses along with erosion of the lateral maxilla (arrow), (B) opacification of ethmoid sinuses (arrow), and (C) opacification of the sphenoid sinuses (arrow). CT = computed tomography.

The surgery was performed in the operating room at the Woodland Park Zoo's Animal Health Care facility. The Zoo's Animal Health team provided the gorilla's anesthesia while the lead author and surgical team performed the surgery. Anesthesia was initiated by intramuscular injection by a remote drug delivery system of medetomidine and ketamine. Animal Health then intubated the patient and placed an intravenous (IV) line to deliver fluids and antibiotics. Anesthesia was administered using inhaled isoflurane. Animal Health monitored vital signs including heart rate, oxygen saturation, end tidal CO_2, body temperature, noninvasive blood pressure monitoring, and frequent blood gas monitoring.

Intraoperatively, the gorilla's nasal mucosa was severely edematous and friable (Supporting Video 1). Image guidance was used (Medtronic, Minneapolis, Minnesota), but due to the swelling of his head that occurred during the 5 days between the CT scan and the time of surgery, "point merge" was needed to obtain the image guidance calibration rather than the standard point tracing with this system (Fig. 3).

Gorilla sinuses have many similarities to human sinuses, but also have several important distinctions from human sinus anatomy.[4] Compared to humans, gorilla frontal sinuses are small, their ethmoid sinuses are even smaller, yet their maxillary sinuses are much taller and their sphenoid sinuses are much deeper. In fact, preoperative planning demonstrated that the distance from the nostril to the sphenoid os was 13 cm in this gorilla, in contrast to 7 cm in the average human. Despite the increased depth of the gorilla nose, the width of the nasal cavity is similar to that of a human. In retrospect, it would have been helpful to have a variety of laryngeal or spine microdebrider blades as well as skull-base instruments to use during the surgery. The length of those debrider blades and surgical instruments are longer than standard sinus instruments and would have allowed easier manipulation of the deeper posterior ethmoid and sphenoid tissue.

Intraoperatively, his nasal cavity was packed with firm, polyp-like masses (Fig. 4). Frozen specimen interpretation was not available onsite at the Zoo. Fortunately, final histopathology revealed inflammatory polyp tissue and not neoplasm. Once the polyps were removed and his sinuses were opened, thick inspissated mucopurulent material was extracted from his sinuses (Fig. 5). Culture of this debris would later reveal *Escherichia coli*. Bilateral maxillary antrostomies, total ethmoidectomies, and sphenoidotomies were performed using image guidance. At this point however, his condition became unstable, with a rising serum potassium and declining blood pH, necessitating the need to terminate surgery fairly abruptly. Without time to perform complete frontal sinus decompressions, the lead author performed balloon sinus dilation (Medtronic, Minneapolis, Minnesota) of the frontal sinuses and placed mini mometasone-furoate steroid-releasing implants (Intersect ENT, Menlo Park, California) into bilateral frontal recesses. Although these implants are not approved for use in animals, the team concluded this was the only way to deliver topical steroids to this gorilla's sinuses. A gelatin-based gelfoam-thrombin hemostatic matrix (Baxter Medical Deerfield, Illinois) was applied to both nasal cavities to assist with hemostasis. Prior to emersion from anesthesia, he received atipamezole to reverse the medetomidine. He was transferred to his enclosure and slowly emerged from anesthesia in the lateral decubitus position.

His initial recovery went smoothly. On postoperative day 1 (POD 1), he began eating and mobilizing. However, on POD 3 he had a significant setback. His preoperative soft tissue edema was, in retrospect, indicative of subcutaneous infection. He developed an open fistula in his right superior neck (Fig, 6) as well as a draining fistula from his right lateral orbit. Although gorillas do have air saccules that can become infected,[5] the neck fistula was thought to be more likely related to extension of his advanced sinus infection through the maxilla erosion depicted on the CT scan.

The culture from surgery returned showing *E. coli* with intermediate resistance to the amoxicillin/clavulanic acid that was administered postoperatively. After discussion with our infectious diseases colleague (P.S.P.), he was then put on enrofloxacin as well as continued on clindamycin. It was felt that his present condition was too critical for a second anesthesia, so no washout of the wounds could be performed. With careful attention from the gorilla keepers, hand feeding and providing fluids, and continued antibiotic support provided by intramuscular injection, his condition gradually improved over the following week.

