Surgical Management of an Inguinal Hernia in an Infant Captive Eastern Hoolock Gibbon (*Hoolock leuconedys)*

Ambar, N.,[1]* Levi, O.,[1] Martin, H.,[2] Lee, L.,[1] Fahie, M.,[1] and Eshar, D.[3]

[1] Western University of Health Sciences College of Veterinary Medicine 309 E. Second Street Pomona, California 91766, USA.
[2] Gibbon Conservation Center PO box 80029 Santa Clarita, California 91380, USA.
[3] The Department of Clinical Sciences, College of Veterinary Medicine, Kansas State University, 1800 Denison Avenue, Manhattan, Kansas 66506, USA.

* **Corresponding Author:** Dr. Neta Ambar, College of Veterinary Medicine, Kansas State University, 1800 Denison Avenue, Manhattan, Kansas 66506, USA, nambar@vet.k-state.edu

ABSTRACT

A 3-week old infant Eastern Hoolock gibbon (*Hoolock leuconedys)* underwent successful anesthesia and surgical repair of a right inguinal hernia and right testicle removal. The young gibbon recovered well post operatively and was later reintroduced to his family at six months of age. This is the first report of this condition and its management which can aid other clinicians treating neonatal gibbons with a similar condition.

Keywords: Gibbon; Inguinal Hernia; Surgery, Anesthesia; *Hoolock leuconedys.*

INTRODUCTION

Gibbons (*Hylobatidae*) are arboreal apes distributed throughout the tropical and subtropical rainforests of Southeast Asia, South China, Bangladesh and Northeast India (1). Gibbons are the most diverse group of apes with high adaptive radiation and speciation. There are currently 19 species divided into four genera. All species of gibbons are on the IUCN Red List of Threatened Species, some of which are on the brink of extinction. Despite their status, the rate of extinction of most gibbon taxa has continued or accelerated (1). In addition to rescued and confiscated gibbons, *ex situ* captive populations have been suggested as an important supplement to *in situ* conservation for the long-term survival of gibbon species through public education, professional training, research, and support of *in situ* conservation efforts (2). The development of captive care practices is important for meeting the increased demand for appropriate care of a captive population in rescue, rehabilitation, and conservation centers, as well as in other zoological institutions.

Inguinal hernias account for 75% of abdominal hernias in humans and usually require surgical repair (3, 4). Inguinal hernias have been described in several nonhuman primate species including chimpanzees, cynomolgus monkey (or crab-eating macaque, *Macaca fascicularis*), pig-tailed macaque (*Macaca nemestrina*), rhesus macaque (*Macaca mulatta*), and baboons (5-16), but has not previously been reported in gibbons. The incidence of human pediatric inguinal hernia is more than double in preterm infants (3). Regardless of term, inguinal hernias are repaired shortly after diagnosis to avoid complications such as strangulation of the bowels and gonadal infraction and atrophy (3, 17). However, the risk of these complications must be taken into consideration against the risk of surgical and anesthetic complications in a neonate (3, 17).

To the best of the authors' knowledge, the case presented here is the first report of successful anesthesia and surgical repair of an inguinal hernia in a three-week-old infant gibbon (*Hoolock leuconedys)*.

CASE SUMMARY

A 12-year-old, 8.2kg female Eastern Hoolock gibbon housed at the Gibbon Conservation Center (CA, USA), gave birth following an uncomplicated pregnancy to an infant weighing 500 grams. Later that day, the staff noticed that the infant was weak, and unable to nurse. To facilitate examination of the infant, the dam was tranquilized with ketamine (4.9 mg/kg; Ketaset, Zoetis, Parsippany, NJ, USA) and acepromazine (0.05 mg/kg; VetOne, Boise, ID, USA) intramuscularly (IM) in a single injection. On examination, the infant was found to be 5% dehydrated and 25 ml LRS fluids (Pfizer, New York, NY, USA) were administered subcutaneously. He was then bottle-fed with a baby formula (Similac Alimentum, Abbott Laboratories, Abbott Park, IL, USA) and cared for by the staff.

