EVALUATION OF THE HARMONIC SCALPELÔ FOR LAPAROSCOPIC BILATERAL OVARIECTOMY IN STANDING HORSES

by

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(ABSTRACT)

Objective – To evaluate a surgical technique for performing laparoscopic bilateral ovariectomy in standing horses.

Study Design – Experimental study.

Animals or Sample population – 8 mares, age 2-20 years, weight 410-540 kg.

Methods – Standing laparoscopic bilateral ovariectomy was performed in 8 mares with normal anatomy of the reproductive tract. The Harmonic Scalpel™ (an ultrasonically activated instrument) was used to transect the ovarian pedicle and to obtain hemostasis simultaneously. Necropsy was performed on 4 mares 3 days after surgery and 30 days following surgery on the remaining 4 mares. Gross and histopathologic evaluation of the ovarian pedicles was performed to characterize the effects of the Harmonic Scalpel™ on the transected tissue.

Results – The Harmonic Scalpel™ achieved complete hemostasis of the vasculature of the ovarian pedicles in all mares. Median transection time for the ovarian pedicle was 28 minutes. Postoperative complications included transient fever in one mare, moderate subcutaneous emphysema in another, and incisional seroma formation in a third mare.

Post-mortem examination 3 and 30 days postoperatively revealed no signs of generalized peritonitis, postoperative hemorrhage or adhesion formation. Mild to moderate acute inflammation, and scar formation with moderate chronic inflammation at the ovarian pedicle was found 3 and 30 days after surgery, respectively. Median depth of coagulation necrosis 3 days postoperatively was 2.87 mm.

Conclusions – The Harmonic Scalpel™ appears to provide reliable hemostasis of the ovarian pedicle during elective laparoscopic ovariectomy in horses.

Clinical Relevance – The Harmonic Scalpel™ represents a safe alternative to other means of hemostasis during elective laparoscopic ovariectomy in horses.

Diese Arbeit ist meiner Familie gewidmet, im Andenken meiner Großeltern!

This work is dedicated to my family, in loving memory of my grandparents!

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

APH	American Paint Horse
AV block	Atrio-ventricular blockage
Baso	Basophilic granulocytes
Band	Band nuclear granulocytes
BAR	Bright, alert and responsive
Eos	Eosinophilic granulocytes
HCT	Hematocrit
IV	Intravenously
Lymph	Lymphocytes
Mono	Monocytes
N/A	Not applicable
PP	Plasma protein
QAR	Quiet, alert and responsive
Seg	Segmented neutrophils
THB	Thoroughbred
WBC	White blood cell count
WNL	Within normal limits

Chapter 1. Introduction

Removal of the ovaries in mares has been associated with serious perioperative complications, including incomplete hemostasis, shock, postanesthetic myopathy, colic, incisional complications and even sudden death. Causes for these have not always been elucidated (Nickels 1988, Scott and Kunze 1977, Meagher et al. 1977, Greet and Bathe 1993, Bartmann et al. 1999). Other reports showed fewer complications (Moll et al. 1987, Hooper et al. 1993, Carson-Dunkerley and Hanson 1997), but ovariectomy in the mare is still regarded as a technically difficult procedure with potentially severe postoperative complications.

Recently, laparoscopic techniques for elective ovariectomy in standing (Palmer 1993, Bouré et al. 1997, Hanson and Galuppo 1999, Mariën et al. 2000, Röcken 2000, Rodgerson et al. 2001, Hand et al. 2002) or dorsally recumbent mares (Ragle and Schneider 1995) have been described. Advantages of standing laparoscopic surgery over conventional approaches include the avoidance of general anesthesia, greatly improved intraoperative visibility, secure hemostasis, decreased surgical morbidity, decreased postoperative discomfort, rapid and uncomplicated healing and faster return to a normal level of activity (Palmer 1993, Hanson and Galuppo 1999, Walmsley 1999, Dechant and Hendrickson 2000). Disadvantages of laparoscopic ovariectomy are increased surgery times (Minami et al. 1997), the need for specialized equipment and special surgical skills (Palmer 1993).

The Harmonic Scalpel™ (Ethicon Endo-Surgery, Inc., Cincinnati, OH) is a relatively new device for providing hemostasis during laparoscopy (Lange et al. 1996, Amaral and Chrostek 1997, Minami et al. 1997, Lee and Park 1999, Holub et al. 2000, Gyr et al. 2001, Lanz et al. accepted for publication). It is an ultrasonically activated instrument that is able to coagulate and cut tissue at the same time. In human laparoscopy, the Harmonic Scalpel™ has been shown to decrease operating time and complications (Laycock et al.

1996, Erian et al. 1999, Gertsch et al. 2000, Takao et al. 2000). The Harmonic Scalpel™ has been reported to provide secure hemostasis of vessels up to 3.5 mm in diameter (Spivak et al. 1998) and its use in human laparoscopy has increased since its introduction in the 1990s (Feil 2002).

Chapter 2. Objectives and Hypothesis

The objective of this study was to evaluate a surgical technique for performing standing laparoscopic bilateral ovariectomy in horses using the Harmonic Scalpel™. It was hypothesized that the Harmonic Scalpel™ would provide adequate hemostasis during transection of the ovarian pedicle, while causing minimal collateral tissue damage.

Chapter 3. Review of Literature

3.1. Surgical Anatomy of the Equine Ovaries

The ovaries are located within the abdomen, approximately at the level of the 5th lumbar vertebra, caudoventral to the kidneys and cranioventral to the iliac wings. They are suspended from the dorsal body wall by the ovarian pedicle or mesovarium, which is continuous caudally with the broad ligament of the uterus or mesometrium (Figure 1). The ovarian pedicle contains the proper ligament of the ovary in its ventral aspect, a fibromuscular band that connects the ovary to the cranial aspect of the uterine horn. The uterine tube is a convoluted tubular structure extending from the infundibulum at the cranial pole of the ovary to the cranial aspect of the uterine horn, coursing parallel to the proper ligament of the ovary. A mesenteric fold originating from the mesovarium forms the mesentery suspending the uterine tube (mesosalpinx) (Nickel et al. 1979). The space in-between the proper ligament of the ovary and the uterine tube is termed the ovarian bursa. The ovary is located at the cranial extent of the ovarian bursa and extends more or less into it (Dyce et al. 1996).

Blood supply to the ovaries is provided by the ovarian arteries. The left and right ovarian artery originate directly from the abdominal aorta (Dyce et al. 1996), cranial to the caudal mesenteric artery, at the level of the 4^{h} lumbar vertebra. Each artery runs along the dorsal abdominal wall into the most-cranial aspect of the mesovarium towards the respective ovary, becoming more and more contorted. The ovarian artery gives rise to a uterine branch, which anastomoses with the cranial branch of the uterine artery (Ginther et al. 1972, Schummer et al. 1981a). Both arteries are accompanied by veins that are substantially greater in diameter than their corresponding arteries. This is likely due to the uterine branch of the ovarian vein representing the main venous drainage for the uterus (Ginther et al. 1972, Schummer et al. 1981b). Investigations on the approximate diameter of the ovarian arteries and veins are unavailable to the author's knowledge. It has been

stated that they appear to be less than 3 mm (Rodgerson et al. 2001) or less than 1 cm (Hand et al. 2002) in diameter as observed subjectively during laparoscopic ovariectomy.

A cycle-dependent flow pattern within the ovarian artery has been shown to exist in the mare (Bollwein et al. 2002). The highest pulsatile index (a measure for blood flow obtained by means of transrectal Doppler ultrasonography) was found 1 to 2 days after ovulation. The pulsatile index then decreased until 5 to 6 days post ovulation, when lowest values were recorded, and increased again until 15 days after ovulation. During diestrus (0-15 days post ovulation), the artery supplying the ovary carrying the corpus luteum showed lower blood flow than the contralateral artery.

3.2. Ovariectomy in Equids

3.2.1. Indications

Indications for elective bilateral ovariectomy in the mare include elimination of objectionable behavior or colic during estrus, sterilization, and preparation of embryo transfer recipients and jump mares (Hooper et al. 1993, Hanson and Galuppo 1999). In contrast, mares with ovarian pathology, such as granulosa cell tumors, teratomas, melanomas, cystadenomas or cystadenocarcinomas, epitheliomas, dysgerminomas, as well as ovarian abscesses or hematomas, are commonly treated by unilateral ovariectomy (Moll and Slone 1998).

3.2.2. Effects of bilateral ovariectomy

Bilateral ovariectomy will not eliminate estrus behavior in all mares (Asa et al. 1980, Hooper et al. 1993, Palmer 1993, Gottschalk and van den Berg 1997). In one study, 35 % of ovariectomized mares continued to show signs of estrus behavior, but in only 9 % did

the owner judge the behavior as objectionable. Further, most mares (11/12) were able to compete at the same or higher level of performance after bilateral ovariectomy (Hooper et al. 1993). Mares exhibiting extreme aggression toward humans or other horses may not change their behavior after bilateral ovariectomy (Scott and Kunze 1977).

3.2.3. Conventional surgical approaches

Elective bilateral ovariectomy in the standing mare was traditionally performed via colpotomy with the use of a chain écraseur for hemostasis (Hooper et al. 1993). Potential complications include hemorrhage from the ovarian pedicle, eventration through the colpotomy incision, peritonitis, postoperative pain, colic, delayed vaginal healing, abscess and hematoma formation at the incision site within the vaginal vault, as well as vaginal adhesions. Damage to the rectum, bladder, cervix, or vessels of the pelvic regions have been described (Nickels 1988, Moll and Slone 1998), as well as erroneous removal of omentum, mesentery, intestines, or fecal balls within the small colon (Nickels 1988). This technique is limited to the removal of normal ovaries or tumors up to 8 or 10 cm in diameter, due to the increased vascular supply in larger tumors (Scott and Kunze 1977, Colbern and Reagan 1987). Also, a larger colpotomy incision likely predisposes the mare to postoperative eventration. Limitations with operative visibility and exposure prevented this approach from becoming popular with veterinarians.

In 1 study, 4 % of mares undergoing elective bilateral ovariectomy via colpotomy developed postoperative peritonitis (Hooper et al. 1993). In another study, 10 mares undergoing bilateral ovariectomy via colpotomy showed moderate to severe inflammatory changes within their peritoneal fluid 3 and 7 days postoperatively, but bacteria were not noted (Colbern and Reagan 1987).

Laparotomy through the flank in the standing mare represents an alternative approach to colpotomy. Exposure for ligation of the ovarian blood supply is the major problem

encountered and an écraseur, emasculator, or stapling device may be needed for hemostasis (Beard 1991, Moll and Slone 1998). Possible complications include hemorrhage from the ovarian pedicle, peritonitis, colic and incisional problems. Wilson et al. (1995) reported a high incidence of incisional complications (88%) when celiotomies were performed in a region other than ventral midline.

In the anesthetized horse, caudal ventral midline or oblique paramedian approaches may be used for elective bilateral ovariectomy. These approaches are recommended over standing approaches in intractable mares. Adequate exteriorization of the ovaries for ligation of the ovarian blood supply is less difficult with the oblique paramedian approach, compared to the ventral midline approach. However, problems may still be encountered with exteriorization and manual ligation of the ovarian blood supply. An écraseur, emasculator, or stapling device may be used for hemostasis (Moll and Slone 1998). Hypotension, shock, hemorrhage, abdominal pain, peritonitis, nerve paresis, postoperative myopathy, wound dehiscence, herniation, diarrhea, and death during surgery are reported complications of ovariectomy under general anesthesia (Meagher et al. 1977, Scott and Kunze 1977).

The use of a surgical stapling device has been reported to facilitate hemostasis especially for removal of pathologic ovaries with a more extensive blood supply. It also makes tedious dissection of the ovarian pedicle prior to ligation unnecessary (Doran et al. 1988, Greet and Bathe 1993). The additional cost of the equipment may be offset by a decrease in surgery time.

The type of approach and means of hemostasis for ovariectomy in mares should be determined by considering the size of the ovary or ovaries to be removed, possible pathology, temperament and physical condition of the mare, economical constraints, experience of the surgeon and availability of facilities and equipment (Scott and Kunze 1977).

