CHAPTER 68

Laparoscopic Surgery in the Elephant and Rhinoceros

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Traditional abdominal surgery in the elephant and rhinoceros has rarely been performed and, in those cases in which it has, success has been limited.[1,4] Emergency cesarean sections in elephants have been attempted and have proved fatal for both the calf and mother. Successful castration of bull elephants has been described.[2,3,12] In these reports, young animals were castrated in a single procedure, whereas adults required multiple procedures. These elephant castration procedures were difficult and it was not uncommon for incisions to break down and heal by second intention. An abdominal exploratory and ovariectomy has been reported in an Indian one-horned rhinoceros, but the animal died 48 hours after the surgery.[11]

Abdominal surgery in the elephant and rhinoceros is difficult for several reasons, the first being the animal's overall size and how it affects the surgeon's ability to reach and manipulate organs. Second, there is considerable thickness to the skin and body wall, which requires larger incisions and an inordinate amount of time for closure. Surgical sites may also be predisposed to dehisce and break down.[2,12] An additional complicating anatomic variation in elephants is their peritoneum. Unlike most other mammal species, the peritoneum is covered by a fibroelastic layer and is itself redundant and only loosely attached to the body wall.[5] For this reason, entering the peritoneal cavity of elephants, even after making an incision through the dermis and associated muscle layers, may be very challenging. Finding a route to and through the peritoneum is much more of an issue when animals are in lateral recumbency (versus standing), when there is less tension on the peritoneum. Rigid laparoscopy, or minimally invasive surgery (MIS), offers a variety of advantages over traditional surgical procedures. In humans and animals, MIS has been shown to be less painful, requires less healing time, allows faster return to normal function, and has less chance for infection.[19] For the elephant and rhinoceros, MIS has these advantages and thus makes abdominal surgery a realistic and much less risky procedure. Laparoscopic abdominal surgeries have been successfully performed in the African elephant, white rhinoceros, and black rhinoceros.[6,13,15-17] Procedures have included abdominal exploration with diagnostic sampling and a variety of reproductive surgical techniques.

LAPAROSCOPY IN THE ELEPHANT

Animal Positioning

Abdominal laparoscopic surgery in elephants is best accomplished in a standing position, either with the animal sedated and in a restraint device or under general anesthesia, with the animal in a standing position while being suspended from a crane truck.[6,15-17] Using MIS and maintaining the elephant in a standing position allows for small incisions, rapid access to the abdominal cavity, and excellent overall surgical success.[7] In captive situations, in which sedation may be used along with some degree of manual restraint, abdominal laparoscopic surgery may be readily accomplished. We have successfully used butorphenol and detomidine in conjunction with local analgesic nerve blocks with the elephant in a restraint chute (Fig. 68-1). The patient is sedated to the level at which it cannot lift its trunk and maintains a wide stance on all four legs, but is not likely to lie down. Once sedated, a regional analgesic block is accomplished using a 5-inch, 18-gauge spinal needle. In elephants, an elevated platform is used to place the surgeons at the level of the paralumbar fossa. This standing sedation approach has been used for abdominal exploratory

Figure 68-1

Standing sedation being used in an elephant chute for laparoscopic abdominal exploratory in a female African elephant. The surgeons' and associated equipment are on an elevated platform that provides access to the paralumbar fossa. The rigid laparoscope has been placed inside the elephant's abdomen. The surgeons are wearing video goggles, which are attached to the laparoscope camera unit and provide direct image viewing. These goggles significantly reduce glare issues when working outside in sunlight and allow both surgeons the same view without limitations of head position or monitor placement.

Figure 68-2

An anesthetized free-ranging bull elephant in South Africa undergoing laparoscopic surgery. Five-ton capacity ropes are used to suspend the animal from a crane truck in an upright standing position. The elephant has been intubated and is being provided with assisted ventilation. A rigid operating laparoscope has been placed into the abdominal cavity. The laparoscopic viewing monitor has been placed on the animal's dorsum so that the sun is behind it and the unit has been modified with the addition of black side panels to reduce glare.

and reproductive procedures in both adult elephants and rhinoceroses.

