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Abstract: Laparoscopic techniques for veterinary surgery are growing in popularity for the same reason the use of minimally invasive procedures has increased tremendously in human surgery. Compared with open surgery, the benefits of laparoscopic surgery include smaller incisions, reduced postoperative morbidity and pain, shorter hospitalization, a more rapid return to normal activities, and, in some instances, superior access. Laparoscopic surgery is different from open surgery in equipment/instrumentation and psychomotor skills. This first article in a series on equine laparoscopic surgery introduces the necessary equipment and reviews basic techniques (e.g., triangulation, optimal coaxial alignment, ergonomics, instrument use) common to all procedures.

Laparoscopic surgery has become an established, mainstream discipline in human surgery and is becoming increasingly popular in veterinary surgery. Growing interest in minimally invasive surgery in horses is largely based on appreciation of the benefits of this technique in people. Compared with open surgical techniques, the benefits of laparoscopic surgery include smaller incisions, reduced postoperative morbidity and pain, shorter hospitalization, and a more rapid return to normal activities. In addition, recent studies indicate that, at least for some conditions, postoperative complications are less frequent with laparoscopic surgery than with open procedures.1–4 Growing awareness of these advantages has enhanced demand for minimally invasive surgery by horse owners. Therefore, it is increasingly important for equine surgeons to become familiar with laparoscopic techniques and procedures.

The benefits of minimally invasive surgery are counterbalanced by disadvantages such as considerable initial equipment costs and, for inexperienced surgeons, longer anesthesia and operative times because the technical requirements are inherently different from those in open surgery. Laparoscopic surgery is technically challenging for several reasons. First, the surgeon’s depth perception and spatial orientation are limited by a two-dimensional view of the operative field. Second, this difficulty is compounded by a lack of the tactile feedback that conventional surgery usually provides. Third, in contrast to instrument use in open procedures, the range of movement of long-shafted laparoscopic instruments is limited by working through cannulae in fixed positions in the body wall. Therefore, even simple tasks performed by laparoscopy can require additional physical and mental effort, which can add to the surgeon’s stress and fatigue.5 However, with practice, surgeons have adjusted to these limitations, and laparoscopic procedures are becoming increasingly efficient. Moreover, laparoscopy enables surgeons to put their “eyes” in the patient’s abdomen, allowing interventions that were previously difficult or impossible using open techniques.

Because educational resources for equine laparoscopy are somewhat limited at this time, this article and subsequent ones in this series are designed to introduce readers to laparoscopic equipment, techniques, and procedures for use in horses.

Equipment

Laparoscopic surgery requires some specialized equipment and instrumentation. Except for the insufflator, much of the electronic equipment required for laparoscopy is identical to that used in arthroscopy (FIGURE 1).

Laparoscopes

The laparoscope, or laparoscopic telescope, is a rigid
Equine Laparoscopy: Equipment and Basic Principles

Endoscope that is similar to an arthroscope in design and construction. Most laparoscopes employ the Hopkins rod-lens system, which uses rod-shaped quartz lenses and is named for the inventor, a British physicist. Hopkins lenses optimize light transmission and provide a wider field of view than other lens systems. Telescopes with various viewing angles and physical dimensions are available. The most popular telescopes for equine laparoscopy have a 10-mm diameter and either a 0°-angle (straightforward) or a 30°-angle view. Telescopes are available in lengths of approximately 30, 45, or 60 cm, but the exact length varies by manufacturer (FIGURE 2). All angles and sizes are suitable for diagnostic and surgical laparoscopy; choices are frequently based on personal preference. For example, orientation is simplified by using a 0°-angle laparoscope, but some practitioners prefer a 30°-angle telescope because rotating it on its long axis provides a larger field of view. In addition, the offset field of view of a 30°-angle telescope can reduce interference with other instruments. Some practitioners advocate routine use of a 60-cm laparoscope, which allows comprehensive examination of the equine abdomen; however, a 30-cm laparoscope suffices for many procedures and is less unwieldy than longer laparoscopes. While not ideal for general use, a 5-mm, 30°-angle, forward-viewing scope can be valuable for use in foals and for cursory abdominal examination of adult horses through a portal that is half the size required for a 10-mm telescope.

The Camera and the Light Source

Developments in charge-coupled device technology have led to the widespread availability of compact, easily sterilized, robust cameras. Charge-coupled device camera elements detect light and act as optical-electrical interfaces, which, through camera processor signal modification, permit image display on a monitor as well as capture digital information for printing still images and/or recording digital video and still images. Modern camera heads have switches that allow surgeons to white balance (balance for color fidelity), zoom in/out, and obtain images and video. Images are displayed on a video monitor. High-definition liquid crystal display monitors offer the best image quality; however, conventional cathode ray tube monitors suffice for most procedures and are relatively inexpensive.