3.2.4. Laparoscopic Ovariectomy

3.2.4.1.Preparation of the animal for laparoscopy

In order to decrease intestinal content, avoid gas distention of the intestines and allow for improved exposure of the abdominal organs, horses are held off feed prior to laparoscopic procedures. Length of time during which horses were withheld feed range from 72 hours (Palmer 1993) over 36 hours (Galuppo et al. 1995, Hand et al. 2002), 24-36 hours (Fischer et al. 1986, Hanson and Galuppo 1999) to 24 hours (Wilson 1983). Alternatively, offering reduced quantities of feed or using a low bulk-residue diet for at least 48-72 hours preoperatively has been used to decrease intestinal content prior to laparoscopic ovariectomy (Ragle and Schneider 1995, Ragle et al. 1996). No apparent difference in the quality of exposure of abdominal organs was seen between horses fasted for 48 hours and horses held off hay for 24 hours and off grain for 12 hours prior to standing laparoscopic ovariectomy (Bouré et al. 1997). Withholding feed for a minimum of 24 hours was deemed to be necessary by Hanson and Galuppo (1999) for adequate abdominal exposure, as intestinal distention greatly impeded abdominal observation in one mare that was held off feed only for 12 hours prior to standing laparoscopic ovariectomy. In contrast, Rodgerson et al. (2001) withheld feed for at least 12 hours in mares prior to standing laparoscopic ovariectomy, and reported adequate decrease of bowel distention.

For a standing laparoscopic procedure, the horse typically is restrained in stocks and medicated with an α_2-agonist alone, such as xylazine or detomidine hydrochloride (Gottschalk and van den Berg 1997), or in combination with butorphanol tartrate to augment analgesia (Fischer et al. 1986, Palmer 1993, Galuppo et al. 1995, Hendrickson and Wilson 1996, Ragle et al. 1996, Hanson and Galuppo 1999, Rodgerson et al. 2001, Hand et al. 2002, Rodgerson et al. 2002). In some studies, horses also received acepromazine maleate (Palmer 1993, Bouré et al. 1997).

Epidural anesthesia using detomidine hydrochloride may be used to provide sedation and analgesia of the ovarian pedicles. Additional local anesthesia of the paralumbar fossa is however required, as flank analgesia with epidural detomidine is usually inadequate for surgical procedures (Dechant and Hendrickson 2000). Similarly, Seyrek-Intas et al. (2001) reported that lumbosacral subarachnoidal injection of 40µg/kg detomidine hydrochloride resulted in profound sedation, but flank analgesia was insufficient for placement of laparoscopic trocar-cannula units.

Desensitization of the abdominal wall for insertion of the laparoscopic cannulas can be achieved by local infiltration of the portal sites with a local anesthetic (Fischer et al. 1986, Galuppo et al. 1995, Ragle et al. 1996, Bouré et al. 1997, Hanson and Galuppo 1999, Walmsley 1999, Rodgerson et al. 2001, Hand et al. 2002), or by infiltration of the flank in an inverted "L" pattern (Hendrickson and Wilson 1996, Gottschalk and van den Berg 1997, Röcken 2000).

The ovary is usually desensitized under laparoscopic control by infiltration of a local anesthetic into the ovarian pedicle and broad ligament of the uterus alone (Palmer 1993, Bouré et al. 1997, Hanson and Galuppo 1999, Rodgerson et al. 2001, Hand et al. 2002), or in combination with injection of local anesthetic into the ovary (Gottschalk and van den Berg 1997).

3.2.4.2. Approaches in standing laparoscopy

Several different locations of laparoscope and instrument portals have been described for laparoscopy in the standing horse. Fischer et al. (1986) used a laparoscope portal located midway between the last rib and the tuber coxae, dorsal to the origin of the internal abdominal oblique muscle, to perform diagnostic laparoscopy in standing horses. Visible structures with an approach from the left side included the spleen, perirenal fat, the dorsal aspect of the stomach, diaphragm and liver cranially, and small and large intestine, small

colon, left inguinal ring, left ovary and horn of the uterus, and bladder caudally. On the right side of the abdomen, the base of the cecum, root of the mesentery, descending duodenum, right lobe of the liver and diaphragm are visible cranially, and similar structures as on the left side are visualized caudally. This approach has been used and modified slightly since.

Palmer (1993) used a laparoscope portal at the level of the ventral aspect of the tuber coxae and equidistant between the last rib and the cranial border of the tuber coxae for standing laparoscopic ovariectomy in mares. The instrument portals were located 3 cm dorsal and ventral to the laparoscope portal. Rodgerson et al. (2001) used similar portal locations for laparoscopic ovariectomy in small mares, but in larger animals, the location for the laparoscope portal described by Fischer et al. (1986) with instrument portals cranio- and caudoventral to the laparoscope portal was perceived to facilitate manipulation of the instrument handles.

Hanson and Galuppo (1999) placed their laparoscope portal just caudal to the last rib, immediately dorsal to the internal abdominal oblique muscle. The first instrument portal was placed just cranial to the tuber coxae, and the second was located approximately 3-4 cm distal in the same vertical plane.

Bouré et al. (1997), Walmsley (1999), and Mariën et al. (2000) placed the laparoscope portal between the last two ribs, and the 2 instrument portals in the paralumbar fossa to perform ovariectomy on standing mares. This placement may facilitate intraabdominal manipulations, especially in short-coupled mares. A potential complication is the intrathoracic placement of the cannula located between the last 2 ribs and a subsequent pneumothorax.

Hand et al. (2002) placed the laparoscope portal just cranial to the tuber coxae and the first instrument portal in-between the last 2 ribs at the level of the ventral aspect of the

tuber coxae. This portal placement could also result in entering of the thoracic cavity, especially if placed too far dorsally. The second instrument portal was located slightly caudal to the last rib and dorsal to the internal abdominal oblique muscle.

3.2.4.3.Entry into the abdomen and insufflation

Most authors describe insufflation of the abdomen with carbon dioxide to augment visualization of abdominal organs during laparoscopic procedures (Fischer et al. 1986, Palmer 1993, Hendrickson and Wilson 1996, Bouré et al. 1997, Hanson and Galuppo 1999, Walmsley 1999, Röcken 2000, Rodgerson et al. 2001, Hand et al. 2002). Mariën et al. (2000) noted that the intraabdominal workspace was enlarged with carbon dioxide insufflation compared to only passive influx of air into the abdomen during standing laparoscopic ovariectomy. However, standing laparoscopically assisted ovariectomy has been performed on mares with pneumoperitoneum caused by passive influx of room air (Gottschalk and van den Berg 1997, Rodgerson et al. 2002).

Several different techniques have been described to first enter and insufflate the abdomen. One option is to carefully insert a trocar and cannula assembly through the abdominal wall of the paralumbar fossa, confirm penetration of the peritoneum with the laparoscope and subsequently start carbon dioxide insufflation (Fischer et al. 1986, Palmer 1993, Gottschalk and van den Berg 1997, Bouré et al. 1997, Mariën et al. 2000, Röcken 2000). A possible complication of this technique is puncture of intraabdominal organs with the sharp trocar. Galuppo et al. (1995) penetrated the abdominal musculature with a trocar-cannula unit, but penetration of the peritoneum was performed with the laparoscope exchanged for the trocar. Hand et al. (2002) replaced the sharp trocar with a blunt trocar prior to penetration of the peritoneum.

Ragle et al. (1996) suggested inflation of the abdomen prior to placement of a trocar-cannula unit using a long metal urine catheter, which is inserted through a stab incision in

the paralumbar fossa. Other authors also advocate insufflation of the abdomen prior to placement of the trocar-cannula unit through a trocar catheter or Veress needle in the paralumbar fossa (Wilson 1983, Hendrickson and Wilson 1996 Walmsley 1999, Rodgerson et al. 2001). Presence of the tip of the catheter in the peritoneal space is confirmed by air being sucked into the catheter or with a negative pressure reading on the insufflator after connection to the catheter. Initial insufflation through the left paralumbar fossa may be safer than through the right, since the cecum is more likely to be penetrated if the right flank is approached without prior insufflation of the peritoneal space (Walmsley 1999). Rodgerson and Hanson (2000) inflated the abdomen prior to standing laparoscopic ovariectomy through a teat cannula inserted through the ventral abdomen.

Insufflation at 2.7 l/min (Röcken 2000), or at 3-5 l/min (Hanson and Galuppo 1999) until intraabdominal pressure of 6-8 mmHg (Röcken 2000), 8-10 mmHg (Bouré et al. 1997), 10-15 mmHg (Walmsley 1999), 12-15 mmHg (Hanson and Galuppo 1999, Hand et al. 2002), 15-20 mmHg (Galuppo et al. 1995, Hendrickson and Wilson 1996), or even 40 mmHg (Wilson 1983) is obtained has been described.

3.2.4.4.Intraoperative complications

Injury to larger abdominal vessels (cranial or caudal epigastric or superficial epigastric vessels) has been reported during placement of the cannula-trocar unit in dorsal recumbency (Ragle et al. 1998, Walmsley 1999). This lead to an increase in surgery time, hematoma formation, and hemoperitoneum with decreased surgical visibility. Measures to prevent damage to larger abdominal vessels during laparoscopy in dorsal recumbency included avoiding the placement of portals in the lateral half of the rectus abdominis muscle, ensuring that stab incisions for the portals do not extend beyond the external rectus sheath, and the use of blunt or conical obturators as opposed to sharp, pyramidal trocars (Ragle et al. 1998). Damage to branches of the circumflex iliac artery or vein during standing laparoscopy has also been reported (Palmer 1993, Hanson and Galuppo

1999, Walmsley 1999, Röcken 2000). Hemorrhage from the portal sites may be stopped either by direct pressure or by enlargement of the incision and ligation of the bleeding vessel. It has also been suggested to close the portal completely and create a new portal in an adjacent location (Ragle et al. 1996).

Other complications like insufflation of the retroperitoneal space in obese or large horses, puncture of the cecum or spleen with an unguarded trocar cannula unit (Walmsley 1999), ligature slippage and incomplete hemostasis of the ovarian pedicle (Rodgerson and Hanson 2000), as well as loss of an ovary from the grasping forceps while being drawn through the body wall (Palmer 1993, Hanson and Galuppo 1999, Rodgerson et al. 2001, Hand et al. 2002) or a 33 mm cannula (Bouré et al. 1997) have also been reported.

3.2.4.5. Hemostasis of the ovarian blood supply

Several different methods are described for achieving hemostasis of the ovarian pedicle during laparoscopic ovariectomy. Palmer (1993) used an Nd:YAG laser in contact mode to divide the uterine tube and mesosalpinx (lateral wall of the ovarian bursa), as well as the proper ligament of the ovary and its mesentery (medial wall of the ovarian bursa). Hemostasis was augmented by coagulation of vessels with the laser in non-contact fashion. The ovarian vessels were isolated by laser and blunt dissection of the ovarian pedicle and subsequently occluded either with laparoscopic vascular clips or laparoscopic stapling equipment. Hemorrhage from the ovarian pedicle was not encountered.

Röcken (2000) reported on the use of a linear laparoscopic stapling device to achieve hemostasis of the ovarian blood supply of normal and neoplastic equine ovaries without prior dissection. Two to three stapling applications were needed to seal the ovarian pedicle, depending on the size of the ovary. Hemostasis was achieved in ovaries weighing up to 3.5 kg.

Gottschalk and van den Berg (1997) used extraabdominal emasculation of the ovarian pedicle for hemostasis after laparoscopically guided local anesthesia of the ovary. Rodgerson et al. (2002) performed hand-assisted laparoscopy to remove ovarian tumors in standing mares. Hemostasis was achieved with intraabdominal, digitally guided application of a conventional abdominal stapling device over the ovarian blood supply. If hemostasis was incomplete, either hemoclips or bipolar electrosurgical forceps were used to stop any bleeding.

Ligation of the ovarian pedicle with a self-made ligature loop, using a modified Roeder knot, without previous dissection of the ovarian pedicle has been reported first by Ragle and Schneider (1995). Ligature slippage occurred on one pedicle and hemostasis was obtained by placement of another ligature. A commercially available ligature loop has also been used to double ligate the ovarian pedicle without previous dissection (Bouré et al. 1997). Hanson and Galuppo (1999) ligated the ovarian pedicle with a self-made ligature loop after transection of the uterine tube with mesosalpinx (lateral wall of the ovarian bursa) and the proper ligament of the ovary with its mesentery (medial wall of the ovarian bursa). Hemostasis was inadequate after application of a single ligature in 3 of 43 ovaries, and a second ligature was placed over the vascular stumps to obtain complete hemostasis. A similar technique was used by Mariën et al. (2000), with the difference that dissection was carried out with a monopolar electrocautery hook biopsy punch, and the ligature loop was tied with a Tayside slipping knot. Rodgerson and Hanson (2000) reported on ligature slippage as a complication of the use of a ligature loop for hemostasis. The suture loop slipped from the mesovarium during transection of the latter, resulting in hemorrhage from the transected ovarian vessels. A laparoscopic bipolar electrosurgical instrument was used to coagulate the bleeding vessels, and complete hemostasis was achieved.