In free-ranging elephants, for which restraint facilities do not exist and the location of the patient is difficult to predict, the animals are placed under general anesthesia via a remote injection system. Once the patient is laterally recumbent, large padded straps or ropes (5-ton capacity with foam or wool padding) are placed around the proximal base of each leg and connected to the hook of a crane truck. These ropes are looped around the axilla or inguinal areas, ensuring limited pressure on the thoracic or abdominal cavities (Fig. 68-2). Limited pressure on the thorax greatly improves respiration and limited pressure on the abdominal cavity assists in insufflation and laparoscopic visibility. Once the ropes have been placed around each leg and secured to the crane, the elephant is lifted into a standing position. An additional rope is placed around the base of the tusks and attached with the other ropes so that the head is held in a normal upright position. In most cases, these animals are intubated to facilitate assisted ventilation when insufflation is applied.

Surgical Equipment

The nonlaparoscopic surgical instruments used for creating and closing the abdominal incisions are commonly available through veterinary surgical catalogues. In most cases, the large versions are used. The procedure benefits from two to four no. 8 surgical scalpel handles with no. 60 scalpel blades, and two to four long no. 4 scalpel handles with no. 22 scalpel blades. Elephant and rhinoceros skin is tough, dense, and thick, so many blades are generally used for a single incision. It is always better to have too many blades than not enough. Other instruments include penetrating towel clamps, large Mayo scissors, long needle holders, long thumb forceps, vulsellum forceps, wire needle holders, and wire cutters. Modified Finocetto rib spreaders are also used to distract the skin while making the primary incision (Fig. 68-3).

Laparoscopic Surgical Instruments

Laparoscopic surgical equipment for minimally invasive surgery in the megavertebrate species must be longer and stronger than traditional equipment. The telescope—a rigid laparoscope— should have at least an 80-cm working length for bull elephants younger than 20 years and for cow elephants. In larger bull

Figure 68-3

Skin incision made in the paralumbar fossa of an African elephant. Note the use of Finocetto rib spreaders to retract the skin margins and provide access and visibility to the underlying muscle layers. In larger animals, the blades of the rib spreaders will need to be lengthened to retract the entire body wall of the elephant. Once the laparoscope is placed into the abdomen and insufflation has begun, the rib spreaders are removed.

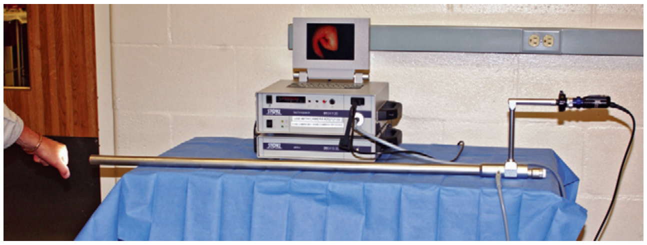

Figure 68-4

This 112-cm megavertebrate telescope (Karl Storz Endoscopy) has been developed for minimally invasive surgery in elephants and rhinoceros. This is an operating laparoscope, which has a 10-mm working channel for placement of laparoscopic instruments. The Techno Pack (Karl Storz Endoscopy) system is a self-contained, battery-operated light source, monitor, and camera. This system is easily transported in field situations. This is a halogen light system and a xenon light source may be required for optimum viewing in elephants.

elephants, a working length of 100 to 112 cm is helpful (Fig. 68-4). A traditional telescope may be used but, to reduce the number of portals necessary, an operating laparoscope is more useful. Specialty telescopes (Karl Storz Endoscopy, Tutlingen, Germany) with two light source input posts will improve the amount of light that may be delivered into a potentially large peritoneal space. Visibility may be difficult because of the size of the abdominal cavity and the amount of fat and bowel distension that may occur. Having an appropriate amount of light is important. In the rhinoceros, depending on the size of the animal and procedure being attempted, an equine telescope (Hopkins Telescope, Karl Storz Endoscopy, 10 mm × 57 cm, 30-degree angle) may be used.[13]

