Hemostasis must be accurate in laparoscopic surgery because it is vital to extirpative and reconstructive procedures. Even small amounts of hemorrhage can negatively influence the efficiency and safety of any procedure. In addition to physically obscuring anatomic structures, hemorrhage—even modest amounts—can darken the surgical field, reducing reflection of light and, therefore, visibility. During laparoscopic procedures, hemostasis can be effected by a number of means, which can broadly be categorized as mechanical or electrical/electronic.

Mechanical Hemostasis

Mechanical hemostasis can be accomplished by one or more of three general means: ligatures, hemostatic clips, and laparoscopic staples. While clips and staples are more convenient and easier to use, they are considerably more expensive than ligation with standard suture materials. Many equine laparoscopists use ligature loops for diverse applications and reserve the use of clips or staples for particular situations or exceptional circumstances.

Ligature Loops

In laparoscopic surgery, ligatures are placed for the same reasons as in open surgical procedures, but the mechanics of their placement differs. In human laparoscopic surgery, the most common ligature may be ligating loops—commercially prepared preformed loops with a locking, sliding knot and a free suture strand that traverses the length of a pushrod within its lumen. The structure to be ligated is encircled with the loop, and when traction is applied to the free end of the suture, the loop progressively tightens by the action of the pusher on the locking, sliding knot. Commercial ligating loops are composed of absorbable or nonabsorbable material and are most popular in USP sizes of 2-0 or 0 (FIGURE 1). Prepackaged, sterile ligature loops are relatively expensive and are not always large enough for encircling structures in a horse's abdomen; in addition, the caliber of these sutures is occasionally inadequate for use in equine laparoscopy. Therefore, equine surgeons often prepare their own ligature loops and use purpose-made autoclavable pushrods to reduce expense and allow placement of relatively large loops over the large distances often encountered in equine surgery. A functional ligature loop is relatively easily fashioned by tying a unidirectional sliding knot (see below); if monofilament absorbable materials are used, the shape of the loop is usually reasonably well maintained due to the suture's inherent memory. Ligature loops should be prepared tableside rather than pretied and sterilized, as clinical experience and research indicate that sterilization significantly weakens sutures, predisposing them to breakage or knot failure. A number of unidirectional slipknots have been described; while certain ones have been shown to be stronger than others, most are satisfactory for routine hemostatic purposes. Conventional and modified Roeder, Weston, Tayside, and Melzer knots are popular. When clinical circumstances require a knot of maximal strength, certain ones have been shown to be stronger than others, most are satisfactory for routine hemostatic purposes. Conventional and modified Roeder, Weston, Tayside, and Melzer knots are popular. When clinical circumstances require a knot of maximal strength, comparative research supports the recommendation of using a 4-S modified Roeder knot fashioned with 2 USP polydioxanone. Thorough familiarity with one or more unidirectional slipknots is a prerequisite to preparing and using ligature loops, and specific techniques for preparing knots can be found in standard texts and online.

Preformed ligature loops are useful for effecting hemostasis or ligating structures with a pedicle and a free end. In equine surgery, this most commonly includes the vascular pedicle of cryptorchid...
testicles or ovaries (once they are freed from uterine attachments). Ligating loops are placed with the assistance of a second instrument that steadies the structure of interest while the loop is placed and manipulated to its intended final position. Then tension is applied to the tail of the suture to tighten the loop. The final location of the loop is controlled by placing the tip of the knot pusher at the desired final location of the knot (FIGURE 2).

In contrast to preformed loops, ligatures can be placed by passing a length of suture around the structure to be ligated, exteriorizing the free end of the suture strand, and completing the loop by tying one of the aforementioned locking slipknots extracorporeally, essentially creating a ligature loop within the abdomen and preparing the knot outside the patient. Then the knot can be advanced to its final position using a laparoscopic Babcock forceps (FIGURE 3). While extracorporeal knots can be used for the same reasons as preformed loops, the knots are more frequently used when the structure to be ligated is in continuity (i.e., there is no free end over which a preformed loop can be placed) or when the free end of the structure with a pedicle is large (e.g., ovarian tumor).