The dam appeared to have a significantly reduced milk production and was given oxytocin (200 units IM; Vet Tek Inc., Blue Springs, MO, USA) in an attempt to induce milk let down, and started producing milk 24 hours following this treatment. Two days post-delivery she was lightly sedated using ketamine (2.7 mg/kg) and acepromazine (0.03 mg/kg) IM in a single injection, and the infant was returned to her. The dam accepted him, and he was observed nursing later that afternoon. A day later the staff noticed the newborn becoming weaker and unable to nurse despite the mother's efforts to feed him. The infant was separated again from the dam and bottle-feeding was reinitiated. At six days of age, both testicles had descended into the scrotum. However, at 20 days of age, a firm swelling was noted on the right inguinal region (Figure) and was suspected to be a reducible unilateral right inguinal hernia.

Following a period of initial monitoring and manual reduction by staff, an increased frequency of herniation, swelling of the hind limbs, and increased infant discomfort, as assessed by increased vocalizations and general fussiness and uneasiness, were observed. The infant was otherwise bright and alert with normal temperature, appetite, and regular bowel movements. A surgical herniorraphy was recommended due to the risk of vital organ entrapment within the hernia sac. A hemi-orchidectomy was considered in order to reduce surgery time and minimize risk for future anesthesia due to operative complications or recurrence (4). Further considerations included the ability for the remaining testicle to hypertrophy and maintain reproductive function (18) and a lack of aesthetic concerns, as opposed to similar cases in human medicine.

The Infant gibbon was referred to Western University Pet Health Clinic for surgery at 26 days of age. Due to his young age, milk replacement feeding was discontinued only 2 hours prior surgery in order to minimize the risk of hypoglycemia. The infant weighed 500 grams and anesthesia was induced with ketamine (2 mg/kg) and midazolam (1.2 mg/kg; Akorn Inc, Lake Forest, IL, USA) IM in a single injection into a gluteal muscle. An appropriate level of sedation was achieved within three minutes of anesthetic induction, and he was then intubated with a 2.5 mm ID uncuffed endotracheal tube (ET). A Bain circuit was connected to administer 3.5% sevoflurane (Petrem, Primal Critical Care, Bethlehem, PA, USA) at 1 L/min 100 % oxygen flow rate for maintenance of anesthesia throughout the procedure. A 24G IV catheter was placed in the left cephalic vein and lactated Ringer solution (Hospira, Lake Forest, IL, USA) was administered at 10 ml/kg/hr using an infusion pump. A small blood sample was obtained off the catheter and his PCV found to be 28%. Monitoring of the vital signs throughout the anesthesia using a multi-parameter monitor (BM7Vet, Bionet, Tustin, CA, USA) included the heart rate (HR) and rhythm via ECG,

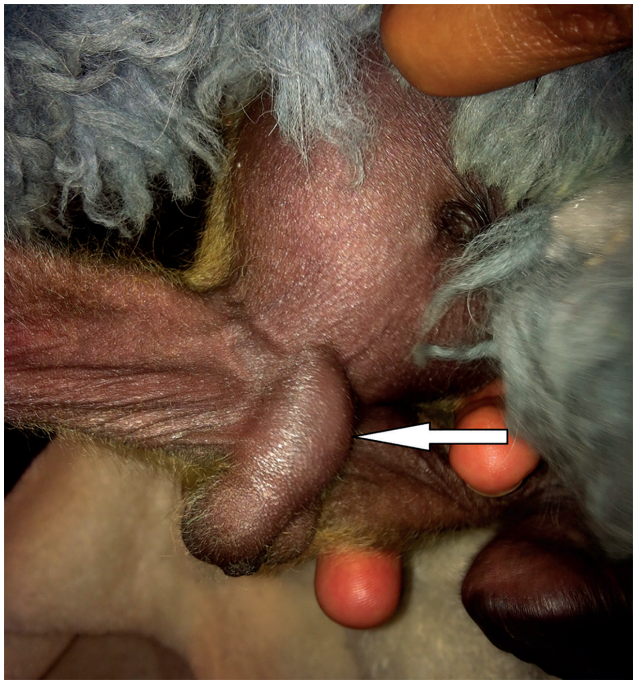

Figure 1: Palpable firm swelling in the right inguinal region (pointed to by the white arrow head) of this 20-day-old male Eastern Hoolock gibbon (*Hoolock leuconedys)*.