Cannulas and Obturators

Laparoscopic cannulas are designed to allow exchange of instrumentation with minimal loss of intra-abdominal pressure, thereby maintaining an operating space within the abdominal cavity. Traditional diameter cannulas with their associated instruments and telescopes may be used. However, they should be 50 cm long and have thicker walls than traditional cannulas. If a larger diameter telescope is used, a larger diameter cannula is helpful. At least one of the cannulas should have two high-volume, stopcocks installed to allow larger volumes of insufflation gas to be instilled into the abdomen. The second stopcock may be used to measure intra-abdominal pressure. When using a longer large-diameter cannula as described earlier, the cannula should be at least 75 cm long but may be 50 cm long if the shorter telescope is used. In general, a large- diameter (30 mm for introduction of an operating telescope) and a traditional diameter (11 mm for introduction of instruments) cannula are used. This combination allows two instruments for diagnostics and surgical procedures. A third cannula would be necessary if a nonoperating telescope is used.

Obturators (trochars) for megavertebrate laparoscopy are similar to those used in traditional surgery. Because the primary cannula is placed using an open technique, no obturator is needed for the telescope. When placing the accessory instrument portal, a conical obturator is the best choice. This portal is placed blindly, after the abdomen has been insufflated, but the surgeon must be careful to avoid trauma to the bowel or other structures when placing the sharp obturator. The cannula-obturator unit is advanced until it may be seen laparoscopically tenting the peritoneum. The obturator is then removed and a hooked scissors is used to cut through and penetrate the peritoneum under direct visualization.

Hand Instruments

Hand laparoscopic instruments based on traditional instruments have been adapted for megavertebrate surgery. In general, these instruments have been designed with a 95- to 130-cm working length (Karl Storz Endoscopy and Surgical Direct, Deland, Fla). The most commonly used instruments are acute claw (Senn) graspers with lengthened jaws, atraumatic (Babcock) graspers, and scissors. Small-hook scissors tend to work best for entering through the peritoneum while placing the accessory portal and larger serrated scissors work best for transecting tissue such as the ductus deferens. Neither bipolar nor unipolar electrosurgery appears to be useful when using longer instruments and cannot be recommended at this time. Other instruments, including vessel-sealing devices and stapling equipment are being considered, but have not been tested at the time of this writing.

Instrument Sterilization

Instruments may be sterilized using ethylene oxide or glutaraldehyde solution. In general, the telescope and laparoscopic instruments are stored and sterilized inside a padded gun case. The case is left open for the sterilization process and then closed for transport after degassing. A challenge of ethylene oxide sterilization in outdoor environments may be low ambient temperatures that are often experienced when working in the field. A heated area would be ideal, but is rarely available. Specially designed portable tubs are used for glutaraldehyde sterilization because of the unique size and shape of the laparoscopic instruments. These lightweight plastic tubs allow cold sterilization between animals, when multiple procedures are occurring in a single day.

Light Source

As in all minimally invasive surgery, the light source is a critical piece of equipment. The anatomic and environmental considerations with the megavertebrate species require the best visualization possible to limit further complications. In our experience, a 300-W xenon light source may be effective in bulls that are 4500 kg or smaller. However, if the animal is larger, two light sources are helpful. The largest diameter light cords available should be used because they allow more light transmission into the abdominal cavity. When working outdoors, it is important that light sources are well built and sturdy enough to withstand the jostling that occurs with surgery in the bush. Having replacement light cords and light bulbs are a necessity when working in the field.

Camera and Monitors

The best-quality camera available should be used; the higher the quality of the camera, the better the image on the monitor. High-quality cameras will also provide better light-collecting capacity, reducing the amount of light required in the abdominal cavity. Positioning the monitor screen is one of the most challenging aspects of performing minimally invasive surgery in an outside environment. In general, the best monitor position is one in which the telescope may point at the monitor. Because of the size of the animal and limited positioning options, this generally means that the monitor must be placed on the animal's dorsum. When working outside, the direction of the sun is also important. Usually, having the sun behind the monitor is best. A better alternative to a single monitor is the use of video goggles. There are several commercially available sources for goggles that may be fed a video signal from the endoscopy camera unit. We have used goggles manufactured by MyVu (Wellesley, Mass; http://www.myvu.com) with good success. The main benefit to the use of video goggles is that the surgeon and assistant may be looking in the direction of the telescope at all times. The presence of bright sunshine is also less of a problem. The main detractor is that only those wearing goggles have access to the video image. This may be remedied by placing a small monitor (often a video recording device) in a position where staff and observers may watch.