Cannulae

Instruments are usually introduced into the abdominal cavity via a cannula, permitting rapid, atraumatic exchange and movement of instruments. Various laparoscopic cannulae are available, including reusable, autoclavable forms (FIGURE 3); disposable, plastic models (FIGURE 4); and hybrids of these two (FIGURE 5). They are available in various sizes: 5- and 10-mm-diameter cannulae are generally used,
but 12- to 15-mm-diameter cannulae are required to accommodate large-diameter equipment, such as stapling devices.

Cannulae have a valve that prevents loss of insufflation gas. The three main types of valves are the automatic spring-loaded valve (trumpet valve), which closes automatically when an instrument is removed from the cannula; the multifunctional valve, which is essentially a trumpet valve with a lever that permits manual opening of the valve; and the silicone leaflet valve, which is frequently found on disposable cannulae. For economic reasons, reusable (autoclavable) metal cannulae are the most popular and logical choice. Cannulae with multifunctional valves are preferred. Manual opening of the valve facilitates the introduction of sharp instruments, such as needles for suture or injection, without dulling them or damaging the rubber ring lining the valve flap (FIGURE 6). Metal cannulae are also popular because they reduce the risk of inadvertent thermal burns (i.e., direct and capacitative coupling) when monopolar cautery is used for hemostasis. Metal cannulae permit the conduction of stray currents to the return electrode via the relatively large volume of tissue in contact with the cannula wall, lessening the likelihood of arcing of current to another intraabdominal organ.

The Insufflator
An insufflator is used to distend the abdominal space with an inert gas, creating pneumoperitoneum—the “working space” necessary to examine the viscera, conduct surgical manipulations, and minimize the risk of inadvertent damage to intraabdominal structures when instruments are introduced into the abdominal cavity. Insufflators are widely available, but it is important to obtain one capable of high insufflation rates (i.e., 20 to 40 L/min) to fill a horse’s voluminous equine abdomen in a timely fashion (FIGURE 7). Modern insufflators can self-regulate: when a predetermined pressure is obtained, the insufflator shut-off mechanism activates so that no additional gas is injected.

Various inert gases have been used for insufflation; however, carbon dioxide (CO₂) is the most popular because it is associated with a low risk of venous gas embolism, is not combustible, and is relatively less expensive. Insufflation with CO₂ carries the risk of inducing hypercarbia and acidosis, a detailed discussion of which is beyond the scope of this article; however, at moderate insufflation pressures (≤15 mm Hg), these effects are limited in healthy patients. For most procedures, an insufflation pressure of 8 to 15 mm Hg is used, but with experience, lower insufflation pressures are frequently possible. It is seldom necessary (or desirable) to exceed 15 mm Hg.

Hand Instruments
Although many laparoscopic instruments are available and specialized ones are required for certain procedures, many routine equine laparoscopic procedures (e.g., cryptorchidectomy, ovariectomy) have relatively modest instrument requirements (BOX 1). Instruments are available in diameters of 5 and 10 mm and...
Box 1. Basic Equipment for Routine Laparoscopic Procedures in Horses

<table>
<thead>
<tr>
<th>Tower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical table (with independent height adjustment at each end)</td>
</tr>
<tr>
<td>Color monitor (liquid crystal display or cathode ray tube)</td>
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<tr>
<td>Halogen or xenon light source with cable</td>
</tr>
<tr>
<td>Charge-coupled device camera and control unit</td>
</tr>
<tr>
<td>(\text{CO}_2) insufflator and compressed (\text{CO}_2) tanks with a (\geq 20\text{-L/min}) capacity</td>
</tr>
<tr>
<td>Digital capture unit with a color printer(^{\text{a}})</td>
</tr>
<tr>
<td>Electrosurgical unit(^{\text{b}})</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Instruments/tools</th>
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</thead>
<tbody>
<tr>
<td>30°-angle, 10-mm telescope (30 or 60 cm in length)</td>
</tr>
<tr>
<td>Laparoscopic cannulae (four or five reusable cannulae suffice for many procedures)(^{\text{c}})</td>
</tr>
<tr>
<td>Laparoscopic scissors(^{\text{d}})</td>
</tr>
<tr>
<td>Grasping forceps with teeth (two or three suffice for many procedures)(^{\text{e}})</td>
</tr>
<tr>
<td>Laparoscopic Babcock forceps (grasper and knot pusher)(^{\text{f}})</td>
</tr>
<tr>
<td>Laparoscopic injection needle (for local anesthetic injection)</td>
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\(^{\text{a}}\) Optional.