Monopolar or bipolar electrosurgical laparoscopic instruments and laparoscopic scissors were used to sequentially coagulate and transect the ovarian pedicle of normal ovaries by

Rodgerson et al. (2001). Intraoperative hemorrhage occurred in some mares when the ovarian pedicle was inadvertently transected prior to adequate coagulation. Bleeding was controlled with repeat application of the electrosurgical instrument. A "second-look" laparoscopy 8 months after ovariectomy revealed no complications or adhesions related to the initial procedure. Hand et al. (2002) used an electrosurgical bipolar vessel-sealing device and laparoscopic scissors to sequentially coagulate the ovarian pedicle and transect the sealed tissue. Mild hemorrhage occurred in 4 of 13 mares when tissue proximal to the coagulated area was inadvertently cut with laparoscopic scissors. Hemostasis was achieved by reapplication of the vessel-sealing device. No untoward effects of the use of electrosurgery were noticed on repeat laparoscopic exam 3 or 10 days after ovariectomy.

3.2.4.6. Extraction of the ovaries from the abdomen

In order to extract the transected ovary from the abdomen, two portal sites were connected to create one single abdominal incision. The ovary was carefully withdrawn through the incision (Palmer 1993, Hanson and Galuppo 1999). Alternatively, one portal site was enlarged to allow extraction of the ovary (Mariën et al. 2000, Rodgerson and Hanson 2000, Röcken 2000, Hand et al. 2002). Large follicles were aspirated (Palmer 1993) or punctured (Bouré et al. 1997) to facilitate extraction.

Bouré et al. (1997) used a 33 mm cannula to extract normal ovaries from the abdomen.

3.2.4.7. Duration of surgery

The time necessary to perform bilateral standing laparoscopic ovariectomy including equipment setup, abdominal insufflation and preparation of the ligature loops has been estimated to be 1.5-2 hours (Hanson and Galuppo 1999). In a study by Hand et al. (2002) surgery times for bilateral laparoscopic ovariectomy using a bipolar electrosurgical

instrument were reported to be 50 to 110 minutes. Time for ovarian transection ranged from 10 to 25 minutes. Other authors reported surgical times for laparoscopic removal of one ovary using a ligature loop for hemostasis to be 50-120 minutes (Bouré et al. 1997), 20-110 minutes (Mariën et al. 2000), and 15-65 minutes (Rodgerson et al. 2001). These times were measured from insertion of the first trocar-cannula unit until closure of the incisions.

3.2.4.8. Postoperative observations

Both abdominal fluid protein concentration and white blood cell count increased significantly 24 hours after laparoscopy, with predominance of neutrophils (Fischer et al. 1988). Palmer (1993), as well as Ragle and Schneider (1995) saw similar changes in abdominal fluid values in mares after laparoscopic ovariectomy. Clinical signs of peritonitis were not noted. Changes in abdominal fluid values may be related to abdominal insufflation with carbon dioxide, reacting with water to form carbonic acid and resulting in irritation of serosal surfaces (Ragle et al. 1996).

In one study, most mares were mildly depressed for up to 2 days and showed a transient decrease in appetite after standing laparoscopic ovariectomy (Hanson and Galuppo 1999). A transient fever during the immediate postoperative period was observed in some mares by several authors (Hanson and Galuppo 1999, Röcken 2000, Hand et al. 2002). Mild incisional swelling and subcutaneous emphysema occurred commonly after standing laparoscopic ovariectomy, but resolved within several days (Galuppo et al. 1995, Bouré et al. 1997, Hanson and Galuppo 1999, Rodgerson et al. 2001, Hand et al. 2002). Mariën et al. (2000) noticed subcutaneous emphysema only in mares where carbon dioxide insufflation had been used. Seroma formation (Bouré et al. 1997) or dehiscence (Rodgerson et al. 2001) of the incision used to remove an ovary has been reported and healing occurred by 2^{nd} intention. Incisional infection occurred infrequently and resolved with systemic antibiotic therapy (Hanson and Galuppo 1999).

Mild colic may occur in some mares post laparoscopic ovariectomy, but usually resolves with administration of flunixin meglumine (Bouré et al. 1997, Hanson and Galuppo 1999, Röcken 2000, Rodgerson et al. 2001). Signs of abdominal pain may be related to irritation of serosal surfaces due to insufflation with carbon dioxide or, more likely, to ligation of the neurovascular ovarian pedicle (Ragle et al. 1996).

Cosmetic outcome of standing laparoscopic ovariectomy was generally considered to be excellent (Palmer 1993, Bouré et al. 1997, Hanson and Galuppo 1999, Mariën et al. 2000), and mares returned to pasture turnout or exercise 14 days (Palmer 1993, Hanson and Galuppo 1999) or 21 days (Bouré et al. 1997) postoperatively.

3.2.4.9. Second look surgery

Rodgerson et al. (2001) performed a 2nd look laparoscopy 8 months after laparoscopic ovariectomy with monopolar or bipolar electrosurgical instrumentation. No adhesions were seen and the stump of the ovarian pedicle had a sharp demarcation in the area of original ovarian attachment. Hand et al. (2002) reported mild edema and hyperemia of the tissue immediately adjacent to the site of transection 72 hours after laparoscopic ovariectomy using an electrosurgical vessel-sealing device. Ten days after the surgery, minimal inflammation was seen, and the transection site was covered with granular-like tissue.

3.3. The Harmonic Scalpel™

3.3.1. Mode of action

The Harmonic Scalpel™ consists of a generator, a foot pedal, a handpiece with a connecting cable, and a blade system (Figure 2). A transducer within the handpiece converts electrical energy from the generator into ultrasonic vibration. The ultrasonic

vibration is transmitted along an extending rod to the active blade tip causing it to move longitudinally 50 – 100 µm at 55,500 cycles/second against the inactive part of the blade system. A microprocessor within the generator senses changes in frequency of the active blade or tissue impedance. It is able to adjust the frequency of the blade movement to optimize performance. In case the ability of the generator to overcome changes is superseded, it automatically shuts down the system and releases an audible warning signal (Amaral 1994).

The mechanism by which the Harmonic Scalpel™ causes hemostasis of vessels has been termed coaptive coagulation. The mechanical energy from the vibrating blade is transferred to tissue protein and is sufficient to break down the hydrogen bonds that provide the tertiary structure of the protein (Amaral 1994, McCarus 1996). Protein disorganization and denaturation result in a sticky protein coagulum capable of sealing vessels up to 5 mm in diameter (Amaral and Chrostek 1993, Mueller and Fritzsch 1994). Vessel seals created during coaptive coagulation are intrinsic to the vessel walls and thus hemostasis is independent of the formation of a thrombus (McCarus 1996).

Two mechanisms for cutting have been proposed. The first mechanism may be termed "power cutting" or "mechanical cutting", where a relatively sharp blade vibrates over the tissue. When pressure with the blade is exerted onto the tissue, division takes place. Tissue high in protein or collagen is transected in this manner. The second mechanism is called cavitational fragmentation. As the blade vibrates, it produces large transient pressure changes within the contacted tissues, causing intra-and extracellular water to vaporize at low temperatures. This results in disruption of cells and vapor bubble formation, leading to separation of tissue planes (Amaral 1994, McCarus 1996). The phenomenon of cavitational fragmentation has been investigated by activation of the Harmonic Scalpel™ on agar (Suzuki et al. 1999) or sodium carbonate containing jelly (Fukata et al. 2002). The shape of the blade of the Harmonic Scalpel™ appears to influence the direction of the created vapor bubbles (Suzuki et al. 1999), whereas the total

time of Harmonic Scalpel™ application, but not the power level determined the depth of the bubble layer. The mean depth ranged from 3.06 mm with just one short application to 6.90 mm with quick repetition of 5 applications on jelly (Fukata et al. 2002).

3.3.2. Blade system

The Harmonic Scalpel™ Laparosonic® Coagulating Shears (Ethicon Endo-Surgery, Inc., Cincinnati, OH) are a blade system composed of the active blade and a hinged tip, equipped with a toothed silicone pad. By closing the hinged tip, unsupported tissue is pushed against the active blade and coagulated or cut. The active blade may be rotated into 3 different positions, exposing a sharp, blunt or flat blade (Figure 2). The Harmonic Scalpel™ Laparosonic® Coagulating Shears allow the surgeon to control the balance between cutting and coagulation by varying the power setting, changing the blade configuration, and varying the amount of tissue tension and grip force. Cutting speed and extent of coagulation with the Harmonic Scalpel™ are inversely proportional, and are related to the power setting, blade sharpness, tension and pressure applied to the tissue (McCarus 1996). The Harmonic Scalpel™ has 5 power settings. Higher power settings result in increased distance traveled by the blade (50 µm at level 1, 100 µm at level 5) and thus increased cutting speed and decreased coagulation. Sharper blades result in faster cutting and less coagulation. Increasing pressure from the blade onto the tissue increases cutting speed and decreases coagulation. Further, the Harmonic Scalpel™ Laparosonic® Coagulating Shears (Ethicon Endo-Surgery, Inc., Cincinnaty, OH) represent one of the few available multifunctional laparoscopic instruments that can be used as grasper, dissector, coagulating and cutting device (Gossot et al. 1999).

3.3.3. Lateral thermal tissue damage

During application of the Harmonic Scalpel™ to tissue, heat is generated, especially with longer application times (Kinoshita et al. 1999). Heat generation has been stated to be less than with electrocoagulation or laser application, as tissues were not heated over 80°C during application of the Harmonic Scalpel™, using a hook blade (Amaral 1994). This statement has been confirmed by Orejola et al. (2000), who reported on Harmonic Scalpel™/tissue coupling temperatures during internal mammary artery harvesting. After application of the Harmonic Scalpel™ hook blade for 10 seconds at power level 5, temperatures of 60°C were measured. When a monopolar electrosurgical instrument set at 30 W was used, temperatures around 200°C were measured. The increase in tissue temperature appears to be rather localized, as reported by Boddy et al. (1987). The temperature of minipig bladder mucosa, cut with an ultrasonically activated scalpel vibrating at 25,000-30,000 Hz, rose by 17-18°C 1 mm from the tip of the ultrasonic scalpel, by 8-9°C at 2 mm distance and by 3-4°C at 3 mm distance. Further, temperatures appear to increase with longer activation times of the Harmonic Scalpel™. Kinoshita et al. (1999) found that tissue temperatures remained below 80°C until 8 seconds of tissue contact with the active blade of the coagulating shears. Tissue temperatures subsequently increased rapidly up to 150°C with longer contact times. Differences in temperatures between the latter study and the report by Orejola et al. (2000) may be explained by the different blade systems used: Kinoshita et al. (1999) used the Laparosonic® Coagulating Shears and measured substantially higher temperatures than Orejola et al. (2000), who utilized the hook blade. Thus, the type of blade may also influence the amount of heat generated within the tissues.

Tissues transected with the Harmonic Scalpel™ have been shown to have varying amounts of thermal damage. Histologic evaluation of rat testicles 24 hours after being incised with an ultrasonically activated scalpel (25,000-30,000 Hz) showed hyaline degeneration of seminiferous tubules with little infiltration of inflammatory cells into

adjacent tubules (Boddy et al. 1087). Kadesky et al. (1997) reported transmural damage to tubular structures such as the common bile duct, caudal vena cava or ureter in adult pigs after dissection with the Harmonic Scalpel™, using a hook blade. These authors concluded that the Harmonic Scalpel™ eased difficult dissections with good hemostasis, but care should be taken to avoid injury of adjacent structures.