Hemostatic Clips
The various forms and appliers of hemostatic clips are similar in overall design. Clips can be loaded individually into reusable appliances (FIGURE 4) or can be applied using preloaded, multiple-feed devices available from surgical supply companies. These mechanisms produce flat or banana-shaped, open clips that occlude small vessels (FIGURE 5). Although orienting the structure of interest (tissue presentation) can be somewhat awkward, clip application is relatively straightforward. Potential problems associated with using clips include their expense—particularly with disposable, multifeed devices—and occasional slippage or failure to occlude the vessel due to inadequate compressive force. Most clips are composed of titanium or stainless steel; polymer-based devices are also available, some of which have small teeth to improve the gripping surface. When using clips, it is important to adequately dissect the vessel from the surrounding fascia to minimize the amount of tissue within the clip.

Staples
While manufactured for use in gastrointestinal (GI) anastomosis, laparoscopic versions of GI staplers can be useful hemostatic tools (FIGURE 6). Staplers can help control unanticipated hemorrhage and are useful for simultaneous transection and hemostasis of relatively large pedicles, such as the mesovarium of a neoplastic ovary. Staplers are also convenient for obtaining biopsy specimens while controlling hemorrhage.\(^6,7\) Like GI anastomosis staples used in open surgery, laparoscopic staplers place three staggered rows of staples on either side of a centrally located incision (FIGURE 7). Several cartridge sizes are available, depending on the manufacturer, and staple dimensions also vary. Typically, staples with long (4.5 mm) “legs” are recommended for equine applications.

Electrocautery and Electromechanical Coagulation

**Conventional Electrocautery**

In laparoscopic surgery, electrocoagulation is accomplished using principles and devices similar to those used in open surgery. Monopolar and bipolar electrocautery equipment can be used laparoscopically. In monopolar electrocautery, the current is delivered through an instrument to a focused, small point that generates an elevated current density in a relatively small amount of tissue, causing it to heat. Current flows through the patient to a return electrode, via a dispersive plate, to complete the electrical circuit. The large surface area of the dispersive plate reduces current density and prevents unintended burns at the electrode. Monopolar cautery is technically simple and relatively inexpensive, and virtually any instrument with a cautery post can be used to deliver electrical energy to target tissues. Monopolar cautery is versatile: cutting and/or coagulation can be accomplished by selecting an appropriate electrical waveform on the generator. A disadvantage of this mode of electrosurgery is that there are several ways in which stray electrical current can unintentionally damage tissue. Because stray current can pass through tissues outside the field of view, thermal injuries may not be detected during surgery.\(^6,7\) Depending on the organ(s) affected, thermal burns can have serious clinical consequences; delayed onset of relatively vague clinical signs is common.\(^6,8\)

The most insidious reason for unnoticed arcing to intraabdominal organs is capacitative coupling, in which electrical energy is stored in two conductors separated by an insulator. This form of stray current is less likely to cause damage when metal cannulae are used because the stored energy is conducted via the cannula wall.
to a relatively large surface area of adjacent body wall and skin, dissipating the current density and substantially reducing heating of tissue. Thus, for monopolar cautery, the use of metal cannulae is recommended.

Stray currents can be avoided with bipolar cautery (FIGURE 8). In bipolar systems, the instrument tip houses both active and return electrodes so that current does not flow through the patient. Only the tissues within the tines of the instrument are included in the electrical circuit. In addition, bipolar instruments are usually used with lower power settings than monopolar units. As a result, many of the problems associated with monopolar cautery are circumvented; however, even with this selective, focused application of current, tissue can be heated and damaged at a distance from the target tissue. The principal disadvantages of bipolar electrosurgery are that coagulation is relatively slow, largely due to its low-voltage waveform, and the electrodes often adhere to tissue. Although bipolar electrosurgery is effective for coagulation, it has minimal cutting ability, necessitating frequent exchange of scissors and the cautery forceps. Repeated instrument exchanges, which laparoscopic surgeons call instrument traffic, can add significant time to surgery.