respiratory rate and end tidal CO_2 via capnography, respiratory sevoflurane concentration via anesthetic gas analysis, hemoglobin oxygen saturation via pulse oximetry, and continuous rectal body temperature with a digital thermometer. Systolic blood pressure monitoring was attempted using a noninvasive ultrasonic Doppler device (model 811; Parks Medical Electronics, Aloha, OR, USA) with a #1 cuff size, but with limited success.

Normal values for an infant gibbon were not found in the literature, however, vital signs measurements were consistent and did not raise any concerns throughout the procedure. The HR ranged between 190-228 bpm, respiratory rate ranged between 17-31 bpm, and end-tidal CO_2 was maintained steadily at around 20 mmHg. SPO2 initially was maintained at 94% but the pulse oximetry sensor was too large for this small-sized patient and fell off repeatedly. Time from induction to start of surgery was approximately 15 minutes. Rectal temperature was 34.4C at the time of surgical draping most likely due to the relatively cold ambient temperature the infant was exposed to during preparation. The rectal temperature had gradually risen to 37.6C with effective heating support with forced circulating warm air around the animal's body throughout the procedure. Hydromorphone (0.01mg/kg, IV; Baxter pharmaceuticals, Deerfield, IL, USA) was administered 35 minutes after anesthetic induction for analgesia, to stabilize anesthetic depth, and anticipated cardiovascular benefit. Within minutes of hydromorphone administration, the HR decreased from 234 to 125 bpm and remained in similar ranges for approximately 10 minutes with no accompanying abnormal dysrhythmias except sinus bradycardia, which a pure opioid agonist can induce. The femoral pulse on palpation felt strong with pink lingual mucous membrane and CRT less than 1.5 seconds, and therefore no anticholinergic administration to correct bradycardia was administered. The HR returned to 224 bpm within 15 minutes following hydromorphone administration with no other remarkable changes in pulse strength or CRT observed throughout the rest of the procedure.

The infant gibbon was placed in dorsal recumbency, left inguinal ring was palpated and found to be normal, and the caudal abdominal and inguinal areas were prepared routinely for aseptic surgery using a chlorhexidine scrub. Following the aseptic preparation, Bupivacaine (0.1 mg/kg or 0.25 ml; Pfizer, New York, NY, USA) was infiltrated along the incision line as a local block. The hernia contents were easily reduced on manipulation prior to the first incision. A 1 cm incision was made in the inguinal region over the right lateral aspect of the hernia swelling, parallel to the flank fold. The hernia sac was exposed by blunt dissection of the subcutaneous tissue. The hernia sac was opened and the spermatic cord was ligated using one circumferential ligature with 5-0 absorbable poliglecaprone 25 suture material (Monocryl- Ethicon, Somerville, NJ, USA). The right testicle was removed after bluntly disrupting the ligament of the tail of the epididymis. The hernia sac contents, which included small intestinal segments, were reduced back to abdominal cavity, then the base of the hernia sac was ligated at the level of the external inguinal ring and the excess hernia sac tissue was removed. The external inguinal ring was closed using horizontal mattress sutures in a simple continuous suture pattern, with 5-0 absorbable Polydioxanone (PDS – Ethicon, Somerville, NJ, USA). Single layer skin closure was performed with three simple interrupted cutaneous sutures, using 4-0 polypropylene (Prolene – Ethicon, Somerville, NJ, USA).

