Laparoscopic Vasectomy in African Elephants (*Loxodonta africana*)

Luis M. Rubio-Martínez[1], MRCVS, DVM, DVSc, PhD, Diplomate ACVS & ECVS, Dean A. Hendrickson[2], DVM, MS, Diplomate ACVS, Mark Stetter[3], DVM, Diplomate ACZM, Jeffery R. Zuba[4], DVM, and Hendrik J. Marais[1], BVSc, MSc

[1] Department of Companion Clinical Studies, Faculty of Veterinary Science, University of Pretoria, Onderstepoort, South Africa ,[2] Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, Colorado ,[3] Walt Disney Parks & Resort, Orlando, Florida and [4] San Diego Zoo Safari Park, Escondido, California

Corresponding Author
Luis M. Rubio-Martínez, MRCVS, DVM, DVSc, PhD, Diplomate ACVS & ECVS, Equine Division, Philip Leverhulme Equine Hospital, School of Veterinary Science, University of Liverpool, Leahurst Campus, Chester High Road, Neston CH64 7TE, United Kingdom.
E-mail: luis.rubiomartinez@hotmail.com

Submitted July 2012
Accepted January 2013

DOI:10.1111/j.1532-950X.2014.12163.x

Objective: To describe a surgical technique for, and outcome after, laparoscopic vasectomy of free-ranging elephants.
Study Design: Case series.
Animals: African elephants (*Loxodonta africana*; n = 14).
Methods: Male elephants (12–35 years old) were anesthetized with etorphine and supported in a sling in a modified standing position, and positive pressure ventilated with oxygen. Anesthesia was maintained with IV etorphine. Vasectomy was performed under field conditions by bilateral, open-approach, flank laparoscopy with the abdomen insufflated with filtered ambient air. A 4-cm segment of each ductus deferens was excised. Behavior and incision healing were recorded for 8 months postoperatively.
Results: Successful bilateral vasectomy (surgical time, 57–125 minutes) was confirmed by histologic examination of excised tissue. Recovery was uneventful without signs of abnormal behavior. Large intestine lacerations (3 elephants; 1 full and 2 partial thickness) were sutured extracorporeally. One elephant found dead at 6 weeks, had no prior abnormal signs. Skin incisions healed without complication.
Conclusions: Laparoscopic vasectomy can be performed in African elephants in their natural environment.

INTRODUCTION

Elephant population control is one of the most critical regional conservation issues in Africa. Improved habitat and reduced poaching have resulted in unrestricted growth of the African elephant (*Loxodonta africana*) population. This has resulted in conflict with people in countries (e.g., Botswana, Kenya),[1] where elephants roam freely and deforestation in these and other countries (e.g., Zimbabwe, South Africa)[2] where elephants are restricted by fences. Elephant overpopulation causes habitat destruction, decreasing biodiversity.[2]

Over the last 4 decades, several population control methods have been used. Culling resulted in rapid reduction in elephant population;[2] however, because of ethical considerations, negative publicity, and consequential destabilization of elephant behavior and population dynamics, culling was discontinued in the mid-1990s in South Africa. Elephant relocation is only a temporary solution and has negative effects on behavior and the cow's breeding cycle.[3] Relocation is no longer an option in some countries because parks cannot accommodate additional elephants.

Contraception techniques attempted in free-ranging females include pregnancy termination, use of estrogen implants, and immunocontraception.[1,4,5] These techniques usually require multiple manipulations and repeated treatments, which can lead to increased stress levels and behavioral changes.[5] Further, response to treatment (whether contraception was successful or not) can only be assessed after prolonged observation to determine if the cow gives birth. Hand-assisted laparoscopic ovariectomy has been described in free-ranging elephants.[6]

Male contraceptive techniques have been investigated to a lesser extent. The testes are intra-abdominal and located caudal and lateral to the kidneys.[7,8] Instead of a true epididymis, the ductus deferens is elongated and courses within the mesoductus towards the bladder, and dilates caudally to form the ampulla gland, where semen is stored.[7] Castration and vasectomy of elephants requires entering the abdominal cavity.

Castration substantially reduces musth behavior (characterized by aggressive behavior and a large rise in reproductive hormones; similar to rut in North American deer) and aggressiveness, which facilitate management of adult males.[9]

This work was performed at a private wildlife reserve in South Africa.
Presented in part at the 21st Annual Scientific Meeting of the European College of Veterinary Surgeons, July 5–7, 2012, Barcelona, Spain.
[a]Elephant population program (www.elephantpmp.org).

Castrated elephants are infertile and lack libido eventually leading to changes in population dynamics where younger or less dominant bulls breed receptive cows. After vasectomy, male behavior is still displayed so the effect on population dynamics is less. Because of family and social hierarchy, vasectomy should offer social, technical, and financial advantages over female contraception techniques.[10] Bokhout et al.[10] postulated that vasectomy of <2% of males, including the most dominant breeding bulls, would stabilize elephant population growth to a natural rate.