Insufflation

As in all minimally invasive surgery, space must be created to maneuver the instruments in the peritoneal space. Traditionally, in domestic animals, CO_2 is used for insufflation and to create pneumoperitoneum. Access to compressed CO_2 in the field is limited. Consequently, other sources of compressed gas have been used. When working with free-ranging elephants, compressed air was selected because of the ease of access.[6,15-17] Compressed air is supplied via a commercially available 30-gallon tire inflation unit. The unit is plugged into a power generator for power and the air is filtered in line prior to entering the abdomen. In humans, a few studies have been performed comparing CO_2 with room air pneumoperitoneum. In one large study,[8] patients undergoing room air pneumoperitoneum were more likely to have wound infection and abdominal discomfort. However, it was concluded that room air pneumoperitoneum is safe, cheap, and available and can be used in low-resource settings. A more recent study comparing CO_2 and room air in both laparoscopy and natural orifice transluminal endoscopic surgery found it to be acceptable.[18]

In humans and animals, the recommended intra-abdominal pressure during laparoscopy is 10 to 15 mm Hg.[9] Pressures greater than 20 mm Hg for prolonged periods may produce negative cardiovascular and respiratory effects. However, when working with elephants and rhinoceros, traditional insufflators (0 to 20 mm Hg) do not provide enough intra-abdominal pressure to move the bowel out of the way and allow adequate visualization. An intra-abdominal pressure of between 0.5 and 3 psi (25 to 150 mm Hg) is necessary for most surgical procedures.[6,17] Although we recognize that this pressure is above what is used in other species, there have been no identifiable long-term consequences seen in 26 elephants that have undergone laparoscopic surgery. In general, intra-abdominal pressure is kept between 0.5 and 1 psi (25 to 50 mm Hg), except for short periods during which increased visualization is necessary. A specially designed insufflator that allows rapid air flow from the air compressor and continuous monitoring of the higher intra-abdominal pressures has also been used successfully (Fig. 68-5). Because of the potential respiratory complications associated with laparoscopy during general anesthesia, intubation and assisted ventilation are recommended in humans and veterinary species. It is important to have positive-pressure ventilation available when using any insufflator, especially when using higher pressures.

Figure 68-5

Photograph of a specially designed insufflator for megavertebrate laparoscopy. *A*, First filter. *B*, Acetylene welding regulator used to adjust air flow into the abdomen. *C*, Intra-abdominal pressure gauge.

Surgical Anatomy of the Elephant

Several different laparoscopic approaches have been evaluated and a flank approach, just rostral to the tuber coxae and ventral to the caudal ribs, has been deemed the best approach to the abdomen.[6,15-17,19] The ribs of the elephant extend into the traditional area of the paralumbar fossa and are very difficult to palpate under the thick skin. The tuber coxae is palpated and 5-inch, 18-gauge spinal needles are placed into the body wall and used to identify and avoid the ribs when the incision is made. The skin incision (approximately 15 cm) for the primary cannula is made approximately 10 cm rostral to the tuber coxae and immediately ventral to the ribs.[18] The skin is incised using a no. 60 BD scalpel blade on a no. 8 handle because the length of the blade is sufficient to penetrate the skin of even large bull elephants. A set of Finocetto rib spreaders is place into the skin incision and the skin edges are retracted to allow access to the external abdominal oblique fascia and muscle, which are transected using a similar scalpel handle and blade as for the skin. The Finocetto rib spreaders are removed and a specially designed, long-blade version of Finocetto rib spreaders (Scanlan Surgical Instruments, St. Paul, Minn) is inserted through the skin and muscle incision. A long-handled no. 4 scalpel handle with a no. 22 BD scalpel blade is used to divide the internal abdominal oblique muscle along the incision, and the rib spreaders are placed deeper into the incision. The transverse abdominus muscle is divided sharply along the same line as the skin and other muscles. Vulsellum forceps are introduced into the incision and the fibroelastic layer over the peritoneum is grasped at the center portion of the incision and pulled through the incision. An additional Vulsellum forceps is placed on the fibroelastic peritoneum at the dorsal and ventral portion of the incision. A long Mayo scissors is used to remove a portion of the fibroelastic peritoneum and fat. The Vulsellum forceps are released, a single Vulsellum forceps is again introduced into the central portion of the incision, and a portion of the peritoneum is exteriorized from the incision. Vulsellum forceps are again applied at the dorsal and ventral portions and a central portion is removed.