In order to quantify the amount of thermal damage, the depth of coagulation necrosis caused by the Harmonic Scalpel™ has been measured and compared to that with the use of electrosurgery or laser application. Higami et al. (2000) reported coagulation necrosis depth of porcine internal thoracic arteries harvested with the Harmonic Scalpel™ hook blade to range from 0.5 –1.0 mm. Similarly, coagulation necrosis depths of 0.5-1.0 mm were measured in carcinomas of the tongue or soft palate after resection with the Harmonic Scalpel™, using the hook blade. No correlation between power setting and coagulation depth was seen in this study (Metternich et al. 2002). Fukata et al. (2002) also estimated the lateral thermal damage at about 1 mm after transection of small vessels with the Harmonic Scalpel™ hook blade. Thermal damage appeared more extensive when the coagulating shears were used for transection. Schemmel et al. (1997) measured coagulation necrosis depth in rabbit uteri and ovaries after incision with the Harmonic Scalpel™. Depths ranged from 0.3 to 0.38 mm and were similar to those measured after incision with electrosurgery or a CO_2 laser. In a second part of the study, these authors showed that depth of coagulation necrosis increased with longer application times and increasing power settings. Application to rabbit uteri for less than one second at power level 3 or 5 resulted in 0.30 mm of lateral thermal damage, whereas application at power level 5 for 6 seconds resulted in 0.51 mm coagulation necrosis. Kwok et al. (2001) also noted an increase in lateral thermal damage with higher power settings, as well as with greater tissue thickness. Greater lateral thermal damage was attributed to longer application times for transection of thicker tissues. Schemmel et al. (1997) found greater than previously reported depth of coagulation necrosis in sheep uterine horns and jejunum transected with the Harmonic Scalpel™ Laparosonic® Coagulating Shears (0.7

to 2.2 mm). The authors suggested that coagulation necrosis with the Laparosonic® Coagulating Shears was greater than with the hook blade, which had been used in previous studies.

Fukata et al. (2002) proposed 5 factors determining the degree of lateral thermal damage with the use of the Harmonic Scalpel™: 1) the strength of compression with a blade edge on tissue, 2) the duration of contact between active blade and tissue, 3) the output power level, 4) the direction of pressure applied to a blade edge, and 5) the shape of the blade edge.

3.3.4. Hemostasis

Studies investigating the efficacy of hemostasis provided by the Harmonic Scalpel™ generally support its safety and reliability, as vessels uncommonly burst when subjected to intraluminal pressures within physiological limits. Spivak et al. (1998) compared bursting pressures of arteries in porcine mesentery sealed with vascular clips, bipolar electrosurgery, or the Harmonic Scalpel™ Laparosonic® Coagulating Shears. The Harmonic Scalpel™ was used at power level 3 and applied for 3-5 seconds. Arteries 2-3.5 mm in diameter were sealed up to 300 mmHg pressure in 100% with the vascular clips, in 83% with the Harmonic Scalpel™, and in 75% with bipolar electrosurgery. Success rates were not significantly different between methods of hemostasis. In another report, porcine intraabdominal vessels of 3-3.5 mm diameter were sealed by an ultrasonically activated instrument up to bursting pressures of 1204 and 1193 mmHg at 70% and 100% power output, respectively (Kanehira et al. 1999). Landman et al. (2002) investigated the bursting strength of porcine renal arteries and veins sealed with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. Five of 6 arteries (2.8-3.9 mm diameter) were sealed up to bursting pressures of greater than 350 mmHg, whereas 3 of 6 veins (7.0-12.8 mm diameter) were sealed up to bursting pressures above 160 mmHg. Vessel transection time

was 4-10 seconds for arteries and 3-8 seconds for veins. It appears that proper surgical technique is required to seal vessels safely with the Harmonic Scalpel™, as shown by Higami et al. (2000). Bursting pressures of porcine internal thoracic arteries sealed with the Harmonic Scalpel™ hook blade were greater than 350 mmHg for 91.7 % of all transected arteries. The time required to cut and coagulate a vessel with the Harmonic Scalpel™ correlated with the outer diameter of the vessel. Smaller vessels (0.3-0.6 mm diameter) required 2 to 3 seconds for transection and sealing, whereas larger vessels (0.7-1.2 mm diameter) required 3 to 4 seconds. Vessels that burst at pressures less than 350 mmHg consistently had shorter cutting and coagulation times than vessels that were able to withstand up to 350 mmHg. Thus, hasty surgical technique may result in less reliable hemostasis.

3.3.5. Wound healing

Incision with the Harmonic Scalpel™ may result in faster wound healing than with electrosurgical instruments or a CO_2 laser. Lateral thermal damage of pigskin was significantly greater when using electrosurgery or a CO_2 laser compared to an ultrasonically activated knife. Further, eschar and edema were greater, and complete reepithelialization and increase in tensile strength were slower with electrosurgery or a CO_2 laser than with the ultrasonically activated knife. A cold steel scalpel was however superior in all parameters to the ultrasonically activated knife (Hambley et al. 1988). Similar results were obtained in a study incising the oral mucosa of guinea pigs (Sinha and Gallagher 2003).

Whether the Harmonic Scalpel™ causes fewer adhesions after intraabdominal use than electrosurgery or a CO_2 laser is controversial. Tulandi et al. (1994) compared healing of full thickness incisions into rat uteri using a cold steel scalpel or the Harmonic Scalpel™. The incisions were closed with a single suture of 6-0 polypropylene. Adhesion scores, as

well as degree of inflammatory cell infiltration were similar between both instruments. Another study compared the Harmonic Scalpel™ to electrosurgery or a CO_2 laser in a rabbit model, and found similar adhesion scores. However, fibrin deposition was greater with the Harmonic Scalpel™ at high power settings (Schemmel et al. 1997). Amaral and Chrostek (1997) reported fewer adhesions (22%) after laparoscopic cholecystectomy in pigs when the Harmonic Scalpel™ was used, compared to electrosurgery (67%) or laser surgery (88 %). The higher rate of adhesions especially with laser surgery was attributed to higher temperatures produced.

3.3.6. Use in human and veterinary laparoscopy

In the field of human reproductive surgery, the Harmonic Scalpel™ has been used for a great number of different procedures, including laparoscopic hysterectomy (Erian et al. 1999, Gyr et al. 2001) and laparoscopic transection of the uterine tubes (Stefanidis et al. 1999). Further it has been used during laparoscopic cholecystectomy, herniotomy, appendidectomy, fundoplication, or adhesiolysis (Lange et al. 1996). The Harmonic Scalpel™ has also been used for laparoscopic partial nephrectomies with supplemental methods of hemostasis necessary for larger resections (Jackman et al. 1998).

Satisfactory hemostasis of the short gastric vessels during laparoscopic Nissen fundoplication surgery (Bischof et al. 1999) was achieved with the Harmonic Scalpel™, but bleeding near the dorsal aspect of the spleen had to be stopped with vascular clips. No information about the size of the vessels was provided. During resection of lung parenchyma, the Harmonic Scalpel™ has been shown to provide good hemostasis, but lung tissue was not sealed air-tight and had to be sutured to stop air leakage (Aoki and Kaseda 1999). One report describes successful coagulation and division of the umbilical cord and its vessels in a monochorionic twin with the use of the Harmonic Scalpel™ (Lopoo et al. 2000). Laparoscopic appendectomy has been described with the Harmonic

Scalpel™ as the only means to seal the amputated bowel (Del Olmo et al. 2002). The safety of the seal, however, has been questioned (Schwaitzberg 2002) as intestinal sealing with the Harmonic Scalpel™ may be inconsistent. The Harmonic Scalpel™ has further been used for tissue dissection and coagulation of vascular pedicles during laparoscopic colorectal surgery (Msika et al. 2001).

Laparoscopy assisted ovariohysterectomy has been performed using the Harmonic Scalpel™ on 2 dogs with pyometra. Hemostasis of both ovarian arteries was incomplete after transection with the Harmonic Scalpel™ and vascular clips were applied to stop the bleeding (Minami et al. 1997). Successful laparoscopic ovariohysterectomy and hysterectomy in 5 african lions using the Harmonic Scalpel™ as the sole means of hemostasis has also been described (Kolata 2002). The Harmonic Scalpel™ Laparosonic Shears have also been used successfully for laparoscopic elective ovariohysterectomy in dogs (Lanz et al. accepted for publication).

3.3.7. Complications

A thermal bowel injury during use of the Harmonic Scalpel™ hook blade during laparoscopic adhesiolysis has been reported (Awwad and Isaacson 1996). The thermal damage occurred when the extender shaft of the blade was pushed against a segment of sigmoid colon overlying the sacral promontory, resulting in moderate physical pressure. The Harmonic Scalpel™ performance decreased suddenly and the generator shut down and emitted a warning signal. Reproduction of the situation in the laboratory revealed that the shaft temperature increased to 82.2°C when pushed against a solid object. The authors recommended avoiding any physical strain on the extender shaft during use of the instrument and responding promptly to malfunction signals from the generator in order to avoid similar complications. Shutdown and inability to reactivate the Harmonic Scalpel™ generator has also been reported as an intraoperative complication (Lange et al. 1996).

Gyr et al. (2001) reported an incidental injury to the bladder during laparoscopic hysterectomy with the Harmonic Scalpel™ in a case series of 48 laparoscopic hysterectomies. The lesion was sutured laparoscopically, and conversion into a laparotomy was not necessary. Postoperative bleeding necessitating a blood transfusion and emergency laparotomy has been reported after laparoscopic hysterectomy with the Harmonic Scalpel™ in a woman who had been taking acetylsalicylate perioperatively to prevent recurrence of pulmonary emboli (Erian et al. 1999).

The possibility for release of viable cancer cells by the Harmonic Scalpel™ during tumor resection was investigated by Nduka et al. (1998). The Harmonic Scalpel™ released large quantities of microscopic droplets of fluid and cell debris while coagulating and cutting tissues, but no viable cells were found and no *in vitro* cell growth was noted.

Chapter 4. Materials and Methods

4.1 Animals

Eight mares (Table 1) with normal anatomy of the reproductive tract as determined by palpation per rectum and transrectal ultrasound were used. Physical parameters (Table 2) and a complete blood count (Table 3) were within normal limits for all horses. Their ages ranged from 2 to 20 years (median 14.5 years), and they weighed between 410 and 540 kg (median 514 kg). Five of the mares had given birth to at least one foal. The study was conducted during the months of November and December. It was determined via transrectal ultrasound that 6 of the 8 mares were cycling at the time of the procedure. Throughout the study, the horses were housed in standard size box stalls (3 x 4 m) with small run – out paddocks or in a 30 x 40 m pasture. All horses had free access to fresh water and were fed a diet of free choice grass hay.

All mares were donated to the Veterinary Teaching Hospital due to problems unrelated to the reproductive anatomy in order to participate in the present study. The experimental protocol was reviewed and approved by the Virginia Tech Animal Care Committee.

4.2 Study Protocol

4.2.1 Preoperative protocol

Feed was withheld from each horse 24 hours prior to surgery. Procaine penicillin G (22,000 IU/kg intramuscularly) and flunixin meglumine (1.1 mg/kg intravenously [IV]) were administered 2 hours preoperatively and continued postoperatively every 12 hours for a total of 2 and 6 doses, respectively. Just prior to surgery, the horses were tranquilized with acepromazine (0.03 mg/kg IV) and placed into stocks. Both paralumbar fossae were clipped, aseptically prepared, and draped. A combination of detomidine

hydrochloride (0.002 - .004 mg/kg IV) and butorphanol tartrate (0.002 - .004 mg/kg IV) was then administered and repeated as needed (Table 4a, b), to provide chemical restraint throughout the procedure.

4.2.2 Surgical procedure

The left ovary was operated through the left paralumbar fossa, and the right ovary through the right paralumbar fossa. Surgical approach and technique were the same for both sides, with the left side always operated first. Three operating portals (one laparoscope and two instrument) were used for each ovary (Figure 3). The laparoscope portal was positioned at the level of the distal aspect of the tuber coxae, midway between the tuber coxae and the last rib. One instrument portal was 5 – 10 cm craniodorsal to the laparoscope portal and the other 5 – 10 cm caudoventral to the laparoscope portal. Analgesia of the operating portals was achieved by subcutaneous and intramuscular infiltration with 20-30 ml of 2% mepivacaine per portal.