On completion of final suture placement, sevoflurane was discontinued, and the infant gibbon was maintained on 100% oxygen. Due to prolonged recovery time and auscultating pulmonary crackles, thoracic radiographs were performed which revealed signs of increased radiopacity in a small part of the left cranial lung lobe. Lung sounds became much clearer on auscultation soon after the radiography. On recovery of the swallowing reflex, the animal was extubated and closely monitored for any signs of adverse postoperative complications and was kept on flow-by oxygen supplementation as the patient would become mildly cyanotic when off oxygen. Thirty minutes after extubation, butorphanol (0.016 mg/kg; Zoetis, Parsippany, NJ, USA) was administered IM to expedite recovery and potentially reverse respiratory depression associated with hydromorphone. A second dose of butorphanol (0.016 mg/kg) IM was administered 20 minutes later after which the infant gibbon became more alert and responsive within a couple of minutes and the IV catheter was removed at that time. A volume of 2.7 ml of 2.5% dextrose (50% dextrose solution, Pfizer, New York, NY, USA) in LRS solution was administered subcutaneously approximately 30 minutes later in order to account for possible hypoglycemia due to fasting during the procedure.

Feeding was resumed post operatively at every 4 hours and buprenorphine (0.005mg/kg; PAR pharmaceuticals, Spring Valley, NY, USA) to be administered transmucosaly

every 8-12 hours as needed for analgesia was prescribed. Suture removal occurred 14 days post- operatively by the attending clinician. No recurrence of the herniation occurred, and the infant gibbon developed normally. He was successfully reintroduced five months later to his mother and family (brother and father) at six months of age. To date, 5 years from the surgery, he is still housed with his family at the Gibbon Conservation Center and has not had any additional health problems.

DISCUSSION

This is the first reported case of an inguinal hernia and the first reported anesthetic protocol and surgical correction in a 3-week-old gibbon. In the human literature the incidence of inguinal hernia in term infants is 3%-5% and 13-30% in preterm infants (4,5,19). Mothers of preterm infants have impaired lactation represented by delayed secretory activation and lowered milk volumes (20). In the current case it is difficult to determine the gestational age of the infant since the exact timing of conception was not recorded. Gibbons, like humans, exhibit reproductive behavior throughout the ovarian cycle and their gestation is approximately 26 weeks (21). However, given the delayed lactation observed in the mother and the presence of an inguinal hernia in the infant there is a high probability that the infant was preterm.

The neonatal human patient presents more anesthetic risk than the adult patient (22-25). Human infants less than 1 month of age have a higher incidence of adverse events both intraoperatively and postoperatively (25). The major challenges in neonatal anesthesia are due to differences in physiology and pharmacology between neonates and adults. Prematurity is a known risk factor as the organ systems are underdeveloped making maintaining homeostasis more difficult and pharmacokinetics more unpredictable (24, 25). In the current case these challenges were evident throughout the procedure.

Infants have poor temperature regulating mechanisms and because of their large body surface area compared to their weight, they tend to lose heat to cold surroundings more easily (25). The respiratory control systems in neonates are underdeveloped and there is a decreased response to hypoxia and hypercapnia (23, 24). In addition, there are some basic anatomical differences including increased anatomic dead space, small airway diameters, and reduced ability to maintain functional residual volume (23-25). They are also more prone to damage by mechanical ventilation and are more sensitive to excessive oxygen supplementation (23).

Infants also have a reduced ability to optimize hemodynamics. They have an immature myocardium with limited capacity for increased preload and underdeveloped regulatory mechanisms (sparse sympathetic innervation, immature baroreceptor response, and absent baroreceptor reflexes while under anesthesia) which make them more sensitive to iatrogenic hemodynamic shifts (23, 24). This is compounded by a lack of data related to optimal blood pressure in neonates which are thought to change and increase in the initial weeks of life in both preterm and term infants (23).

Finally, small size is also a risk factor in anesthesia (23, 24) and one that veterinarians are very familiar with. In human neonates, small size of the patient can make vascular access, intubation, and monitoring more difficult. Monitoring equipment is often inadequate and difficult to maintain in small patients (22-26). A similar problem is well known in veterinary medicine when working with small or exotic animal species. However, due to the aforementioned difficulties in neonatal anesthesia and the much smaller margin of error, inadequate monitoring can have devastating life-threatening consequences.

In the current case, hypothermia was evident within 15 minutes of induction while intubating and obtaining vascular access. Monitoring of all vital parameters was difficult due to the patient's small size and lack of specialized size appropriate monitoring equipment. Despite multiple attempts, a blood pressure was not obtained making cardiovascular monitoring and support more difficult to assess. Pulse oximetry was difficult to maintain throughout as the probe repeatedly fell off or stopped recording and needed constant readjustment.