Castration by conventional abdominal surgery[9,11,12] is difficult, highly invasive, and has high morbidity. Laparoscopy has been used for abdominal exploration and uterine biopsy in a white rhinoceros[13] and for diagnosis of uterine tear and septic peritonitis in a pregnant elephant.[14] In 2004, a multi-institutional collaboration was initiated to develop laparoscopic equipment and techniques for use in rhinoceros and elephants to expand diagnostic and treatment capabilities in these species, and to expand international conservation efforts for improving elephant health and welfare.[15] Our group has worked specifically on developing a laparoscopic technique for elephant vasectomy.[6,16,17] Our purpose is to describe the surgical technique for, and outcome after, laparoscopic vasectomy in free-ranging African elephants. We hypothesized that laparoscopic vasectomy could be performed successfully on elephants in their natural habitat, without major anesthetic, surgical, or postoperative complications.

MATERIALS AND METHODS

This study was approved by the Institutional Animal Care and Use Committee of the San Diego Zoo Global. Free-ranging male African elephants ($n = 14$) kept in a 30,000 hectare wildlife reserve were studied. Wildlife managers selected elephants (estimated weight, 1700–4950 kg) based on estimated age (12–25 years) and dominance because this cohort were considered the most likely breeders in these herds (Table 1). Each elephant was identified from a helicopter and anesthetized by intramuscular dart with a combination of etorphine (11–15 mg intramuscularly [IM]; Captivon, Wildlife Pharmaceuticals SA, Karino, South Africa) and azaperone (30–60 mg IM; Azaperone, Wildlife Pharmaceuticals SA). The helicopter was used to guide the darted elephant to an open area in the bushveld. Once the elephant was recumbent, the ground anesthesia team responded to the needs of the elephant while the surgical team prepared a nearby area to perform surgery.

At a safe depth of anesthesia, the elephant was intubated (35 mm or 45 mm ID cuffed, endotracheal tube) and positive pressure ventilated with a mixture of oxygen and ambient air supplied by a portable, compressed oxygen tank-powered prototype ventilator (J.R. Zuba, personal communication). Anesthesia was maintained using an intravenous (IV) continuous infusion of etorphine titrated to effect (~2.5 mg etorphine/h from a solution containing 0.0104 mg/mL etorphine in saline [0.9% NaCl] solution). Physiologic status was monitored by serial measurements of anesthetic depth, rectal temperature, pulse, respiration, end tidal CO_2, pulse oximetry, direct and indirect blood pressure, and blood gas.

A sling (15-cm wide padded heavy nylon straps [5 ton capacity]) was applied around all 4 limbs in the axillary and inguinal areas and around both tusks to lift the elephant by a crane into a modified standing position (Fig 1). Special attention was given to limb position so that they were in slight flexion but supporting some weight to decrease the risk of peripheral nerve compression. The strap around each tusk held the head in a normal extended position. Most commonly, the long axis of the elephant was positioned perpendicular to the long axis of the crane truck and 2 pick-up trucks were parked on each side of the elephant so that personnel could stand in the pick-up bed to perform surgery. For larger elephants (>3.5 tons), the long axis of the elephant was positioned parallel to the crane truck and surgery performed with personnel standing on the crane truck platform. The elephant was rotated 180° during the procedure to perform vasectomy on the contralateral side.

Both paralumbar fossae were scrubbed with povidone–iodine soap and water using a large scrub brush until grossly

Table 1 Summary Data for 14-Male African Elephants (*Loxodonta africana*) That Had Standing Bilateral Laparoscopic Vasectomy Under Field Conditions

Elephant	Weight (kg)	Estimated age (yrs)	Anesthesia time (min)	Surgical time (min)	First side operated
1	1640	12–13	154	79	Right
2	2200	16–17	139	80	Right
3	3750	22–23	171	88	Left
4	2200	17–18	140	78	Left
5	1650	14–15	116	57	Left
6	4060	24	181	125	Right
7	2090	14–15	131	89	Left
8	1840	15	116	66	Left
9	4950	35	176	90	Left
10	3600	22	136	71	Left
11	3230	22	174	84	Right
12	2480	18	146	68	Left
13	3320	22	169	88	Left
14	1650	15–16	147	78	Right

Anesthesia time was from darting to reversal administration. Surgical time was from 1st incision to last suture placement.

Figure 1 Elephants were supported in a modified standing position in a sling hung from a crane truck.

clean, followed by an ethanol rinse. Two 5-inch, 18 g spinal needles were used to outline the surgical area and to ensure there were no underlying ribs that would hamper entry into the peritoneal space. An iodophor impregnated incise drape (Ioban, 3M Health Care, St. Paul, MN) was applied to the prepared skin and covered by a large impermeable, disposable surgical drape secured with towel camps. An ~20 cm × 30 cm fenestration was made in the disposable drape over the paralumbar fossa. Single doses of flunixin meglumine (1 mg/kg IM) and penicillin (15–20,000 U/kg IM) were administered.