A 15 mm incision was made through the skin and the fascia of the external abdominal oblique muscle over the laparoscope portal. A sharp pyramidal trocar ensheathed in an 11 mm diameter, 20 cm long cannula (Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA) was advanced through the abdominal musculature aiming towards the ovary. When air movement through the cannula and loss of resistance of the body wall against slow advancement of the cannula-trocar unit was noticed, penetration of the peritoneum was assumed. Subsequently the sharp trocar was exchanged for a blunt trocar prior to advancing the cannula-trocar unit further. In cases where only loss of resistance was felt, it was assumed that only the muscular part of the body wall had been penetrated. The sharp trocar was exchanged for a blunt trocar despite lack of air movement through the cannula. Subsequently, the cannula - trocar unit was advanced further more forcefully, in order to penetrate the peritoneum with the blunt trocar. The blunt trocar was then

replaced with a 30°, 10 mm diameter, 57 cm long laparoscope (Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA) connected to a 300 - watt xenon light source (DyoBrite™ 3000, Smith + Nephew, Andover, MA) and video camera (Dyonics® Digital Camera System, Smith + Nephew, Andover, MA), and successful entry into the abdominal cavity verified. The abdomen was then insufflated with CO_2 at a flow of 2 l/min to a pressure of 10 mm Hg using an automatic insufflator (Electric Laparoflator 26012, Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA). Following a brief examination of the abdomen and identification of the ovary and uterus (Figure 3), the instrument cannulas (11 mm diameter, 20 cm long, Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA) were placed. The instrument cannulas were inserted in the same fashion as the laparoscope cannula. Intraabdominal position of the instrument cannulas was ascertained by advancing the cannula – trocar unit toward the ovary and into the visual field of the laparoscope.

The ovary was stabilized with laparoscopic claw forceps (Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA) inserted through the craniodorsal instrument portal and placed on the infundibulum. The ovarian pedicle and the ovary itself were infiltrated with 20 ml and 10 ml of 2% mepivacaine, respectively, using a laparoscopic injection needle (Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA) via the caudoventral portal. Following, Harmonic Scalpel™ 10 mm Laparosonic® Coagulating Shears were inserted through the caudoventral portal. First, the mesosalpinx and uterine tube (lateral wall of the ovarian bursa) were transected using the sharp blade and # 5 power setting. Next, the proper ligament of the ovary and its mesentery (medial wall of the ovarian bursa) was transected using the sharp blade and # 5 power setting (Figure 4). Care was taken to stay close to the ovary with this transection in order to avoid uterine branches of the ovarian artery. These transections left the ovary suspended by a vertical pedicle: the mesovarium (Figure 5). Subsequently, the Laparosonic® Coagulating Shears were moved to the craniodorsal portal and the ovary was stabilized through the caudoventral portal. The vertical part of the ovarian pedicle was then transected using the

blunt blade and # 3 power setting. The first cuts were made on the most cranial part of the ovarian pedicle and used to open up a loose connective tissue plane within the pedicle (Figure 6). The Laparosonic® Coagulating Shears were exchanged for laparoscopic scissors (Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA) and the remaining portion of the ovarian pedicle was separated into medial and lateral components by blunt dissection (Figure 7). The Laparosonic® Coagulating Shears were then reintroduced into the crainiodorsal portal and the lateral aspect of the remaining ovarian pedicle transected (Figure 8), followed by the medial aspect (Figure 9). The time from the start of ovarian pedicle transection until the ovary was free and complete hemostasis was achieved was recorded.

During transection of the ovarian pedicles, the Laparosonic® Coagulating Shears were initially applied with minimal tissue tension and grip force to achieve coagulation (approximately 3 seconds for the horizontal portion of the ovarian pedicle, and 6 seconds for the vertical portion) and then with increased tissue tension and grip force to transect the tissue. Blanching of the tissue lateral to the blade was used as an indicator of sufficient coagulation. If tissue transection did not occur within approximately 12 seconds of total application time, the shears were opened and the tissue was released while the scalpel was still activated. Releasing the tissue while the scalpel is still activated is necessary to prevent the blade from sticking to the tissue. The shears were then reapplied just distal (vertical pedicle) or cranial (horizontal pedicle) to the coagulated area and reactivated with moderate grip force and tissue tension until the tissue divided. The Laparosonic® Coagulating Shears were cleaned periodically by either activating them in the open position to vaporize debris, or by wiping them with a damp surgical sponge.

The transected ovarian pedicle was inspected for bleeding and the adjacent tissues examined for inadvertent injury. The ovary was secured with self-retaining laparoscopic claw forceps, and then the right ovary was approached and transected in a similar fashion.

To extract the ovaries from the abdominal cavity, the caudoventral instrument portals were enlarged to a length of 5 - 8 cm using sharp incision of the skin and fascia of the external abdominal oblique muscle and blunt dissection of the deeper body wall. The ovaries were exteriorized by gentle traction on the laparoscopic claw forceps. The fascia of the external abdominal oblique muscle of the caudoventral portals was closed with 0 polyglactin 910 (Coated Vicryl, Ethicon, Inc., Somerville, NJ) in a simple continuous pattern. Skin incisions were closed with 2 – 0 nylon (Dermalon, United States Surgical, Norwalk, CT) in a simple interrupted pattern.

4.2.3 Postoperative protocol

The mares were returned to their stalls after surgery and gradually reintroduced to food. Four mares were turned out into a pasture on day 15 after surgery for 16 days. Physical examinations were performed twice daily for 72 hours (8 mares) and then once daily for 11 days (4 mares), followed by daily observation of behavior for 16 days (4 mares). Mares were euthanatized with an intravenous overdose of pentobarbital (Fatal plus, Vortech Pharmaceuticals, Dearborn, MI) at 3 (4 mares) and 30 days (4 mares) after surgery. Necropsy examination was performed on each horse.

4.2.4 Gross pathologic evaluation

The abdominal cavities were examined for signs of generalized and local peritonitis. The ovarian pedicles were evaluated for evidence of hemorrhage, inflammation, and adhesions.

4.2.5 Histopathologic evaluation

Each ovarian pedicle was removed en bloc and placed in 10 % neutral buffered formalin in preparation for histologic processing. A tissue section from the cranial and the caudal half of the mesovarium, as well as from the cranial and the caudal half of the ovarian bursa was collected, respectively. All sections were taken perpendicular to the surgical transection line, preserving grossly normal looking connective tissue around the surgical transection line. The tissue samples were embedded in paraffin, sectioned at 4 µm and stained with hematoxylin and eosin. Microscopic evaluation was carried out to characterize the short term (3 days following surgery) and long term (30 days following surgery) effects of the Harmonic Scalpel™ on the transected tissue. Each slide was subjectively assessed for the degree and type of inflammation. Further, the maximum depth of coagulation necrosis was measured on slides obtained from mares euthanatized 3 days after surgery, using a calibrated eyepiece micrometer.

4.3 Statistical Methods

Each numerical variable was reported as median and range of data. Qualitative data was reported descriptively.

Chapter 5. Results

No major operative or postoperative complications were noticed. The chemical restraint provided appropriate control of patient movement and discomfort throughout the procedure (median administered dosage of detomidine hydrochloride 0.0042 mg/kg, range 0.0037 – 0.0073 mg/kg, median time interval between administrations 30.5 minutes, range 5-55 minutes, median administered dosage of butorphanol tartrate 0.0045 mg/kg, range 0.0019– 0.0184 mg/kg, median time interval between administrations 31 minutes, range 13-86 minutes, Table 4a, b). Local anesthetic protocols resulted in sufficient analgesia of the operating portals, the ovary and the ovarian pedicle. The operating portals allowed excellent visualization and access to the ovarian pedicles.

The Harmonic Scalpel™ Laparosonic® Coagulating Shears were relatively easy to use and achieved complete hemostasis of the ovarian pedicles in all mares. No hemorrhage occurred during transection of the horizontal portion of the ovarian pedicle (mesosalpinx and uterine tube, and the proper ligament of the ovary and its mesentery) in any horses. Mild hemorrhage occurred during transection of the vertical portion (mesovarium) of one ovarian pedicle in 2 horses, and both ovarian pedicles in 4 horses (Table 5). When this occurred, the blunt or flat blade of the Laparosonic® Coagulating Shears was reapplied to the bleeding area at setting # 3 for 8 seconds or until hemostasis was achieved. Moderate arterial hemorrhage occurred at the completion of transection of the vertical portion of one ovarian pedicle in one mare. Retraction of the ovarian pedicle against the dorsal body wall made identification of the source of hemorrhage difficult. In order to visualize the source of hemorrhage, the ovarian pedicle was grasped with laparoscopic bowel forceps (Karl Storz Veterinary Endoscopy - America Inc., Goleta, CA) inserted through the craniodorsal instrument portal and rotated toward the surgeon. Hemostasis was achieved by applying the Laparosonic® Coagulating Shears across the vessel through the caudoventral instrument portal, using the blunt blade and setting # 3. Time used to transect the ovarian pedicles and achieve complete hemostasis with the Harmonic

Scalpel™ Laparosonic® Coagulating Shears ranged from 15 to 62 minutes/pedicle (median, 28 minutes, mean 31 minutes, standard deviation 13 minutes) (Table 5). Times appeared similar for left and right ovarian pedicles (median, 29 minutes, range 15-51 minutes, and median, 27 minutes, range 18-62 minutes, respectively).

It was discovered that if tissue transection did not occur within approximately 12 seconds of total application time of the Harmonic Scalpel™, it was unlikely to do so. As well, continued activation of the Harmonic Scalpel™ on the tissue often resulted in system shut down, characterized as an abrupt cessation of the vibrating action of the blade, while the generator produced an audible warning signal. Cessation of the blade motion usually resulted in the blade tips sticking to the tissue. System shut down necessitated that the blade be carefully removed from the tissue to avoid tearing off the coagulated tissue, followed by reactivation in an adjacent location. Reactivation over the same desiccated area usually resulted in system shut down again. Transected tissue edges appeared blanched and desiccated, with minimal char. A small amount of mist was produced during tissue coagulation and transection, but visibility was never impaired. One ovary dropped from a malfunctioning pair of laparoscopic claw forceps and its location could not be identified with the laparoscope. The caudoventral instrument portal was enlarged to a length of about 12 cm and the abdomen was explored manually. The ovary was located ventrolateral to the bladder, brought up to the incision manually and extracted from the abdomen using Allis tissue forceps.

Postoperative physical exam findings are documented in table 6a-h. All mares appeared comfortable following surgery. Transient mild elevation of heart rate and rectal temperature was noticed through the first day postoperatively in all but 2 mares. Transiently decreased intestinal sounds were found in all mares especially on day 1 after surgery. One mare was febrile (39.7°C) 9 hours after the surgery. The fever resolved after administration of the scheduled dose of flunixin meglumine (1.1 mg/kg IV). One mare developed moderate subcutaneous emphysema on the right aspect of the abdomen one

day after surgery, which decreased markedly by the time of euthanasia (3 days after surgery). Another mare developed a small seroma at a caudoventral portal site, which resolved without treatment.

At post-mortem examination 3 days following surgery (4 horses, Table 7; Figure 10), no signs of generalized peritonitis, postoperative hemorrhage, or adhesions were observed. The sites of ovarian pedicle transection appeared as lines of white, desiccated tissue. Small focal spots of char were present on the vertical portion of the pedicles. The transection lines were firm on palpation, about 1 mm wide, and raised approximately 2 mm. They were bordered by erythematous margins of about 1 mm in width, and the underlying tissue was mildly edematous, indicating local inflammation. One transection site had moderate subserosal emphysema. Two areas of mild erythema about 10 cm in diameter were found on the mesentery of the small colon adjacent to the transection sites in 1 horse. The abdominal fluid was colored yellow or orange brown.

Histologic evaluation of the transected pedicles 3 days postoperatively revealed coagulation necrosis of the superficial layer of the transected tissue, seen as a homogenously eosinophilic - staining area containing pyknotic cell nuclei (Figure 11). A fibrin layer was noted superficial to the coagulum in some sections. Depth of coagulation necrosis ranged from 0.20 to 5.04 mm (median, 2.87 mm) (Table 8). There was no appreciable difference between sections taken from the horizontal or vertical portions of the ovarian pedicle (median depth 2.95 mm and 2.80 mm, respectively). The tissue adjacent and deep to the area of coagulation necrosis was mildly to moderately infiltrated with neutrophils and lymphocytes. A zone of congested venules and arterioles was noted deep to the coagulum (Figure 12). Thrombosis of muscular arteries was found in most sections (Figure 13).

Post-mortem examination 30 days following surgery (4 horses, Table 9) revealed no signs of generalized or localized peritonitis, evidence of postoperative hemorrhage, or

adhesions. The transection lines of the vertical portion of the ovarian pedicles appeared as brown nodular lines. The transection lines of the horizontal portion of the ovarian pedicles appeared as indistinct, beige lines (Figure 14). Numerous well-vascularized fibrous tags (approximately 1 cm in length and 1 mm in diameter) were present along the transection lines of 3 pedicles (2 horses) (Figure 15). The abdominal fluid was yellow and clear.