The patient's recovery appeared prolonged taking just over an hour from the end of surgery to complete recovery. Crackles were auscultated in the lungs and an increased opacity in the right cranial lung lobe was visualized on radiographs. This may have been secondary to atelectasis due to lack of maintenance of functional residual volume which can cause collapse of alveoli and is a known complication in pediatric anesthesia. Alternatively, it may represent aspiration while the patient was extubated before re-intubation intraoperatively, although the patient did not have long-term adverse effects. The patient had to be maintained on supplemental oxygen throughout recovery otherwise the

gibbon would possibly have become cyanotic. This may be secondary to atelectasis or other respiratory complications common in pediatrics such as bronchospasm, laryngospasm, and hypoventilation (25). Alternatively, it may be related to respiratory depression associated with hydromorphone as the infant appeared to respond to reversal with butorphanol. Butorphanol was used since naloxone was not present in hospital.

There is very little information regarding neonatal pharmacology in humans (22-25) and veterinary medicine (26). In neonatal human medicine, similar to veterinary medicine, there is widespread off label pharmacological use (23-25) and drug dosing errors are more common (25). Pharmacokinetics and pharmacodynamics are greatly affected by the differences in physiology between the adult and neonate (23, 25). Volume of distribution is affected as total body water and extracellular fluid is increased in neonates (25). Moreover, the liver and kidneys are immature (23, 26) which can greatly impact drug metabolism and clearance. Thus, it is possible that a 0.1mg/kg dose of hydromorphone, as used in this case, would have profound and prolonged effects. Reversal of these effects necessitated additional dosing and profound respiratory and cardiovascular effects were observed after administration of hydromorphone. While in this case drug choice was largely affected by availability, in future cases, working with fentanyl or remifentanil may be preferable in the pediatric patient.

In this case, the right testicle was removed, rather than an attempt at hernioplasty with preserving the testicle due to swelling (suspected inflammation) of the testicular tissue with uncertain capacity to return to normal function. Removal of the testicle also minimized post-operative complications such as risk of testicular necrosis, reduced surgery time, and was not thought to impact the infants' development (27) or future reproductive function due to hypertrophy and compensation of the remaining testicle (18).

This case demonstrates the challenges associated with pediatric conditions that necessitate surgical intervention in a non-human primate. These challenges are exacerbated when working with species where little information is available regarding normal physiological parameters and pharmacological dosing. The successful surgical treatment of the inguinal hernia on a three-week-old infant gibbon may serve as a reference for veterinarians presented with neonatal gibbons that require similar surgical intervention.