Two surgical teams were deployed to minimize surgical time. The 1st team performed the approach and laparoscopic surgery on the 1st side while the 2nd team performed the approach on the contralateral side. After completion of the laparoscopic procedure on the 1st side, the teams changed sides so that the 1st team could perform the laparoscopic procedure and wound closure on the contralateral side, while the 2nd team closed the other laparotomy.

Using an open approach, an ~10 cm vertical skin incision was made starting ~8–10 cm ventral to the transverse processes of the lumbar vertebrae, midway between the last rib and the tuber coxa. The skin was retracted with Finochietto rib spreaders to expose the subcutaneous tissue, external oblique, internal oblique, and transverse abdominal muscles, which were sharply incised in a dorsoventral direction. Depending on elephant size, a custom made, long-blade Finochietto rib spreader (Scanlan Surgical Instruments, St. Paul, MN) was inserted and repositioned as each layer was incised to improve exposure of the next tissue layer. A long-handed #4 scalpel handle with a #22 blade was used to divide the internal oblique and transverse abdominal muscles. The long-bladed Finochietto rib spreaders were repositioned to expose the fibroelastic layer of the peritoneum, which was grasped by Vulsellum forceps and exteriorized. Additional Vulsellum forceps were used to grasp and stabilize the exteriorized dorsal and ventral portions of the fibroelastic layer (Fig 2). Fat within the fibroelastic layer held in the central Vulsellum forceps was excised using Mayo scissors. These Vulsellum forceps were then repositioned within the central portion of the incision grasping more of the fibroelastic layer, which was sequentially removed until the thin inner layer of the peritoneum was visible. After stabilizing this layer dorsally and ventrally with Vulsellum forceps, a 2–3 cm long incision was made into the peritoneal cavity (Fig 3).

The primary laparoscopic cannula (3 cm ID, 60 cm long) was inserted into the abdominal cavity through the peritoneal opening and secured with a purse-string suture (0 polyglyconate; Fig 4) in the peritoneum to seal the abdomen. The abdomen was insufflated with filtered ambient air using a

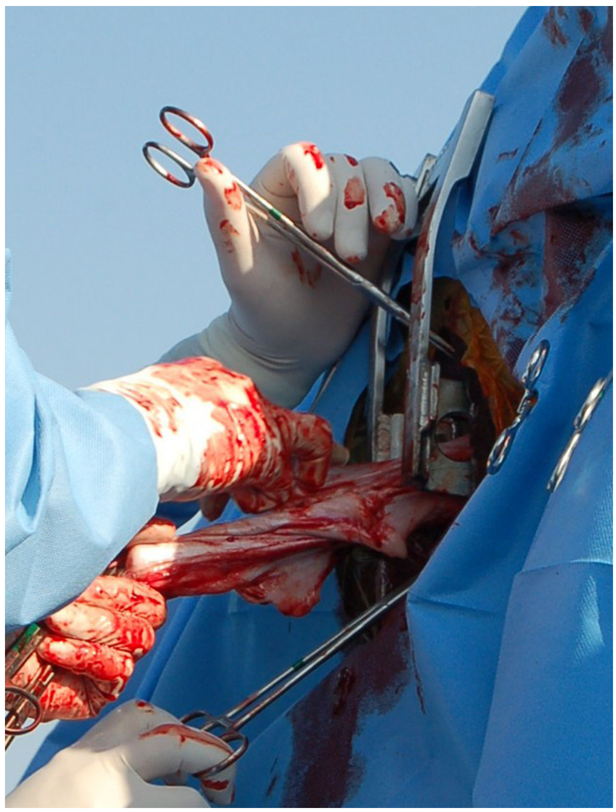

Figure 2 Incised wound edges were retracted with Finochietto rib spreaders, and the fibroelastic layer of the peritoneum was exteriorized by use of Vulsellum forceps.

Figure 3 The peritoneum was stabilized dorsally and ventrally using Vulsellum forceps and a 2–3 cm long incision was made in the central area of the exteriorized portion of peritoneum.

custom insufflator connected to an air compressor. The rib spreaders were removed and a custom 2.5 cm diameter, 98 cm long operating laparoscope (Karl Storz Co., Tuttlingen, Germany; Fig 5) inserted through the cannula into the abdominal cavity. One or 2 Vulsellum forceps attached to the peritoneum above and/or below the cannula were used to stabilize the peritoneum during surgery. A 3-chip, laparoscopic camera connected to 1 or 2 light sources (300W XenonTechno Pack, Karl Storz Endoscopy), depending on elephant size, was attached to a custom laparoscope with 2 light posts. After confirmation of intra-abdominal location of the cannula, the abdomen was insufflated (26–77.7 mmHg) and respiratory function closely monitored. In some cases, the direction of the sun was inconvenient for viewing and video goggles (MyVu Video Goggles, Myvu Corporation, Westwood, MA) were used.