Histopathologic evaluation of the transection sites 30 days postoperatively revealed a moderate chronic inflammatory response. Mildly inflamed serosa covered a zone of maturing fibrous tissue in most sections. Remains of the coagulum were sometimes noted within the maturing fibrous tissue, as was hemosiderin. Inflammatory cells seen were predominantly mononuclear, with fewer eosinophils and giant cells (Figure 16). No signs of inflammation were observed deep to the zone of maturing fibrous tissue. Organizing thrombi were noted within several lumina of muscular arteries (Figure 17).

Chapter 6. Discussion

The results of the present study indicate that standing elective bilateral ovariectomy in the horse can be performed safely and effectively using the Harmonic Scalpel™. The procedure used for ovarian pedicle transection was designed to maximize the efficiency of the Harmonic Scalpel™.

The Harmonic Scalpel™ is becoming widely employed in laparoscopic surgery in humans (Lange et al. 1996, Gyr et al. 2001, Kauko 1998, Power et al. 2000, McNally et al. 2001, Msika et al. 2001). Its use for laparoscopic ovariohysterectomy in the dog (Minami et al. 1997, Lanz et al. accepted for publication) and in the african lion (Kolata 2002) has also been described recently. The instrument is simple to use and offers a number of advantages. It is able to grasp, coagulate, and cut tissue, thereby minimizing the number of instrument exchanges needed to complete a procedure. The surgeon can control the balance between coagulation and cutting by varying the power setting, blade configuration, grip force, and tissue tension. Visibility of the surgical field is not compromised by smoke or char production, as only a small amount of mist is emitted during application. There is no risk of electrical injury to the patient because there is no current flow through the patient. The scalpel must be activated and placing pressure on the tissue in order to coagulate or cut, making the risk of inadvertent distant tissue damage low. Because ligatures are not necessary for hemostasis, the risk of ligature slippage is avoided. Lateral thermal tissue damage and postoperative adhesion formation has been reported to be less with the Harmonic Scalpel™ than that associated with lasers or electrosurgery (Amaral and Chrostek 1997), and similar to that with the use of a cold steel scalpel (Tulandi et al. 1994). Reports of complications associated with the Harmonic Scalpel™ are scarce (Lange et al. 1996, Awwad and Isaacson 1996, Erian et al. 1999, Gyr et al. 2001). Tissue dissection with the Harmonic Scalpel™ may result in less postoperative pain than with bipolar electrosurgery or conventional dissection techniques

(Chung et al. 2002, Troxler et al. 2002). A disadvantage is the price for the complete Harmonic Scalpel™ unit. At the time of the present study, the complete setup cost about $ 20,000.00. The price for the Harmonic Scalpel™ Laparosonic® Coagulating Shears used was $ 378.00.

The present study showed, similarly to others (Palmer 1993, Bouré et al. 1997, Mariën et al. 2000, Rodgerson et al. 2001, Hand et al. 2002), a low rate of complications of bilateral standing laparoscopic ovariectomy in mares. Also consistent with previous reports, (Fischer et al. 1986, Palmer 1993, Galuppo et al. 1995, Hendrickson and Wilson 1996, Ragle et al. 1996, Bouré et al. 1997, Hanson and Galuppo 1999, Walmsley 1999, Rodgerson et al. 2001, Hand et al. 2002, Rodgerson et al. 2002) restraint and analgesia using intravenous administration of detomidine hydrochloride and butorphanol tartrate and local infiltration of the portals and the ovarian pedicle with a local anesthetic allowed the procedure to be performed without apparent discomfort to the mares.

Our instrument portals, located crainiodorsal and caudoventral to the laparoscope portal (Figure 3), were different from those previously reported (Palmer 1993, Bouré et al. 1997, Hanson and Galuppo 1999, Mariën et al. 2000, Rodgerson et al. 2001, Hand et al. 2002) for standing laparoscopic ovariectomy in the horse. With our portal placement, efficient triangulation of the instruments and the laparoscope was achieved, even in smaller mares. Further, the position of these portals allowed the Harmonic Scalpel™ to approach and transect the ovarian pedicles perpendicular to their lines of attachment to the ovary with minimal manipulation (Figures 4 and 6). The horizontal portion (mesosalpinx and uterine tube, and the proper ligament of the ovary with its mesentery) of the ovarian pedicle was always transected first. This left the ovary suspended by the vertical portion of the pedicle (mesovarium) and ensured that the remaining tissue could be transected in a relatively tension free fashion. After transecting the cranial portion of the vertical pedicle, it was divided into medial and lateral components using blunt

dissection. This was done to reduce the thickness of the tissue over which the Harmonic Scalpel™ needed to be applied.

The cause of the hemorrhage that occurred during or after transection of the vertical portion of several of the ovarian pedicles is unknown. The vertical portion of the ovarian pedicle is thicker than the horizontal portion and contains the major arteries and veins of the ovary. Although there are no reports objectively detailing the size of the vessels in the ovarian pedicle of horses, our measurements from 3 cadaver animals indicate that the largest vessels in the vertical portion of the ovarian pedicle are approximately 3 mm in diameter. The Harmonic Scalpel™ is reported to be capable of sealing vessels up to 5 mm in diameter (Amaral and Chrostek 1993, Mueller and Fritzsch 1994). It has also been reported that the Harmonic Scalpel™ seals arteries up to 3.5 mm in diameter against bursting pressures of up to 300 mmHg as reliably (85% success) as bipolar electrocautery (75% success) and vascular clips (100% success) (Spivak et al. 1998). Another study reported even higher bursting pressures of similarly sized vessels that were transected with the Harmonic Scalpel™ (Kanehira et al. 1999). This information suggests that the vessels in the vertical portion of the equine ovarian pedicle are within the coagulation capabilities of the Harmonic Scalpel™, and that excessive vessel size was not the cause of the hemorrhage observed. The thickness of the vertical portion of the ovarian pedicle may have contributed to the hemorrhage encountered. The active blade of the Laparosonic® Coagulating Shears is 1.5 cm in length and thus a limited amount of tissue can be effectively grasped, coagulated and cut. Although a tissue thickness limitation for the Laparosonic® Coagulating Shears has not been defined, we feel that the blade ends should nearly approximate each other once applied across tissue in order to expect adequate hemostasis to occur. To reduce the likelihood of attempting to coagulate and cut too much tissue, the tissue thickness of the vertical portion of the ovarian pedicle was reduced by dividing it into medial and lateral components, and then each component transected independently of the other.

Other possibilities for the hemorrhage encountered during transection of the vertical portion of the ovarian pedicle include vessel transection before complete coagulation, or application of the Harmonic Scalpel™ incompletely across a vessel. A linear correlation between vessel diameter and coagulation/cutting time with the Harmonic Scalpel™ has been demonstrated (Higami et al. 2000). It was suggested that hasty surgical technique with too much grip force or too much tissue tension could lead to transection of vessels before complete coagulation. In the present study, we attempted to safeguard against hasty surgical technique by standardizing the coagulation/transection procedure. The Laparosonic® Coagulating Shears were initially applied with minimal tissue tension and grip force to achieve coagulation (approximately 3 seconds for the horizontal portion of the ovarian pedicle and 6 seconds for the vertical portion) and then with increased tissue tension and grip force to transect the tissue. Blanching of the tissue lateral to the blade was used an indicator of sufficient coagulation.

Visualization of vessels within the ovarian pedicle is difficult, making the possibility of applying the Harmonic Scalpel™ incompletely across a vessel high. With increasing experience, the authors of the present study felt that they were able to gain a tactile appreciation of when large vessels were incompletely grasped with the Laparosonic® Coagulating Shears. If this was suspected, the instrument was repositioned until it was thought that the entire vessel was within the blades of the shears. Further, exertion of less tension on tissue to be transected and avoiding bunching of tissue within the jaws of the Laparosonic® Coagulating Shears was also perceived to decrease the occurrence of bleeding during transection of the vertical portion of the ovarian pedicle. Once hemorrhage occurred, it was most effectively stopped by grasping the tissue immediately proximal to the bleeding and activation of the blunt blade at setting # 3 for 8 seconds. In case it was difficult to grasp the tissue, the blunt blade was placed against the bleeding tissue and the Harmonic Scalpel™ was activated at setting # 3 until hemostasis was achieved.

Times used to transect the ovarian pedicle and to achieve complete hemostasis ranged from 15 to 62 minutes. Hand et al. (2002) reported slightly shorter times for ovarian transection using a vessel-sealing electrosurgical device (10 to 25 minutes). Longer transection times with the Harmonic Scalpel™ are unlikely to be of clinical significance, as no negative effects were noticed in any of the mares with longer transection times. Further, times tended to decrease with increasing experience of the authors. Occurrence of hemorrhage during the transection did not seem to increase transection times, although the Harmonic Scalpel™ was subjectively perceived to cut slower when tissue was contaminated with blood. However, hemorrhage from the ovarian pedicle at the completion of transection in one mare increased the transection time substantially to a total of 62 minutes. In comparison, the median transection time in the present study was 28 minutes.

System shut down was encountered several times during the present study, but the occurrence decreased with increasing experience with the instrument. System shut down is a safety feature of the Harmonic Scalpel™ occurring once the generator is unable to overcome changes in vibration frequency of the active blade or tissue impedance. It is designed to prevent overheating of the generator or the active blade. Causes for system shut down include desiccated debris sticking to the shears, excessive grip force, exertion of excessive tension on tissue, grasping too much tissue, as well as technical problems within the shears, handpiece or generator. The incidence of system shut down was reduced in the present study by cleaning the active blade of the Harmonic Scalpel™ periodically, not activating the scalpel on tissue for longer than 12 seconds, avoiding application on desiccated tissue, and avoiding grasping too much tissue.

The loss of an ovary from the laparoscopic grasping forceps occurred in one mare in the present study. This complication has been described previously (Palmer 1993, Hanson and Galuppo 1999, Rodgerson et al. 2001, Hand et al. 2002), and the ovary is typically located with the laparoscope. This was not the case in the present study, but enlargement

of one of the portals followed by manual exploration of the caudal abdomen and extraction of the ovary did not appear to cause any negative effects. Cosmesis of the enlarged incision 30 days postoperatively was satisfactory.

Following surgery, no horses showed major untoward effects attributable to the surgical procedure. Postoperative observations of a transient fever in one mare, decreased appetite and decreased intestinal sounds in most mares of the present study appear to be similar to observations in previous reports (Hanson and Galuppo 1999, Röcken 2000, Hand et al. 2002). Occurrence of subcutaneous emphysema in one mare and an uncomplicated seroma at a portal site in another mare in the present study may also be expected, based on previous reports (Galuppo et al. 1995, Bouré et al. 1997, Hanson and Galuppo 1999, Rodgerson et al. 2001, Hand et al. 2002).

One horse necropsied 3 days after surgery had 2 areas of mild erythema approximately 10 cm in diameter on the mesentery of the small colon immediately adjacent to each transection site. These areas of erythema were not noticed at the conclusion of surgery and may have been the result of postoperative contact between the mesentery and the transected ovarian pedicle. There may have also been a delayed response to heat and debris released by the Harmonic Scalpel™ during the surgery. Two horses necropsied 30 days following surgery had numerous well-vascularized fibrous tags present along the transection lines of one or both of the ovarian pedicles. There was no gross inflammation or adhesions of viscera associated with the tags. The cause of these tags is unknown. They may simply reflect an exuberant healing response.

The histologic changes noted on tissue sections obtained 3 days after surgery were consistent with recent mild to moderate thermal injury. The depth of coagulation necrosis measured ranged from 0.20 to 5.04 mm with a median of 2.87 mm. There was no appreciable difference between sections taken from the horizontal or vertical portions of the ovarian pedicle (median depth 2.95 mm and 2.80 mm, respectively). These

measurements are greater than measurements reported after ovarian wedge resection or transection of a distal uterine horn with the Harmonic Scalpel™ in a rabbit model (range, 0.30 to 0.38 mm) (Schemmel et al. 1997). Further, coagulation depths of porcine internal thoracic arteries harvested with the Harmonic Scalpel™ were reported to range from 0.58 to 0.96 mm (Higami et al. 2000). The differences in coagulation depths between these reports and the present study are probably the result of the longer application times needed to coagulate and cut the equine ovarian pedicle, as it has been demonstrated that collateral tissue damage increases linearly with increasing duration of application of the Harmonic Scalpel™ (Amaral and Chrostek 1995). The need to occasionally reapply the scalpel to the transection line in order to stop hemorrhage could also explain the increased and wide range of coagulation depths found in our samples. Further, the Harmonic Scalpel™ Laparosonic® Coagulating Shears may cause more lateral thermal tissue damage than the Harmonic Scalpel™ hook blade. Kwok et al. (2001) found greater lateral thermal damage in incised sheep uteri when using the Harmonic Scalpel™ Laparosonic® Coagulating Shears at power level 5 compared to monopolar electrosurgical scissors, which is in contrast to previous reports using the Harmonic Scalpel™ hook blade (Hambley et al. 1988, Amaral 1995, Schemmel et al. 1997, Sinha and Gallagher 2003). Also, higher tissue temperatures have been measured with the application of the Laparosonic® Coagulating Shears (Kinoshita et al. 1999) than with the hook blade (Orejola et al. 2000). The clinical impact of greater lateral thermal damage with the Laparosonic® coagulating shears was considered minimal by Kwok et al. (2001). It was concluded that the Harmonic Scalpel™ Laparosonic® Coagulating Shears were a suitable and useful tool for laparoscopic dissection with hemostasis. The histologic changes present 30 days following surgery in the present study were characterized by mild to moderate chronic inflammation and fibrosis, and were consistent with a resolving thermal injury.