Several weeks later he returned to the public viewing area and resumed normal male gorilla activities. True success

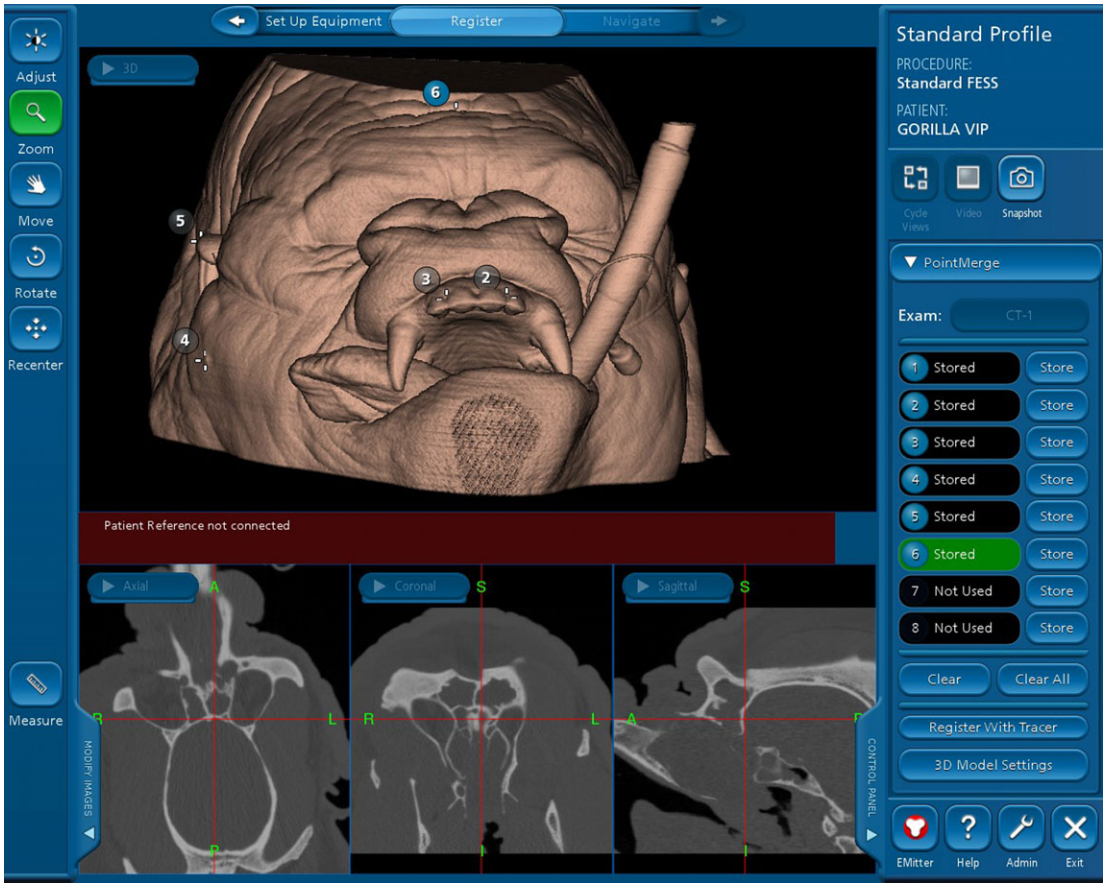

FIGURE 3. Calibration for intraoperative navigation required using point merge technique.

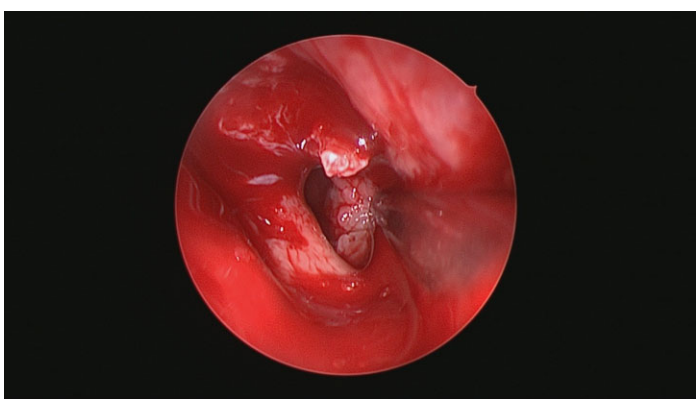

FIGURE 4. Fibrous firm nasal polyps within the left nasal cavity.

was evident a few months later when it was discovered that 1 of the females in his social group was pregnant.

Approximately 1 year after the initial sinus surgery, he began showing symptoms of possible rhinosinusitis. He exhibited intermittent head-holding behavior suggesting headaches as well as decreased appetite, decreased interaction with his female companions, and behavior interpreted as possible chest discomfort. Initially, he was treated with an empiric 3-week course of antibiotics and prednisone; however, his symptoms persisted. The Animal Health Team and otolaryngology team met again to discuss treatment options. At this point, the primary concern was cardiac disease as this is the most common cause of death in this demographic of male gorillas.[6] For a proper echocardiogram examination, a general anesthesia was required. Discussion centered upon whether or not to obtain a new sinus CT scan. Critical to this decision was weighing the risk of general anesthesia in these large animals. Placing them under anesthesia can be traumatic for the animal due to the intramuscular injection required and isolation from the rest