\(^{\text{b}}\) The 10-mm version is most common; larger sizes (12–15 mm) are required for most stapling equipment.

\(^{\text{c}}\) The 45-cm version with an electrosurgery post is most versatile.

Lengths of 33 and 45 cm, with 33-cm instruments available in disposable or autoclavable forms. Equine surgeons usually use 10-mm x 45-cm instruments because they are robust and lessen the need for cannulae in various diameters. I prefer to use 5-mm instruments for most procedures because they are strong enough for use in horses and are available in a suitable length (45 cm) at a substantially lower cost than 10-mm instruments of similar lengths (FIGURE 8). Moreover, the smaller body wall defect created by 5-mm instruments typically requires only skin closure, which is more in line with the tenets of minimally invasive surgery.

**Fundamental Principles of Laparoscopic Surgery**

**Abdominal Access**

Safe abdominal access—a prerequisite to any laparoscopic procedure—will be covered in detail in a subsequent article.

**The Telescope-Camera Unit**

Because the telescope and attached camera are the surgeon’s “eyes,” appropriate use of these tools is important. Less-than-ideal camera work is a significant impediment to surgical efficiency. A fundamental requirement for proficient camera use is to keep the camera head upright at all times (FIGURE 9). This consistent orientation minimizes head tilting and awkward postures by the surgical team. The surgeon should be able to use the 30°-angle offset field of view to obtain different perspectives of the surgical field. In addition, the surgeon should be able to position the telescope tip to reduce interference and collisions between instruments and the telescope (FIGURE 10).

The distance between the objective portion (tip) of the laparoscope and the structures of interest must be optimized. The apparent intensity of light is governed by the inverse-square law: intensity is inversely proportional to the square of the distance from the telescope to the anatomic structure being viewed. Therefore, modest increases in distance from the telescope tip to the surgical field result in substantial decreases in intensity of light (FIGURE 11), and maintaining an optimal distance from the telescope tip to the structure(s) of interest is paramount. The telescope tip can be withdrawn to

**Figure 9.** A three-chip camera attached to a laparoscope. Care should be taken to keep the camera upright (i.e., controls facing upward) at all times, even when the laparoscope is rotated to vary the field of view in the abdomen.

**Figure 10.** Diagrammatic representation of the arrangement of a 30°-angle laparoscope and two hand instruments. The approach angle of the laparoscope reduces interference with instrument manipulations.
obtain a “panoramic” view within the abdomen to allow orientation to tissue and targeting of the surgical field by hand instruments. For precise manipulations (e.g., fine dissection, ligature placement, knot tying), the tip of the telescope is positioned substantially closer to the work area to take advantage of the consequent magnification and improved illumination. Frequent adjustments of light intensity are normal when the laparoscope is telescoped repeatedly.

**Triangulation and Optical-Coaxial Alignment**

After introduction of the laparoscope and examination of the structures of interest, careful portal planning fulfills the fundamental concepts of triangulation and optical-coaxial alignment. Triangulation involves arranging the telescope and instrument(s) to converge on the location of interest at an appropriate angle. While precise angles are often dictated by regional anatomy and the surgical procedure, the efficiency of complex manipulations may be maximized by placing instrument portals so that instruments approach each other at a 25° to 45° angle. Approach angles of <20° tend to increase the likelihood of instrument collision, crossing, and interference.

Intraabdominal manipulations are optimized when at least 50% of the length of the instrument is within the abdomen, as performance of intricate intraabdominal tasks (i.e., intracorporeal suturing) declines when much of the instrument shaft is outside the abdomen. When possible, instrument portals should flank the laparoscope portal (FIGURE 12). Arranging the telescope and instrument portal sites in a converging triad, with the optical port in the center, fosters efficient instrument use and avoids having one instrument “eclipse” the surgeon’s view of another instrument. In some instances, this arrangement is not possible or required, so the telescope is situated to one side of the paired primary instrument portals (FIGURE 13). In this case, transient obstruction of an instrument is unavoidable because one instrument is intermittently situated directly between the telescope and a deeper or more distant instrument. Typically, this portal arrangement should be avoided, particularly by less experienced laparoscopists.

Another important tenet of laparoscopic surgery is optical-coaxial alignment. Ideally, a direct line from the surgeon through the telescope, instruments, and surgical field to the monitor should be established. When optical-coaxial alignment is achieved, movement of an instrument to the left within the patient appears as a movement to the left on the monitor (FIGURE 12). The converse alignment, called reverse camera, occurs when the laparoscope or an instrument situated between the monitor and the surgeon is directed toward the surgeon. In this instance, movements are the

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**Figure 11.** (A) View of the left ovary and uterine horn of a mare with the laparoscope tip ~10 cm from the surface. (B) The same structures as in Figure 11A viewed from a distance of ~5 cm. Note the dramatic increase in illumination and magnification produced by halving the distance from the telescope.