Chapter 7. Conclusions

In conclusion, the Harmonic Scalpel™ provided safe and reliable hemostasis of the ovarian blood supply during standing laparoscopic ovariectomy in normal horses. The instrument was relatively easy to use and appears to be a feasible alternative to other techniques used for hemostasis of the ovarian pedicle.

Chapter 8. Literature cited

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Chapter 9. Figures

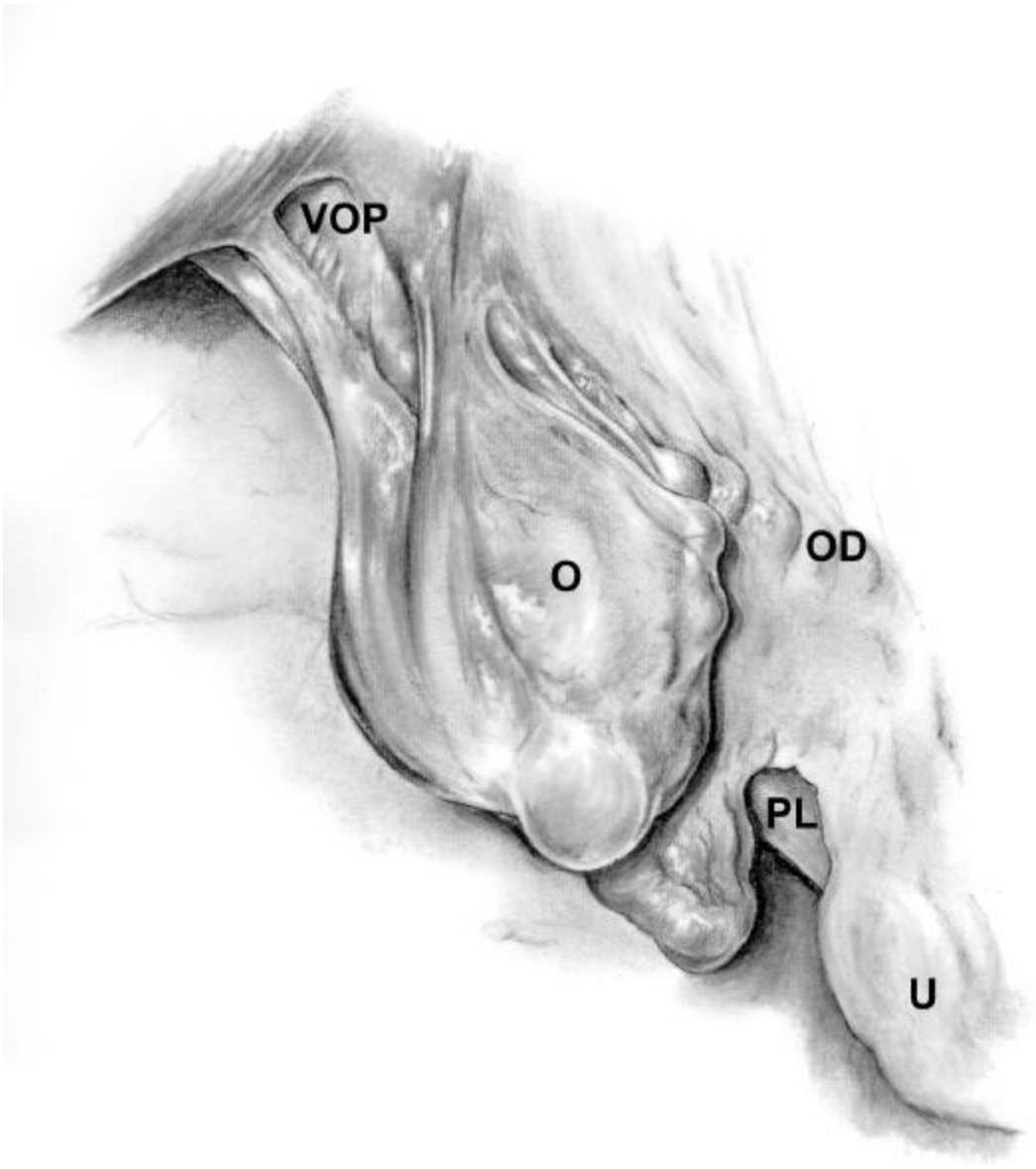

Figure 1: Anatomy of the left ovary as seen during standing laparoscopy. (O – ovary, VOP – vertical part of the ovarian pedicle, OD – uterine tube, PL – proper ligament of the ovary, U – uterine horn)

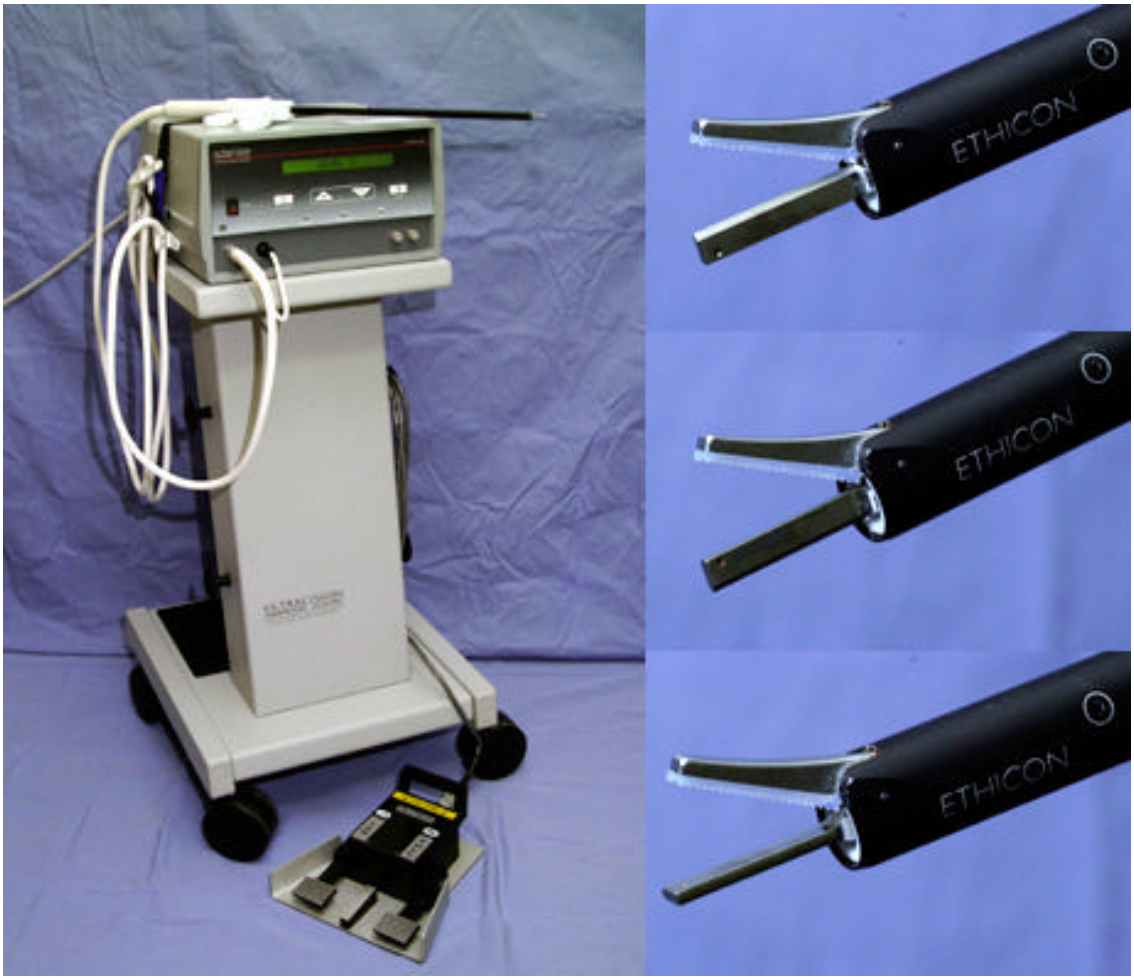

Figure 2: Harmonic Scalpel™ with the Laparosonic® Coagulating Shears. Note the 3 different blade configurations (top: sharp blade, middle: blunt blade, bottom: flat blade).

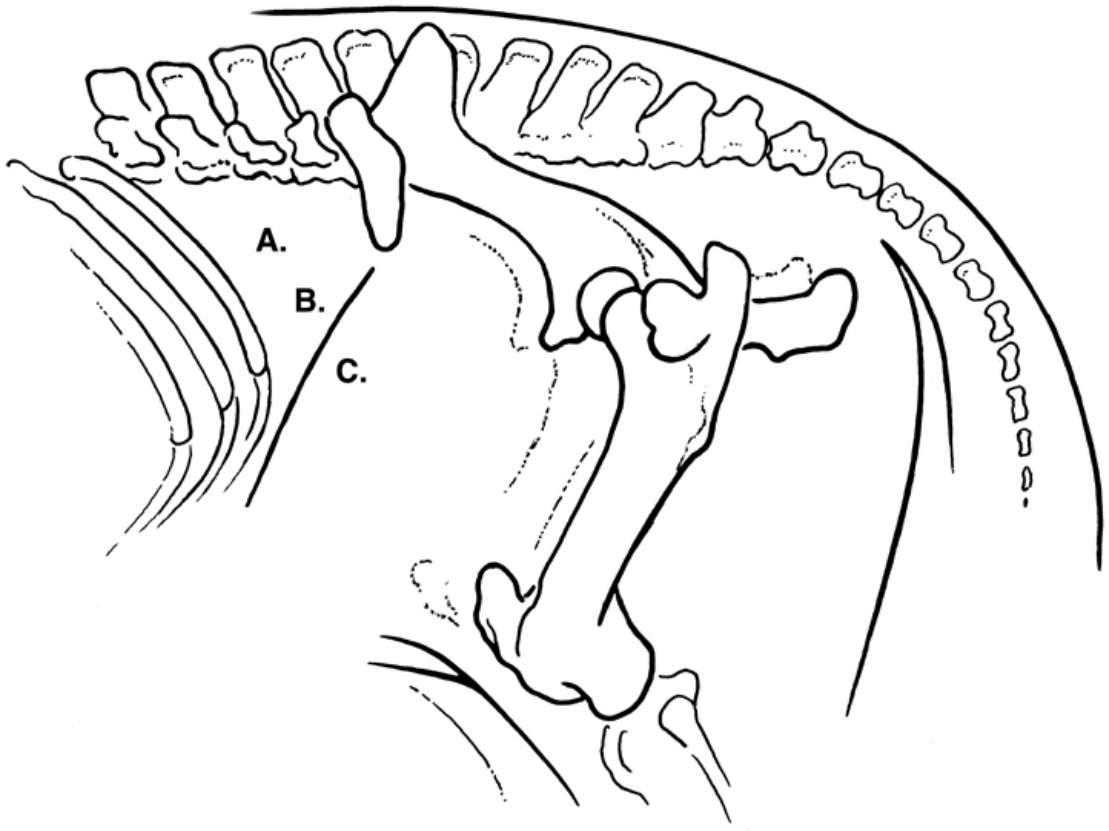

Figure 3: Placement of the operating portals. The diagonal line represents the dorsal aspect of the intrnal abdominal oblique muscle. (A. proximal instrument portal, B. laparoscope portal, C. distal instrument portal)