After abdominal exploration and identification of the ipsilateral testis (Fig 6), a 2nd laparoscopic portal was created by making a 2-cm vertical incision through the skin at the same level, 8–10 cm cranial to the 1st portal. The incision was extended through the subcutaneous tissue, external abdominal

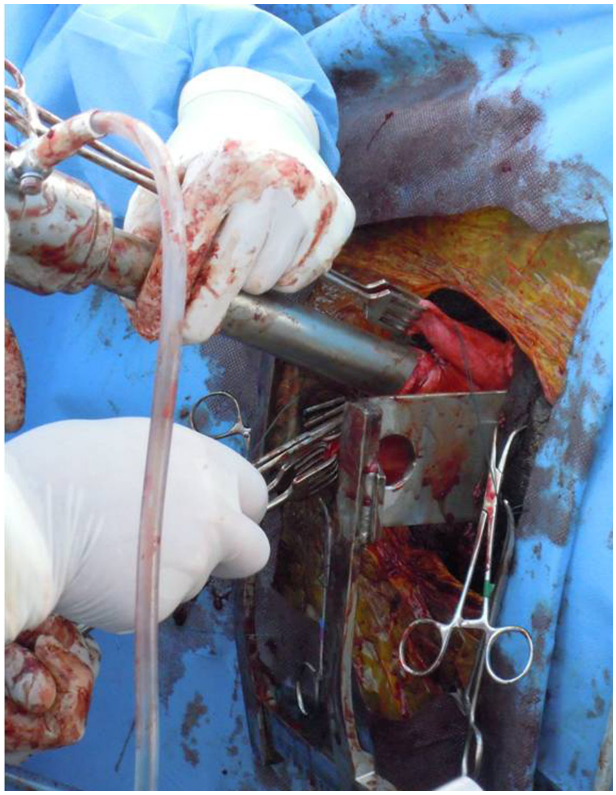

Figure 4 The primary laparoscopic cannula was inserted into the abdominal cavity and the peritoneum opening was secured over the cannula with a purse-string suture.

oblique fascia and muscle, and internal abdominal oblique muscle. An 11-mm diameter cannula with a sharp conical obturator was introduced through this incision, directed towards the testis, until the peritoneum was tented. The obturator was removed and a pair of 10 mm diameter, 75–140 cm laparoscopic scissors (Surgical Direct, Deland, FL, or Karl Storz Endoscopy) introduced to sharply incise the peritoneum under direct observation, then the cannula was advanced through the peritoneum, and the scissors removed.

The ductus deferens was located traversing caudoventrad from the dorsal caudal pole of the testis. During the laparoscopic procedure, if viewing of abdominal organs was

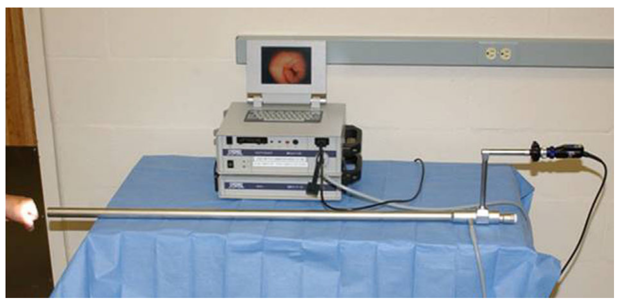

Figure 5 Specially designed 2.5-cm diameter, 98-cm long operating laparoscope (Karl Storz Co., Germany).

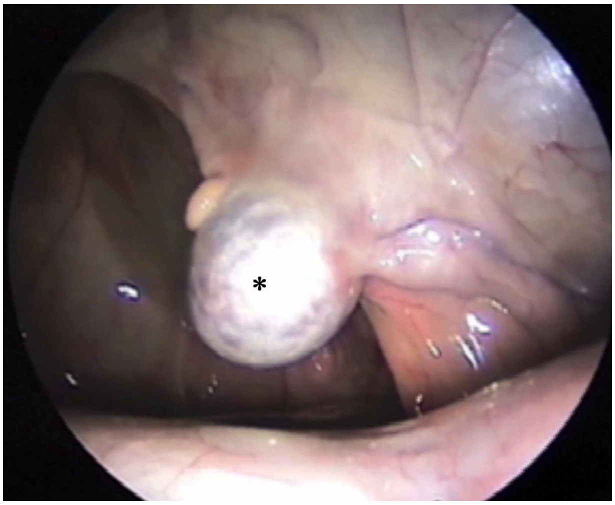

Figure 6 The ipsilateral testis (*) was identified in the dorsal aspect of the abdominal cavity. The ductus deferens (arrow) is located caudal to the testis.