Advanced Bipolar Cautery Technologies

Several technologic developments have provided tools that address some of the shortcomings of conventional electrosurgery systems. These tools entail “smart generators” that use tissue impedance feedback capabilities combined with highly pulsed or continuous current. These systems use low voltage, which reduces the risks of arcing and coulombic effects with conventional monopolar cautery (FIGURE 9). Variations of these systems exist, but they all reduce carbonization, sticking of tissue to the instrument, the smoke plume, and the zone of thermal damage; all of these effects are largely a result of the low voltage of these systems compared with the voltage of conventional cautery units. TABLE 1 compares the general features of four advanced bipolar systems.

Ultrasonic Dissectors

Ultrasonic dissectors are instruments equipped with transducers that produce mechanical energy of electrical origin. Coagulation is effected by mechanically disrupting hydrogen bonds and proteins,
forming a coagulum that seals vessels. These dissectors function by vibrating the “active blade” at 23 to 55 kHz against an immobile Teflon block (FIGURE 10). This vibration imparts mechanical energy into the structure within the shears, forming a coagulum and dividing the structure. Ultrasonic shears and other dissecting instruments are available from several endosurgical instrument manufacturers (TABLE 2).

### Advanced Technologies: Comparative Elements

All of the available advanced bipolar and ultrasonic instrument systems perform well. A comparative study using vessels from porcine cadavers revealed that, although differences were noted among some of the parameters depending on vessel size and the specific instrument, all of the instruments performed adequately with respect to seal time (the time from application of the instrument to sealing of the vessel), burst pressure (strength of the vessel seal), and failure rate (instances in which sealing was ineffective at elevated intravascular pressures). In general, advanced bipolar units produce a seal with a higher burst pressure than that created with ultrasonic devices.

The selection of an electrical or electromechanical vessel-sealing system can be dictated by a various considerations, not the least of which is price. As technology advances, it is frequently possible to obtain generators and handpieces at very reasonable prices from human hospitals that are upgrading their systems. Some consideration should be given to durability, as handpieces are rather expensive; therefore, obtaining devices with autoclavable/reusable handpieces is appealing because they can provide long-term use and facilitate cleaning and sterilization.

### Clinical Use

Clinical use of these advanced instruments has facilitated accurate tissue dissection and hemostasis with much-reduced instrument traffic and safety risks compared with the use of conventional bipolar or monopolar coagulation devices. Nonetheless, safe use of this equipment requires care by the surgeon. These devices should not be activated unless the instrument tip is in direct view and clearly visible on the monitor. Although these devices generate substantially less heat than conventional electrosurgical devices, “isolating” structures at risk for thermal damage before using these devices is paramount. While a standard electrocautery unit that employs monopolar and bipolar coagulation can serve the needs of surgeons who occasionally perform laparoscopic procedures, surgeons who regularly perform these procedures may want a more advanced unit. These newer systems have the important advantages of instruments that grasp firmly and provide safe coagulation with minimal thermal spread.

### References


### Table 2. Ultrasonic Dissection/Hemostatic Systems

<table>
<thead>
<tr>
<th>Name</th>
<th>Manufacturer</th>
<th>Generator</th>
<th>Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autosonix</td>
<td>Covidien Healthcare, Norwalk, CT</td>
<td>Autosonix Generator box</td>
<td>Single-use, 5-mm shears (30 and 38 cm), hooks (35 cm), and ball probe</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(34 cm)</td>
</tr>
<tr>
<td>SonoSurg</td>
<td>Olympus KeyMed, Center Valley, PA</td>
<td>SonoSurg Ultrasonic Generator</td>
<td>Autoclavable, 5-mm shears (34 and 45 cm in length) and hooks/spatulas</td>
</tr>
<tr>
<td>Harmonic</td>
<td>Ethicon Endo-Surgery, Cincinnati, OH</td>
<td>Harmonic Generator 300</td>
<td>Single-use, 5-mm shears (14–45 cm in length); dissecting hooks, blades,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and ball coagulators</td>
</tr>
</tbody>
</table>