ANESTHESIA FOR LAPAROSCOPIC VASECTOMY IN FREE-RANGING AFRICAN ELEPHANTS (*Loxodonta africana*)

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I. Introduction

The clinical use of laparoscopic techniques has become common in both human and veterinary species. Recently this technology has been modified and successfully used in megavertebrates, such as the rhinoceros[1] and elephant.[2,3,4,5,6] The laparoscopic advantage of small incisions, reduced postoperative pain and early return to normal function[7,8,9,10] remain valid regardless of the size of the patient - and possibly even more so when the patient is an elephant released back into the bush of Africa immediately upon completion of surgery. Despite its 'minimally invasive' nature, intraoperative requirements of laparoscopy produce unique and significant alterations in the anesthetized patient's physiology. Therefore, it is essential that the anesthetist have a thorough understanding of the pathogenesis and management of potential complications. The size and disposition of free-ranging African elephants (*Loxodonta africana*), as well as the location and difficult conditions where they are found, add considerably to the list of potential consequences that may arise during anesthesia. In addition, surgical procedures in elephants in their natural environment had never before been attempted so the development of novel anesthetic protocols and equipment was necessary to ensure patient safety. The physiologic consequences of laparoscopy on anesthesia in man and domestic veterinary species will be summarized followed by special considerations for the elephant patient.

II. General Anesthetic Consequences Associated With Laparoscopy

The unique physiologic changes in pulmonary function and hemodynamics due to laparoscopy in man and animals are generally attributed to patient positioning, introduction of insufflating gas and production of increased intra-abdominal pressures (IAP) to create pneumoperitoneum.[7,8,9,10,11,12] These changes are usually well tolerated by healthy individuals but a thorough understanding of their pathogenesis is important so appropriate responses can be made to avoid anesthetic complications.

Body position, such as Trendelenburg's (head lower than body) position, is commonly used during abdominal laparoscopy and can change lung compliance, lung volume and the work of spontaneous breathing.[8,9,13] Intraperitoneal insufflation of CO2, the most common gas used to create pneumoperitoneum, results in ventilatory and respiratory changes and can cause hypercarbia, respiratory acidosis, subcutaneous emphysema, pneumothorax, pneumomediastinum and venous gas embolism.[8,11,13]

In man and animals, the recommended IAP during laparoscopy is 10-15 mm Hg since hemodynamic changes are recognizable at higher pressures.[7,8,9,10,11,12] If pressures are increased >20 mm Hg, compression of venous and arterial vessels produce a rise in

systemic and pulmonary vascular resistance and a reduction in renal and mesenteric blood flow. Mean arterial blood pressure rises and cardiac output will fall proportionally. The physical stretching of the peritoneum may increase vagal tone and trigger bradycardia. Peritoneal and splanchnic vessels can be mechanically compressed at high insufflation pressures resulting in adhesions and peritonitis.

Pulmonary changes occur if insufflation pressures are increased over 15 mm Hg, as well.[7,8,9,10,11,12] Elevated IAP may restrict diaphragm movement, increase airway pressure and decrease pulmonary compliance resulting in reduced tidal volume, minute ventilation and functional respiratory capacity (FRC). There is an increased risk of barotrauma during intermittent positive pressure ventilation. Ventilation perfusion mismatch, hypoxemia and hypercapnia is seen when FRC is reduced excessively. These can be avoided by increasing minute ventilation.[13] Due to the potential respiratory complications associated with laparoscopy during general anesthesia, intubation and assisted ventilation is recommended in man[7,8,13] and veterinary species.[9,10,12]

III. Anesthetic Protocol For Free-Ranging Elephant Laparoscopy

In all anesthetized patients the goals are the same: produce a state of unconsciousness while maintaining normal physiology and providing muscle relaxation and analgesia. Successfully accomplishing this in free-ranging African elephants for laparoscopic surgery is difficult, challenging and sometimes adventurous.

Bull elephant patients are large (range 2000-5000 kg), aggressive, non-compliant and live in inhospitable conditions in the bush of Africa. Specialized wildlife veterinarians and capture teams are necessary to safely anesthetize free-ranging elephants. Surgical patients are identified and pursued by helicopter then darted with potent opioids to induce anesthesia. The main induction agent is etorphine,[14,15,16] a potent opioid capable of fully anesthetizing an adult African elephant within 10-15 minutes. During induction, the helicopter maintains constant visualization of the darted elephant and carefully maneuvers the animal to a safe and accessible area before becoming recumbent. Meanwhile, the laparoscopy team is directed to a nearby location to prepare the “surgical arena”. Once recumbent, the anesthesia team approaches the elephant to place venous and arterial catheters and obtain physiologic data with monitoring devices. Since procedures are prolonged (2-5 hours), elephants are intubated to maintain a safe airway and to control ventilation as needed. The elephant is then loaded onto a flatbed truck equipped with a boom crane for relocation to the awaiting surgical team. Anesthesia is maintained with intermittent intravenous bolus or constant rate infusion of etorphine.

Elephants are intubated with specially designed “mega-vertebrate” endotracheal tubes (ETT) ranging in size from 35-50 mm ID and 1.2-1.8 meter in length. A portable, hand-held ventilator, powered by compressed oxygen, was created specifically for this project (Mallard Medical, Inc. Redding, CA) and is capable of ventilating animals up to 7000 kg.