The actual peritoneum is relatively thin and difficult to differentiate from the fibrous portions until the glistening inner layer can be seen. Once the peritoneum has been penetrated, a purse-string suture is placed and the large diameter, primary cannula is placed into the peritoneal space. The purse-string suture is closed over the cannula and the abdominal space is insufflated to a

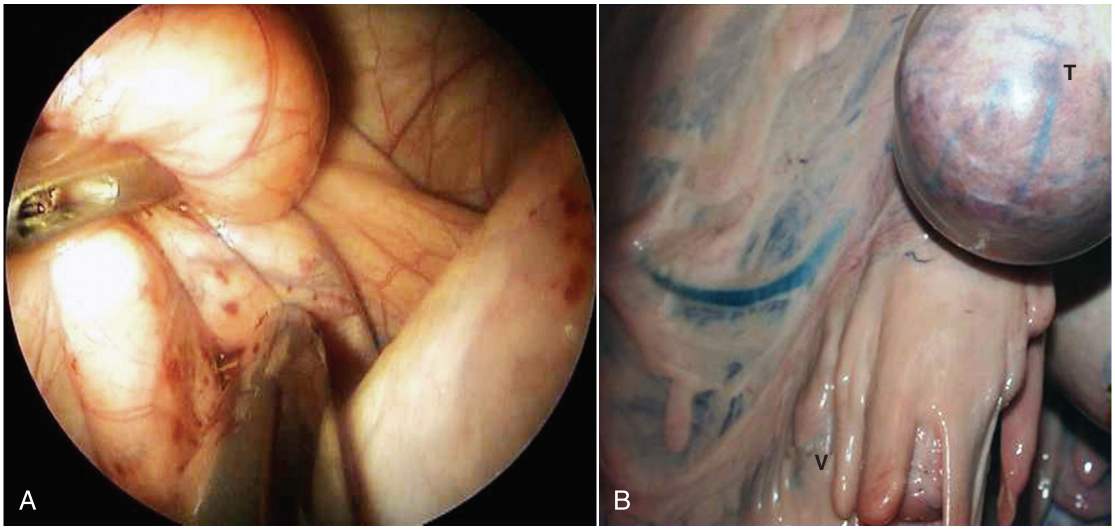

Figure 68-6

Intra-abdominal photographs of an elephant's right abdomen. **A,** Winter season, with 20-mm Hg pressure showing poor organ visibility because of gas-filled bowels. **B,** 75-mm Hg intra-abdominal pressure. *T,* Testes; *V,* vas deferens.

pressure of 0.5 to 1 psi (25 to 50 mm Hg). The rib spreaders are now removed, allowing the body wall and skin margins to come together and help seal the peritoneal space. One to two pairs of Vulsellum forceps are maintained on the peritoneum to stabilize the peritoneum during surgery. When performing the surgical incision on the second side, a similar approach is used. Once the billowing peritoneum is identified (the abdomen has been insufflated), a suture is placed for more rapid identification.