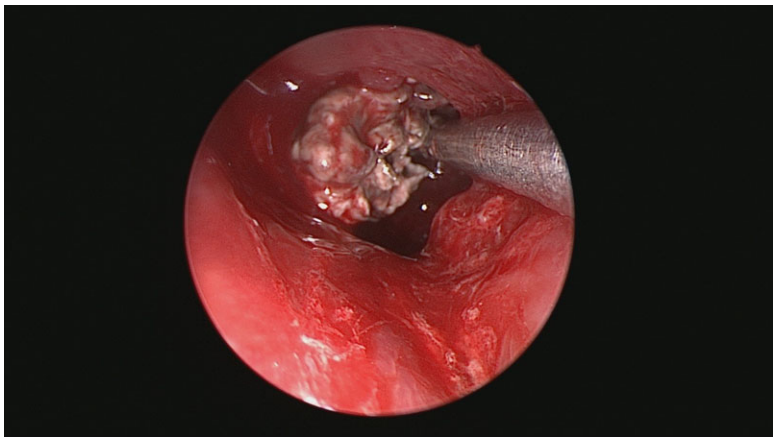

FIGURE 5. Endoscopic view of inspissated mucopurulent material within the left maxillary sinus.

FIGURE 6. Fistula tract in the right neck (white arrow).

of the gorilla family. Additionally, emersion from general anesthesia carries a much greater risk of airway compromise compared to humans, given that jaw thrust and bag mask ventilation are not reliable options in a partially anesthetized adult gorilla. Since obtaining a new CT scan would require a separate general anesthesia followed likely by another anesthesia for surgery, the team decided to forgo the CT scan and proceed directly to a general anesthesia for the cardiac exam. This also allowed an opportunity to perform additional sinus surgery if the endoscopic nasal examination showed evidence of sinus disease. Image guidance would still be possible by using his CT scan from the year before, knowing that his sinus anatomy had changed but his critical skull-base and orbit anatomy would remain relatively constant. Corporate sponsors again kindly supplied the necessary equipment to perform sinus surgery.

In hopes of helping control his inflammatory sinus disease, the lead author requested support from the Immunology Division of the University of Washington (A.G.A.) to attend the surgery and perform allergy skin testing. Intradermal allergy testing showed a significant reaction to elm tree pollen and dust mites (*Dermatophagoides farinae*). He was subsequently started on montelukast. A physician from the Cardiology Division of the University of Washington (K.R.B.) performed a transthoracic echocardiogram. Fortunately, this was negative for any significant abnormalities except for mild left ventricular hypertrophy. Nasal endoscopy showed active chronic rhinosinusitis with purulence from the frontal sinuses and some regrowth of polyps. Therefore, the lead author performed revision sinus surgery on all sinuses (Supporting Video 2). Again, mini mometasone-furoate releasing implants were placed in to bilateral frontal recesses. His recovery went without incident.

Over the past 1.5 years since his last surgery he has thrived, and he is alive and well. A recent need for emergent general anesthesia to repair a life-threatening incarcerated ventral hernia provided an opportunity to assess his sinuses. Examination showed his sinuses were healthy. He has continued montelukast and was also started on fexofenadine for improved allergy control. His new daughter Yola recently celebrated her 1-year birthday, highlighting the successful treatment of this gorilla.

Discussion

The similarities between primates and humans afford opportunities to apply advanced human therapies when needed to improve the lives of our primate cousins. However, applications of these therapies require thought, ingenuity, and preparation. Given the complexities and lack

of guidance from the literature, planning for this surgery required the resources of several specialists including otolaryngology, radiology, allergy and immunology, cardiology, infectious diseases, veterinary medicine, veterinary technicians, human surgical nursing and human surgical technicians. Further examples of similar collaborations are the focus of Dr. Barbara Natterson-Horowitz's book, *Zoobiquity: The Astonishing Connection Between Human and Animal Health* (New York: Vintage Publishing; April 2013). Although this book highlights examples of human and veterinary providers working collaboratively to care for animals, we report the first experience of an advanced endoscopic sinus surgery being performed on a gorilla.

It is important to address the ethics of treating animals in advanced diseased states with modern surgical techniques. Having open communication between all parties involved is critical to help ensure mutual understanding of the risks and potential benefits of the procedures.

An important note is that this surgery was made possible by the generosity of human surgical device equipment companies, to which we are indebted. Due to concerns for prion and other zoonotic infectious exposures, surgical instruments once used on animals are not permitted for use on humans. For this reason, we elected to use equipment that was purposed for human cadaver dissection labs.

All medical providers and assistants donated their time throughout this process.

Conclusion

The success of the surgical and medical treatment of this gorilla's life threatening sinus infection required many experts, careful planning, and corporate generosity. The interaction between human and animal medicine would not have been successful without the close and trusting collaborations between human and veterinary health providers. We encourage human healthcare providers to seek volunteer opportunities through their local zoos by engaging in discussions with their local veterinarians.

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