REFERENCES

1. Geissmann, T.: Status reassessment of the gibbons: results of the Asian primate red list workshop 2006. Gibbon J. 3:5-15, 2007.
2. Snyder, N. F. R., Derrickson, S. R., Beissinger, S. R., Wiley, J. W., Smith, T. B., Toone, W. D. and Miller, B.: Limitations of captive breeding in endangered species recovery. Conserv. Biol. 10:338–348, 1996.
3. Wang, K. S.: Assessment and management of inguinal hernia in infants. Pediatrics. 130:768-773, 2012.
4. Jenkins, J. T. and O'dwyer, P. J.: Inguinal hernias. BMJ. 336:269-272, 2008.
5. Carpenter, R. H. and Riddle, K. E.: Direct inguinal hernia in the cynomolgus monkey (*Macaca fascicularis*). J. Med. Primatol. 9:194–199, 1980.
6. Chaffee V. and Shehan, T.: Indirect inguinal hernia in two baboons. J. Am. Vet. Med. Assoc. 163: 638, 1973.
7. Fox, J. G.: Abdominal hernias in the rhesus monkey (*Macaca mulatta*). Lab. Anim. Sci. 21: 746–747, 1971.
8. Graham-Jones, O.: A case of strangulated scrotal (inguinal) hernia in a monkey. J. Small. Anim. Pract. 1:113–115, 1960.
9. Kumar, V. and Raj, A.: Surgical management of unilateral inguino-scrotal hernia in a male rhesus macaque. Res. & Rev.: J. Vet. Sci. and Tech. 1:1-4, 2012.
10. Pizarro, A. I., Amarasekaran, B., Brown, D. and Pizzi, R.: Laparoscopic repair of an umbilical hernia in a Western chimpanzee (*Pan troglodytes verus*) rescued in Sierra Leone. J. Med. Primatol. 48:189-191, 2019.
11. Rawlings, C. A., Kirk, J. H., Harwell, J. F. and Capps, W. F.: Indirect inguinal hernia in two rhesus monkeys. J. Am. Vet. Med. Assoc. 159:621–622, 1971.
12. Sadoughi, B., Dirheimer, M., Regnard, P. and Wanert, F.: Surgical Management of a strangulated inguinal hernia in a cynomolgus monkey (*Macaca fascicularis*): a case report. Rev. Primatol. 9, 2018. URL: http://journals.openedition.org/primatologie/3372
13. Starzynski, W.: Surgery for abdominal hernia in a pig-tailed macaque (*Macaca nemestrina*). Int. Zoo. Yearb. 5:184–185, 1965.
14. Taylor, A. F., Smith, M. and Eichberg, J. W.: Inguinal hernial surgery in an infant chimpanzee. J. Med. Primatol. 18:415–417, 1989.
15. Warren, R. G. and Piccolie, A.: Bilateral inguinal hernia in a pig-tailed monkey (*Macaca nemestrina*). Lab. Anim. Sci. 29:400–401, 1979.
16. Berg, M. R., MacAllister, R. P. and Martin L. D.: Nonreducible inguinal hernia containing the uterus and bilateral adnexa in a rhesus macaque (*Macaca mulatta*). Comp. Med. 67:537-540, 2017.
17. Lautz, T. B., Raval, M. V. and Reynolds, M.: Does timing matter? A national perspective on the risk of incarceration in premature neonates with inguinal hernia. J. Pediatr. 158:573-577, 2011.
18. Umesiobi, D. O.: The effect of hemi-orchidectomy on reproductive traits of boars. S. Afr. J. Anim. Sci. 36:181-188, 2006.
19. Gulack, B. C., Greenberg, R., Clark, R. H., Miranda, M.L. Blakely, M.L., Rice, H.E., Adibe, O.O., Tracy, E.T. and Smith, P.B.: A multi-institution analysis of predictors of timing of inguinal hernia repair among premature infants. J. Pediatr. Surg. 53:784-788, 2018.

20. Hoban, R., Patel, A. L., Medina Poeliniz, C., Lai. C.T., Janes, J., Geddes, D. and Meier, P.P.: Human Milk Biomarkers of Secretory Activation in Breast Pump-Dependent Mothers of Premature Infants. Breastfeed Med. 13:352-360, 2018.
21. Rafacz, M. L., Margulis, S. W. and Santymire, R. M.: Hormonal and Behavioral Patterns of Reproduction and Parental Care in the Hylobatidae. Anim. Reprod. Sci. 137:103-112, 2013.
22. Bösenberg, A. T.: Neonatal anesthesia with limited resources. Paediatr. Anaesth. 24:98-105, 2014.
23. Bang S. R.: Neonatal anesthesia: How we manage our most vulnerable patients. Korean J. Anesthesiol. 68:434-441, 2015.
24. Thomas, J.: Reducing the risk in neonatal anesthesia. Pediatr. Anesth. 24:106-113, 2013.
25. Edomwonyi, N. and Ekwere, I.: Anesthesia-related complications in children. Middle East J. Anesthesiol. 18:915-928, 2006.
26. Trepanier, L. A.: Neonatal and geriatric pharmacology (Proceedings). dvm360.com. 2010. http://veterinarycalendar.dvm360.com/neonatal-and-geriatric-pharmacology-proceedings?id=&sk=&date=&pageID=2. Accessed May 10, 2019.
27. Sundby, A., Andresen, O. and Standal, N.: Effect of hemicastration on the level of testicular steroids and growth in bulls and boars. Theriogenology. 16: 249-257, 1981.