The telescope is introduced into the large cannula and an initial exploration is performed. After the telescope has been placed and insufflation is complete, an accessory portal is made. A 2-cm incision, located 10 cm rostral to the middle portion of the primary incision, is made through the skin, external abdominal oblique fascia and muscle, and internal abdominal oblique muscle.[6,17] The accessory cannula with a conical obturator, as described earlier, is introduced through the skin and muscle layers directed toward the testis. As soon as the cannula and obturator are noted to be tenting the peritoneum, the obturator is removed, a pair of small hooked scissors is introduced, and the peritoneum is sharply incised under direct visualization. The cannula is advanced through the hole created by the scissors and the small-hook scissors are removed and replaced with grasping forceps. Abdominal exploration, with visibility of the kidney, ureter, testes, ovary, uterus, testes, ductus deferens, colon, and portions of the small bowel, may be facilitated in this way.

Elephant Vasectomy Procedure

Unlike most mammals, elephants do not have a scrotum and external testes. The elephant's testes are intra-abdominal and located caudal and lateral to the kidneys[10,14] (Fig. 68-6). The vas deferens is more appropriately identified as the ductus deferens in elephants and is actually more similar to a long epididymis. It originates at the dorsal caudal pole of the testis and courses toward the bladder in a mesoductus.

A traumatic grasping forceps is advanced into the abdomen through the operating channel of the telescope and the ductus deferens is identified and grasped using the grasping forceps advanced through the telescope. As noted, if visualization is difficult, the intra-abdominal pressure may be increased as necessary up to 3 psi (150 mm Hg) for short periods of time.[6,17] Once identified and grasped, a scissors is introduced through the accessory portal, and a 4- to 8-cm segment of ductus deferens is resected and removed through the large-diameter primary cannula. After a segment of the ductus deferens has been removed on the first side, the abdomen is desufflated, the cannulas removed, and the peritoneum at the primary portal site is closed. It is important to create a gas-tight seal to be able to insufflate the abdomen on the second side. As soon as the ductus deferens is identified on the first side, a second group of surgeons begins a similar approach down to, but not including, the peritoneum on the second side. Either the elephant is rotated 180 degrees or the surgery teams switch sides, and the second ductus deferens is removed in similar fashion.

Closure

The peritoneum is closed with 0 polyglyconate suture in a simple continuous pattern. The external abdominal oblique fascia and muscle are also closed in this pattern. The skin is closed in multiple horizontal mattress sutures using no. 5 stainless steel and plastic stents in the large incision, and a single horizontal mattress suture using no. 5 stainless steel in each of the accessory portals. The two ends of the wire suture are tightly twisted together (i.e., like cerclage wire) rather than tied with a knot. Although the elephant is often laid back down on the side as soon as possible, it should be noted that it is often faster to suture the skin while the elephant is suspended from the crane truck. Once closure is complete, the patient's perisurgical area is scrubbed and the animal is lowered and placed in lateral recumbency for anesthesia reversal.

LAPAROSCOPY IN THE RHINOCEROS

Laparoscopy in the rhinoceros has similar challenges as in the elephant, although rhinoceros skin is also generally thicker than that of African elephants.[19] Surgery performed in the standing animal allows better visualization than in a laterally recumbent animal.[7,13] It is important to recognize that in the white rhinoceros, the skin over the ribs seems to be attached to the ribs, causing a depression in the skin. The fibroelastic tissue associated with the peritoneum is similar but much less extensive than in elephants and much more adherent to the body wall. At the time of this writing, we have performed laterally recumbent laparoscopy in two white and one black rhinoceros and standing sedated laparoscopy on one white rhinoceros. The uterus and ovaries are readily visible in the standing animal and are approachable in the laterally recumbent animal. Gas distension of the bowel occurs quickly, because it is often difficult to withhold feed prior to surgery. Consequently, surgery should be started as quickly as possible after anesthesia is induced in laterally recumbent animals. Surgical procedures have included uterine biopsy, liver biopsy, and ovariectomy. In general, the paralumbar fossa provides the best abdominal access for the urogenital tract. Access to the liver will require a more cranial approach, either between or just below the ribs. In some cases, a partial rib resection may be necessary to gain access to the dorsal abdomen.

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