Figure 8 Skin at the laparoscopic surgical site was closed with size 5 stainless steel suture using an interrupted stented horizontal mattress pattern.

difficult, the intra-abdominal pressure was increased as necessary up to 3 psi (155.7 mmHg) for short periods. A traumatic grasping forceps was advanced into the abdomen through the 10-mm, centrally located, working channel of the telescope and the ductus deferens was identified and grasped. Laparoscopic scissors were introduced through the accessory portal and a 4–8 cm segment of the ductus deferens was sharply resected (Fig 7). The surgical site was observed during and after transection for signs of excess bleeding. The resected tissue was exteriorized through the large diameter primary cannula. After gross examination confirmed the excised tissue was ductus deferens, the abdomen was desufflated, cannulas removed, and peritoneum at the primary portal site closed with size 0 polyglyconate in a simple continuous pattern to achieve a gas-tight seal before insufflation of the abdomen from the contralateral side.

As soon as the ductus deferens was identified on the initial side, the 2nd surgical team performed a similar approach to expose the peritoneum on the opposite side. Once the peritoneum on the initial side was closed, the surgical teams switched sides; the primary team completed laparoscopic vasectomy on the 2nd side while the other team closed the

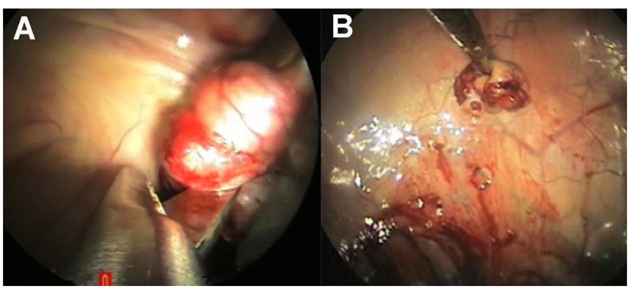

Figure 7 An ~4 cm long section of the ductus deferens was sharply amputated with laparoscopic scissors.

initial flank incision. After the 2nd vasectomy and equilibration of intra-abdominal pressure (equivalent to ambient) the 2nd laparotomy was closed.

After closure of the peritoneum, the abdominal muscle layers and the oblique fascia of the abdominal wall at the surgery site were closed in a single layer with 0 polyglyconate in a simple continuous pattern. The skin was closed with multiple horizontal mattress sutures using 5 stainless steel (Covidien, Mansfield, MA) including ~1 cm stents of plastic IV tubing (Fig 8). A single horizontal mattress suture (5 stainless steel) closed the accessory portal. After incision closure, the surgical sites were cleaned and the elephant lowered into lateral recumbency for anesthesia recovery. Anesthesia was reversed with naltrexone (50 mg IV) and diprenorphine (36–42 mg IV) and recovery from anesthesia was observed.

Surgical time, and surgical and anesthetic complications were recorded. Elephants were monitored daily initially and then weekly for 8 months after surgery by wildlife managers; animal behavior and incisional healing were recorded. Skin sutures were not removed.

RESULTS

Bilateral laparoscopic vasectomy was successfully performed in all elephants (Table 1); surgical time ranged from 57 to 125 minutes (Table 1). The initial approach was from the right in 5 elephants and the left in 9. The skin was 3–4 cm thick and the fibroelastic layer of the peritoneum highly pliable.

In elephant 6, the laparoscopic cannula was inadvertently inserted into the lumen of the large intestine, presumably cecum, during the initial approach on the right side. The laparoscopic portal was enlarged to 20 cm, the intestinal tear exteriorized, and closed extracorporeally with 2 layers of 0 polyglyconate; no untoward effects were observed during follow-up. In elephants 9 and 11, the seromuscular layer of the large intestine was inadvertently grasped by the Vulsellum forceps with the inner layer of the peritoneum and lacerated during the initial approach. These lacerations were similarly exteriorized after enlarging the incision and sutured; no complications occurred during follow-up.

The testes were typically identified in the dorsal aspect of the peritoneal cavity caudal and lateral to the kidneys. Some individual variation in the presence or absence, and length of a vascular pedicle for the testis was observed. The ductus deferens surrounded by a variable amount of retroperitoneal fat within the mesoductus coursed along the dorsolateral aspect of the testis to the bladder. We had the impression that retroperitoneal fat was increased with age and size but this was not established. When retroperitoneal fat obscured the ductus deferens, grasping the tissue with claw forceps and rotating it, facilitated identification of the ductus deferens. In elephant 10, sharp dissection of the superficial mesoductus layer and underlying fat was used to facilitate identification of the ductus deferens. Minimal hemorrhage occurred at the ductus deferens transection sites.