Clinical monitoring devices include pulse oximetry, direct and indirect blood pressure, end-tidal CO2 and acid-base/blood gas analysis.

Elephants are unique in that they have intra-abdominal testes located near the kidneys. Therefore, to provide optimal exposure for laparoscopic vasectomy,[2] the elephant is placed into a modified standing position for a bilateral paralumbar fossa approach. A four-strap sling is placed around the axillary and inguinal area on each side of the animal that is then supported by a crane attached to the capture truck. Splints are applied to the elephant's legs to fix in rigid extension and to reduce some of its weight from the sling.

Pneumoperitoneum is produced with an air compressor controlled by a specially designed insufflator.[2] High IAP of 80-105 mm Hg are necessary to expand the 12-18 cm body wall for adequate visualization of the male internal reproductive tract. Due to the anticipated physiologic side effects and for the safety of the elephant, these pressures are limited for 8-10 minutes then desufflated to allow a return to normal IAP.

To date, 14 free-ranging African bull elephants have been successfully anesthetized and vasectomized. Total surgery time (first incision to final suture) ranged from 1.3-2.5 hr. Total anesthesia time (from dart to standing) has varied from 2.5-5 hours depending on several, sometimes uncontrollable, factors. These include size of the elephant, proper anesthetic induction, ability of capture truck and anesthesia team to get to and load the recumbent elephant, proximity to surgical staging area, ability to properly position the patient within the sling, status of patient anesthesia and surgical time. Upon completion of surgery, elephants are extubated then reversed with a combination of two intravenous opioid antagonists, naltrexone and diprenorphine.[14,15,16] The vasectomized animal typically stands within 2 minutes and is fully recovered to return to the bush in 5 minutes. All elephants are radio-collared during the procedure to assist in post-procedural monitoring for a minimum of six months.

IV. Anesthetic Considerations And Complications During Laparoscopy In Elephants
For prolonged anesthesia of free-ranging African elephants the goal is to intubate to maintain an airway; ventilate and oxygenate as needed; and use clinical monitoring devices to identify early changes in pulmonary and hemodynamic physiology.

The modified standing position within a sling has caused several elephants to experience temporary, post-procedural, front limb neuropraxia and paresis. This is presumed to be due to direct trauma of the brachial plexus by the suspension straps but fortunately persists for only 2-4 minutes. This is of concern since recovery is rapid and the elephant immediately attempts to rejoin its herd while managing its forelimb weakness. All animals have made a full recovery to normal locomotion. Extra padding will be placed on pressure points on the sling to decrease future problems. Sling straps are carefully placed to prevent pressure on the sternum and across the chest to avoid problems with respiration.

Evidence of pneumothorax, barotrauma or gas embolism has not been recognized during anesthesia. Subcutaneous emphysema was noted in one elephant but it was considered local and minor. The presence of post-procedural adhesions or peritonitis caused by elevated IAP is unknown since no elephant has undergone a follow up investigation.

The effect of using ambient air, instead of CO2, for insufflation in elephants on acid-base physiology is unknown. Evidence of transient decreased tidal volume, hypoxemia, hypercapnia and respiratory acidosis has been documented for short periods in most surgical elephants when the unavoidably elevated IAP are used. The same physiologic mechanisms described in man and animals are presumed to be applicable in this species, as well. Elephant patients under these conditions have responded favorably to increased minute ventilation and/or to desufflation of the elevated IAP. Temporary metabolic acidosis (pH 7.0) is commonly seen in anesthetized free-ranging elephants due to initially elevated lactate levels and is related to the amount of running during helicopter pursuit, capture and immobilization.

Elevated blood pressure has been has been recognized for years as a side effect of the use of etorphine as an immobilizing agent in free-ranging elephants.[14,15,16,17] Etiology is unknown but direct action from etorphine and/or incomplete depth of anesthesia are possible explanations. Pulmonary bleeding, or pink foam syndrome,[16] due to hypertension was seen early in anesthesia in 3 of 14 (21%) surgical elephants. Hypertension, defined as 25% over normal mean arterial pressures,[17] was noted in 11 of 14 (79%) anesthetized patients. New drugs and drug combinations are being investigated to manage this potentially life-threatening complication.

Significant technical problems associated with intubation have been observed. Airway obstruction from a kink in the ETT causing hypercapnia, hypoxemia and cyanosis has occurred due to improper head position while in the modified standing position. Inadvertant endobronchial intubation occurred in one elephant during patient positioning causing excitation, movement and hypercapnia. Repositioning of the patient and ETT immediately resolved the problem.

V. Conclusion

Laparoscopy in free-ranging African elephants presents numerous challenges for the attending anesthetist. Pulmonary and hemodynamic consequences of the elevated insufflation pressures necessary for adequate laparoscopic visualization appear to be similar to those described in man and other animals. Having the ability to intubate, ventilate and monitor patient physiology ensures elephant safety. Important complications include hypercapnia, hypoxemia and respiratory acidosis from elevated intraabdominal pressures; pulmonary and systemic hypertension; neuropraxia from unique body positioning; and endotracheal tube technical problems. New anesthetic drug

protocols to control hypertension in free-ranging elephants need further investigation, especially during prolonged anesthetic events.

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