**Figure 12.** Diagram illustrating triangulation and optical-coaxial alignment. Triangulation involves convergence of the telescope and instruments approximating the shape of an isosceles triangle. A direct line formed by the surgeon, telescope, and instruments toward the monitor (optical-coaxial alignment) is comfortable and avoids (1) paradoxical movement associated with the telescope or (2) reverse camera (direction of an instrument toward the surgeon).

**Figure 13.** Diagrams illustrating (A) conventional placement of a laparoscope in a central position with the instruments to each side and (B) placement of a telescope to the side of a pair of instruments. Arrangement A should be used when possible to maximize efficiency and visibility. In arrangement B, the instrument on the far right can be obscured by the intervening one, potentially reducing efficiency.
opposite of what appears on the monitor (paradoxical movement), which can be difficult to interpret. Reverse camera should be avoided when possible, although in certain circumstances, it is necessary. In reverse camera, instrument manipulation requires considerably more cerebral processing, which can prolong the procedure and increase the surgeon’s fatigue.

Use of Hand Instruments

Because of the decreased field of view in laparoscopic surgery, locating hand instruments within the abdomen can be challenging for a beginner. This problem is remedied by directing the telescope tip toward the cannula through which an instrument is to be introduced while adopting as wide a field of view as possible. Then the instrument, with its jaws closed, can be introduced into the abdominal cavity and advanced to the area of interest under direct vision.

Another fundamental skill of laparoscopic surgery is the use of tactile feedback. To counteract impaired depth perception due to two-dimensional depiction of the surgical field, target tissue can be gently touched to visually confirm the orientation and position of instrument tips. This is also an essential element of laparoscopic tissue handling.

Other general principles of instrument use and tissue handling in laparoscopy parallel those of open surgery. For example, keeping the tips of curved laparoscopic scissors in view confirms their orientation to target tissues. This is important because if scissor tips are oriented away from the laparoscope, they are hidden from view, impairing monitoring of dissection. As a result, suboptimal dissection or even inadvertent injury to abdominal organs can occur. Therefore, efforts to optimally orient tissues with a second grasping instrument are vital to accurate dissection. As in open surgical procedures, the curve of the scissors conventionally follows the corresponding contour of the tissue being incised. Instrument tips can be adjusted using the rotational control wheel on most laparoscopic instruments (FIGURE 14).

Ambidexterity

While many arthroscopic procedures require holding a camera in one hand to monitor the use of an instrument, many manipulations in laparoscopic surgery involve coordinated use of instruments in both hands. Developing ambidexterity is particularly useful for more advanced procedures, including intracorporeal suturing, because in some circumstances, the introduction and advancement of a needle through tissues are best accomplished with the nondominant hand. The involvement of the instrument controlled by the nondominant hand is paramount to appropriately orienting tissues for dissection or for placement of hemostatic loops or stapling devices. Seemingly inconsequential changes in tissue orientation can greatly facilitate or impede a task. Recognition of this elemental requirement has led to the development of curricula to train surgeons how to perform laparoscopic procedures in people, and similar programs are being developed for veterinary surgeons.

Ergonomics

Adopting awkward postures during laparoscopic procedures can increase practitioner fatigue, frustration, and inefficiency. The following recommendations for operating-room setup have been shown to optimize ergonomics and mitigate mental and physical fatigue.

Surgical Table Height

Optimal height of the surgical table is an important consideration because the long-handled instruments used in laparoscopic surgery may lead to a positional mismatch between the patient and the surgeon. Ergonomically, the appropriate angle between the upper and lower arm while performing manual work is between 90° and 120°. Thus, the table height should be adjusted so that the instrument handles are positioned at or somewhat lower than the surgeon’s elbows. This can require supplementary means to optimize the relative positions of the surgeon and the patient. For example, portable steps are often placed next to the surgical table to accommodate the elevated pelvic area in a horse in Trendelenburg position during laparoscopic cryptorchidectomy.

Monitor Position

Laparoscopic surgery can require the surgeon to adopt a relatively static posture for considerable periods of time, and the vertical position of the monitor can significantly influence back and neck posture. For maximum comfort, it has been recommended to position the monitor approximately 1.5 M away from the eyes at 15° to 40° below eye level.

Foot Pedal Switches

Several electrosurgical and other instruments used in laparoscopy are activated by foot pedals. Suitable placement of these pedals can minimize discomfort and fatigue related to awkward body postures. Foot pedals should be placed near the foot and aligned with the orientation of the instruments and monitor, mirroring optical-coaxial alignment.
References