General anesthesia was well tolerated and no anesthesia complications occurred. When elevated intra-abdominal pressures were required, patterns of ventilation were adjusted accordingly to maintain normal acid-base status. Typically, elephants would make 1–2 attempts to rise before standing, which usually occurred 3–5 minutes after reversal agent administration, and then would walk away quietly. Two elephants (6, 7) had transient mild left front lameness (~20–45 s) presumed to be caused by paresthesia before walking normally.

All elephants recovered well from surgery and returned to normal activity without signs of abnormal behavior. All incisions healed without complication within 1 month of surgery. Histologic examination confirmed ductus deferens in all excised tissue samples.

Elephant 9, the oldest (35 years), was found dead 6 weeks after surgery. Necropsy was not performed so the cause of death could not be determined but poaching was suspected based upon proximity of the carcass to the reserve fence. This elephant had a good recovery, returned to normal activity, had no abnormal signs during weekly monitoring, or abnormal behavior detected by telemetry.

During 8 months of observation, no alterations in population dynamics have been observed.

DISCUSSION

We found that laparoscopic vasectomy can be successfully performed on free-ranging African elephants in their normal environment. Conventional elephant abdominal surgery is associated with limited visibility, accessibility, and manipulation of abdominal organs often with serious postoperative complications.[9,11,12,18–20]

Standing laparoscopy of captive elephants and rhinoceros has been performed using chute restraint combined with sedation and local anesthesia.[13,21] In free-ranging animals, general anesthesia is preferred because the location of the animal is difficult to predict and general anesthesia is required for capture. A combination of etorphine and azaperone delivered using a dart followed by a continuous IV etorphine administered to effect was practical and successful. Use of a sling to support elephants in a modified standing position for surgery was successful. Careful placement of the sling and limbs, use of extra padding on the straps in the axilla and inguinal regions, and limiting time in the sling seem to have decreased the incidence of post procedural limb paresthesia and paresis.[22]

Filtered compressed ambient air used for abdominal insufflation was practical in a field setting. Although CO_2 insufflation is more commonly used in people and animals,[23] compressed air for laparoscopy has been considered acceptable in people[24] although there is a higher risk of wound infection and abdominal discomfort than with CO_2 insufflation.[24,25] Based on our study and our previous experience, elephants appear to tolerate the use of compressed air insufflation without untoward effects.[16,17]

Scalpel blades were quickly dulled during the flank approach. Use of a long-handed scalpel is advised for the deep abdominal muscle layers and observation was greatly facilitated by the use, and occasional repositioning of Finochietto spreaders, which also helped control variable bleeding from the incised abdominal muscles. We found that the amount and thickness of fat (reported up to 30 cm[9]) within the fibroelastic layer overlying the peritoneum was variable. This fibroelastic layer was extremely elastic, freely movable and loosely attached to the body wall. A combination of thick, relatively non-compliant, skin together with the deep location of the peritoneum made entering the abdominal cavity challenging. Locating and incising the peritoneum (a thin, glistening tissue layer) is also reportedly difficult during open abdominal surgery in elephants.[9,11,12] In the first description of conventional open castration of an elephant, the intact peritoneum had to be pushed against the testicle before the abdominal cavity was entered and that portion of peritoneum was removed with the testicle.[18] We followed the technique described by Olsen and Byron[9] whereby large tenaculum forceps were used to grasp and exteriorize fatty tissue, which was then sharply excised. This was repeated in the central area of the incision until the peritoneum was penetrated.

Accidental intestinal laceration occurred in 3 elephants during the initial abdominal approach and has also been reported during open castration.[11] Special attention is required during the abdominal approach especially when food has not been withheld before surgery. With laparoscopy, the risk of intestinal laceration is likely to be higher during the initial approach before abdominal insufflation. On the 2nd side, because the abdomen had been insufflated, we commonly observed the fibroelastic layer, retroperitoneal fat, and peritoneum bulging through the flank incision, which greatly facilitated dissection. In the elephant that had a full thickness bowel laceration, the cannula entered the intestinal lumen, but the bowel had not been grasped with the Vulsellum forceps. The cannula end was blunt with a 30° bevel and was inserted without obturator in a caudodorsal direction in an attempt to avoid the viscera. The use of a blunt obturator and preoperative fasting may decrease the risk of intestinal lacerations.

The strong, elastic nature of the peritoneum resisted penetration by a sharp conical trocar at the accessory portal and required the use of laparoscopic scissors for fenestration and cannula-obturator insertion. The robust nature of the peritoneum was also reported during open elephant castration when écraseurs failed to transect the spermatic cord when it was surrounded by the visceral and parietal peritoneum.[18] The secondary cannula was inserted after abdominal insufflation and under laparoscopic observation to avoid intestinal trauma. We used a 0° laparoscope, which provides easier orientation but has reduced lateral visibility when compared to angled laparoscopes.[26] Consequently, viewing of the accessory portal location was restricted and we recommend that the secondary portal be located >10 cm from the primary portal to minimize instrument and cannula interference.

Initial laparoscopic procedures on rhinoceros and elephants were performed with laparoscopic instrumentation designed for horses, because this was the largest (57-cm long, 10-mm diameter laparoscope) available.[13] Those experiences revealed technical and procedural challenges, which limited the application and practicality of laparoscopic surgery in these species.[15] Challenges included instrument breakage, insufficient instrument length, insufficient insufflation with subsequent poor viewing within the abdominal cavity, and inability to reach and manipulate abdominal organs.[15] The laparoscopic instrumentation we used was specifically developed for use in rhinoceros and elephants and other large vertebrates.

Elephants were administered a single dose of penicillin at the end of the procedure. The need for antimicrobial administration is questionable since equine laparoscopic castration is considered a clean procedure.[27] Even though we performed sterile technique, the field surgical setting posed a moderate risk of break in sterility. Presurgical administration of antimicrobials would have been more appropriate; however, this was not performed for logistical reasons. Amoxicillin or ampicillin are usually administered systemically to elephants undergoing open castration from the day before surgery and then for 8 days.[9,11,12] Typically, open castration is more invasive, longer with larger surgical incisions, and surgical site drainage and infection are common.[9,12]

Our surgical incisions healed without complication. Closure of the peritoneal layer was readily performed. Muscle layer closure was more challenging and separate closure of individual layers was not attempted; only the external abdominal oblique muscle and its fascia were closed. Previously after laparoscopic vasectomy, we closed the skin with 2 nylon in a near-far-far-near suture pattern and without stents and had incisional dehiscence.[16] No dehiscence occurred in the elephants in our current study in which we used stent supported 5 stainless steel horizontal mattress sutures for skin closure. Leaving the elephants to remove the stainless steel sutures did not seem to result in any problems or behavioral changes.

Rapid activation of the large greater omentum is commonly observed within 5 minutes after entering the peritoneal cavity in open abdominal surgery of elephants[9] and typically impedes surgery by enveloping the surgeon's arm and instruments. This phenomenon was not observed during laparoscopic vasectomy.

These elephants were >15 years old, weighed >1.6 tons, and food was not withheld preoperatively. We used a bilateral approach and coordination between 2 surgical teams to ensure efficient completion of vasectomy. In 1 elephant, the youngest and lightest, the contralateral testicle was visible from the initial approach. With preoperative food withholding and appropriately sized laparoscopic instrumentation, identification and vasectomy of the contralateral testicle might be possible in smaller elephants; however, further studies are necessary to investigate this and other applications of laparoscopy in elephants.

It has been recommended that castration through laparotomy be performed in elephants between 2 and 4 years of age because the procedure becomes very difficult in older elephants.[9] We found laparoscopic vasectomy is more controlled, can be successfully performed in older elephants in a relatively short surgical time, and seemingly with minimal consequences. Elephants returned to their normal habitat and activity after laparoscopic vasectomy, whereas after conventional castration exercise is restricted for at least 2 weeks[9,12] and appetite was decreased for 10 days.[9] The cause of sudden death in 1 elephant was undetermined but unlikely related to the surgical procedure because initial recovery was good and no abnormal signs were observed over the next 6 weeks.

Summarily, laparoscopic vasectomy can be successfully performed on free-ranging elephants in their normal environment with minimal complications, and allows rapid return to full function with minimal disturbance to the elephant or herd. Studies to evaluate the effect of bull elephant vasectomy on elephant population demographics and dynamics, and the long-term management of vasectomized elephants and related effects on population dynamics remain to be investigated. From observations in reserves where we performed some vasectomies, there is a reduced breeding rate without apparent adverse effects on population dynamics, although this requires longer term study.

ACKNOWLEDGMENT

We thank Selati Game reserve for their interest in this project, facilitating its completion and their hospitality and friendship.

DISCLOSURE

The authors report no financial or other conflicts related to this report.

REFERENCES

1. Poole JH: Kenya's initiatives in elephant fertility regulation and population control techniques. *Pachyderm* 1993;16:62–65

2. Whyte I: Conservation management of the Kruger National Park. PhD dissertation, University of Pretoria, Onderstepoort, South Africa, 2001

3. Raath JP: Relocation of African elephants, in Fowler ME, Miller RE (eds): *Zoo and wildlife medicine: Current therapy* (ed 4). Philadelphia, PA, Saunders, 1999, pp 525–532

4. Fayrer-Hosken RA, Grobler D, Van Altena JJ, et al: Immunocontraception of African elephants. *Nature* 2000;407:149

5. Whyte I, Grobler D: Elephant contraception research in the Kruger National Park. *Pachyderm* 1998;25:45–52

6. Stetter M, Grobler D, Zuba JR, et al: Laparoscopic reproductive sterilization as a method of population control in free ranging African elephants (*Loxodonta africana*). *AAZV AAWV AZA Nutrition Advisory Group* 2005; 199–200

7. Jones RC, Brosnan MF: Studies of the deferens ducts from the testis of the African elephant, *Loxodonta africana*. I. Structural differentiation. *J Anat* 1981;132:371–386

8. Short RV, Mann T, Hay MF: Male reproductive organs of the African elephant, *Loxodonta africana*. *J Reprod Fertil* 1967;13:517–536

9. Olsen JH, Byron HTJ: Castration of the elephant, in Fowler ME (ed): *Zoo and wild animal medicine: Current therapy.* Philadelphia, PA, Saunders, 1993, pp 441–444

10. Bokhout B, Nabuurs M, de Jong M: Vasectomy of older bulls to manage elephant overpopulation in Africa: a proposal. *Pachyderm* 2005;39:97–103

11. Byron HT, Jr., Olsen J, Schmidt M, et al: Abdominal surgery in three adult male Asian elephants. *J Am Vet Med Assoc* 1985;187:1236–1237

12. Foerner JJ, Houck RI, Copeland JF Jr., et al: Surgical castration of the elephant (*Elephas maximus* and *Loxodonta africana*). *J Zoo Wildl Med* 1994;25:355–359

13. Radcliffe RM, Hendrickson DA, Richardson GL, et al: Standing laparoscopic-guided uterine biopsy in a southern white rhinoceros (*Ceratotherium simum simum*). *J Zoo Wildl Med* 2000;31:201–207

14. Gage LJ, Schmitt D: Dystocia in an African elephant (*Loxodonta africana*). *Proc Am Assoc Zoo Veterinarians* 2003;88

15. Zuba JR, Stetter MD, Dover SR, et al: Development of rigid laparoscopy techniques in elephants and rhinoceros. Annual Meeting American Association of Zoo Veterinarians, Minneapolis, USA, 2003; pp 223–227

16. Hendrickson DA, Stetter M, Zuba JR: Development of a laparoscopic approach for vasectomies in free ranging African elephants. Annual Symposium American College of Veterinary Surgeons, San Diego, USA, 2008

17. Stetter M, Hendrickson D, Zuba JR, et al: Laparoscopic vasectomy in free ranging African elephants (*Loxodonta africana*). Annual Meeting American Association of Zoo Veterinarians, 2007; pp 185–188

18. Fowler ME, Hart R: Castration of an Asian elephant, using etorphine anesthesia. *J Am Vet Med Assoc* 1973;163:539–543

19. Klein LV, Cook RA, Calle PP: Etorphine-isoflurance-O2 anesthesia for ovariohysterectomy in an Indian rhinoceros (*Rhinoceros unicornis*). Annual Meeting American Association of Zoo Veterinarians, 1997; pp 127–130

20. Foerner JJ: Dystocia in elephants, in Fowler ME, Miller RE (eds): *Zoo and wild animal medicine: Current therapy* (ed 4). Philadelphia, PA, Saunders, 1999, pp 522–525

21. Stetter M, Hendrickson D: Laparoscopic surgery in the elephant and rhinoceros, in Miller Reflowed ME (ed): *Fowler's zoo and wild animal medicine current therapy.* St. Louis, MO, Elsevier Saunders, 2012, pp 524–530

22. Zuba JR, Grobler D, van Altena JJ, et al: Anesthesia for laparoscopic vasectomy in free-ranging African elephants (*Loxodonta africana*). Annual Symposium of American College of Veterinary Surgeons, San Diego, CA, October 2008; pp 660–663

23. Fischer AT: Basic laparoscopic techniques and training, in Fischer AT (ed): *Equine diagnostic and surgical laparoscopy.* Philadelphia, PA, Saunders, 2002, pp 29–36

24. Trunzo JA, McGee MF, Cavazzola LT, et al: Peritoneal inflammatory response of natural orifice transluminal endoscopic surgery (NOTES) versus laparoscopy with carbon dioxide and air pneumoperitoneum. *Surg Endosc* 2010;24:1727–1736

25. Ikechebelu JI, Obi RA, Udigwe GO, et al: Comparison of carbon dioxide and room air pneumoperitoneum for day-case diagnostic laparoscopy. *J Obstet Gynaecol* 2005;25:172–173

26. Chamness CJ: Nondisposable instrumentation for equine laparoscopy, in Fischer ATJ (ed): *Equine diagnostic and surgical laparoscopy.* Philadelphia, PA, Saunders, 2002, pp 37–50

27. Waguespack RW, Burba DJ, Moore RM: Surgical site infection and the use of antimicrobials, in Auer JA, Stick JA (eds): *Equine surgery* (ed 3). St. Louis, MO, Saunders, 2006, pp 70–87