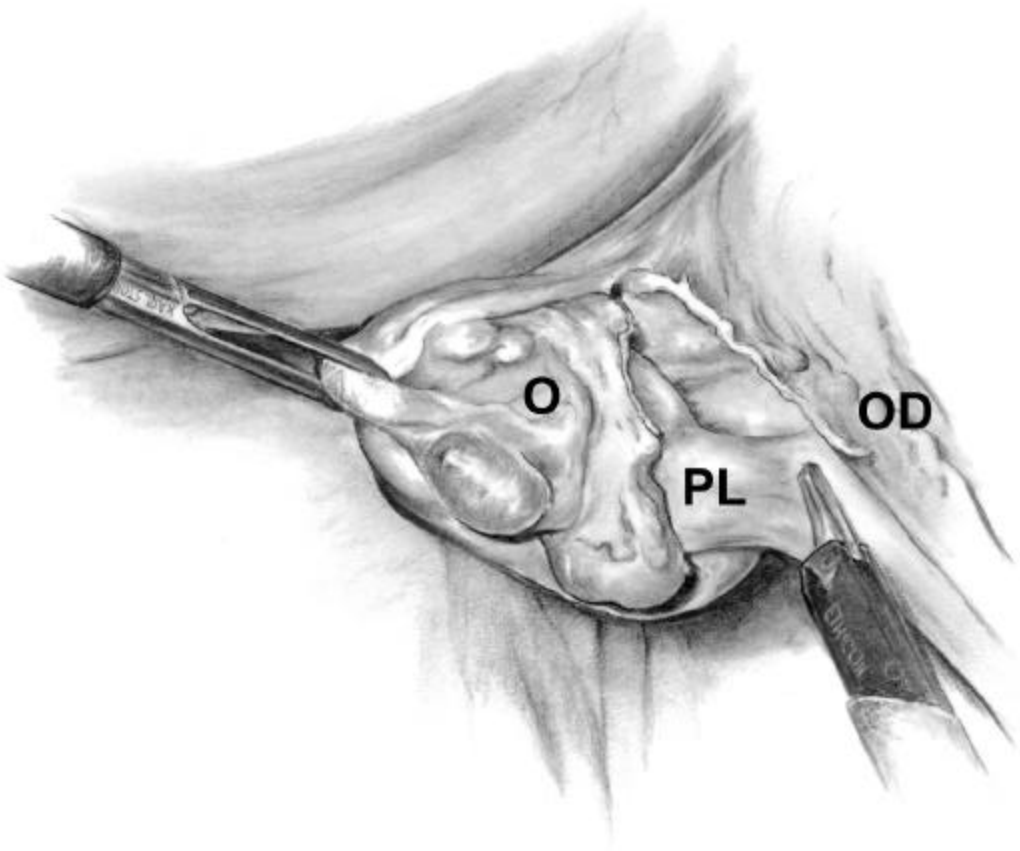

Figure 4: Mesosalpinx and uterine tube (lateral wall of the ovarian bursa) have been transected. (O – ovary, PL – proper ligament of the ovary, OD – uterine tube)

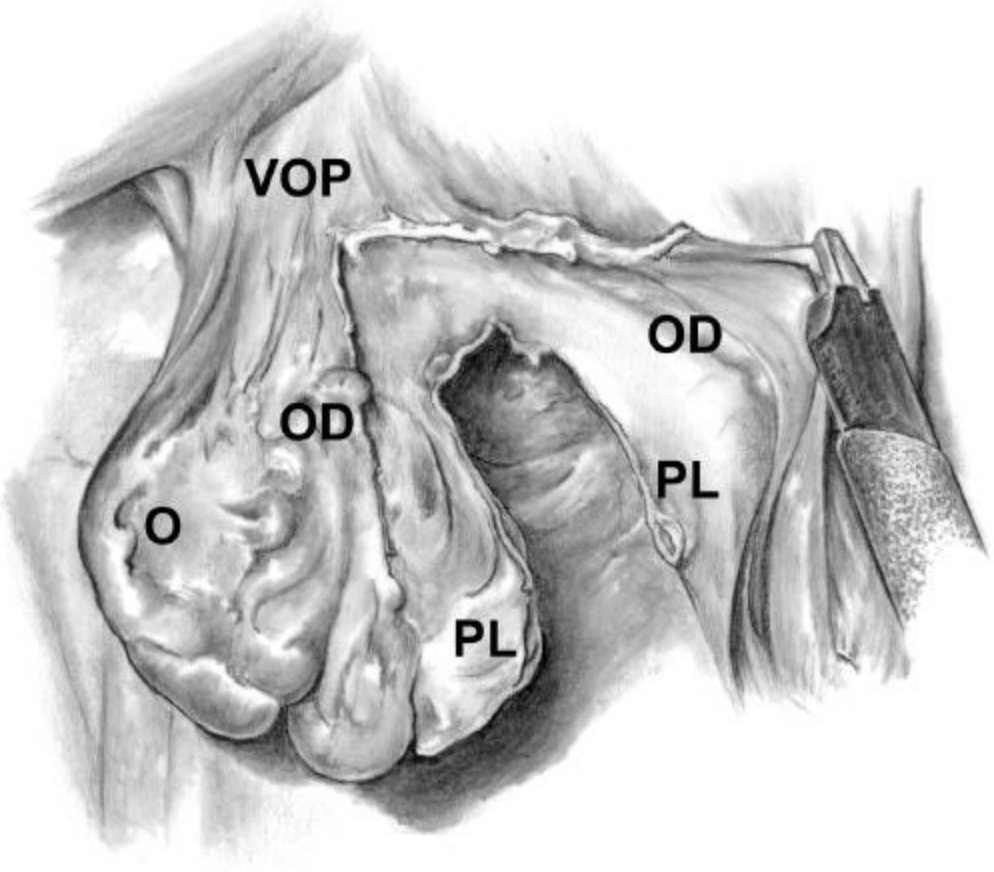

Figure 5: The proper ligament and its mesentery (medial wall of the ovarian bursa) have been transected. (O – ovary, PL – proper ligament of the ovary, OD – uterine tube, VOP – vertical part of the ovarian pedicle)

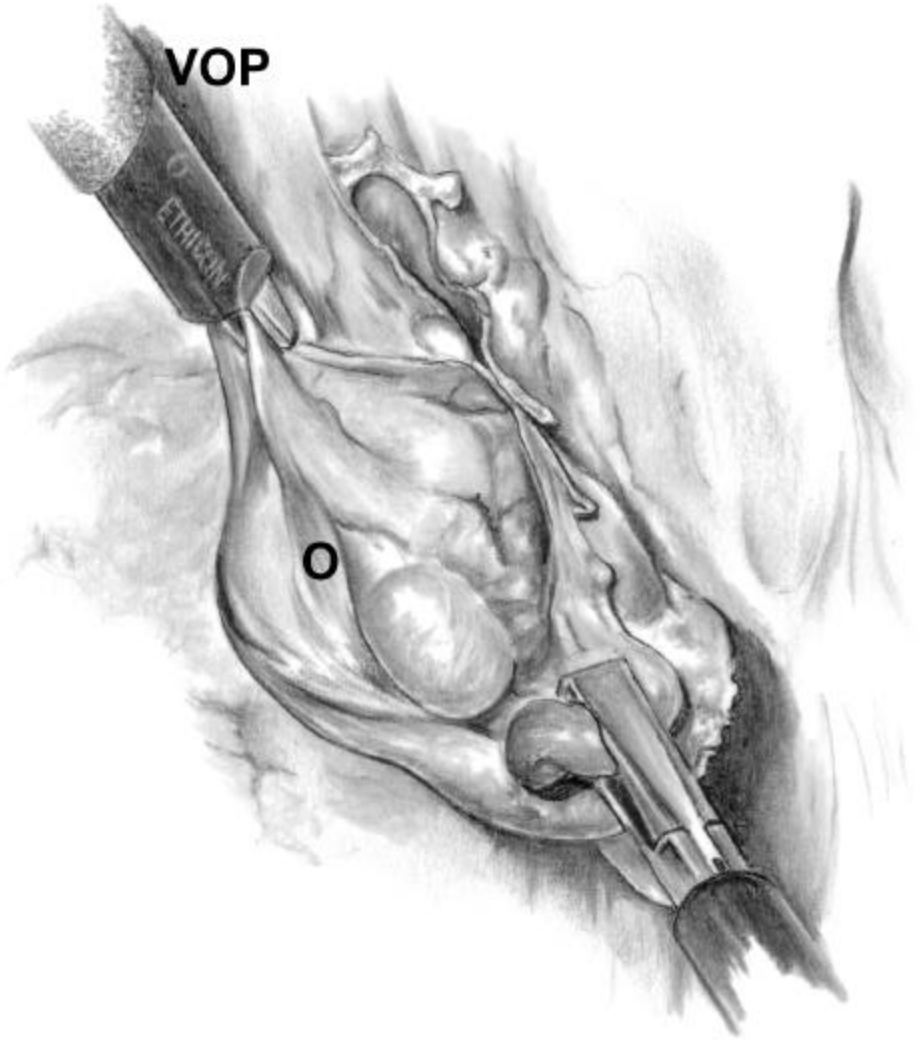

Figure 6: The ovary is stabilized through the caudoventral portal. The first cut to transect the vertical part of the ovarian pedicle is used to open up a loose connective tissue plane within the pedicle. (O – ovary)

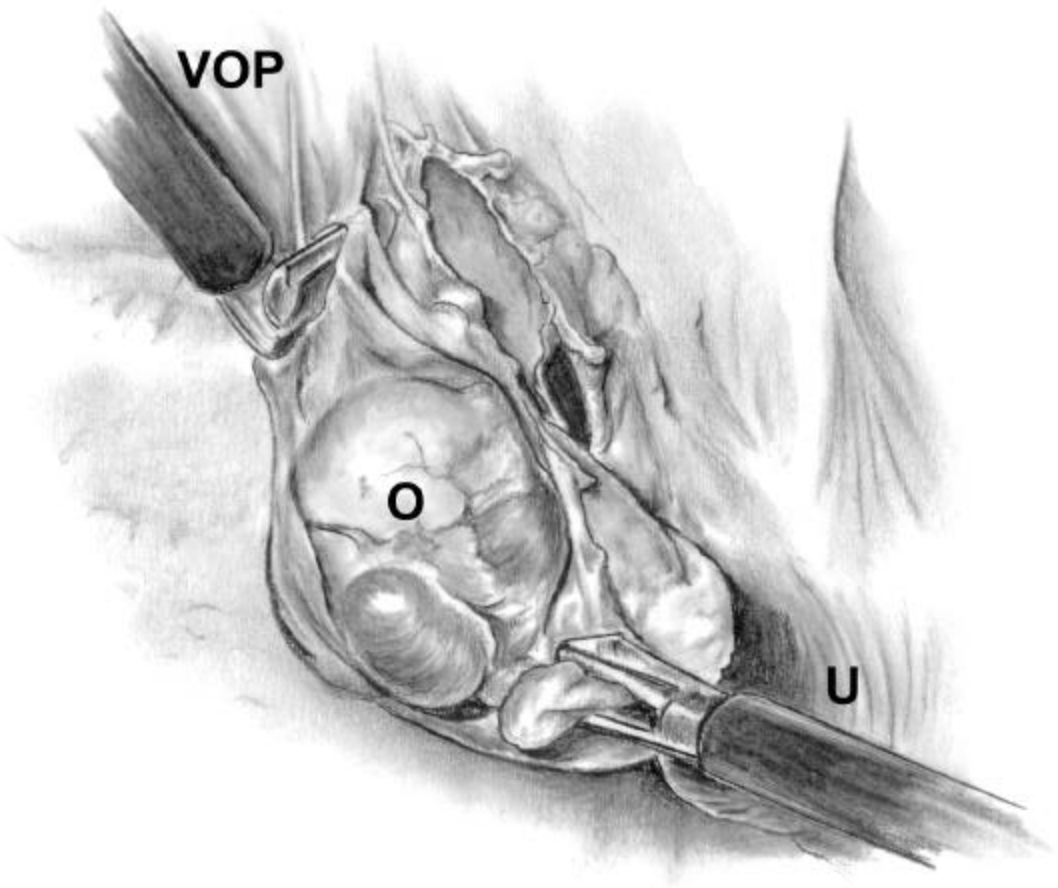

Figure 7: Laparoscopic scissors are used to separate the remaining portion of the ovarian pedicle into medial and lateral components by blunt dissection. (O – ovary, VOP – vertical part of the ovarian pedicle, U – uterine horn)

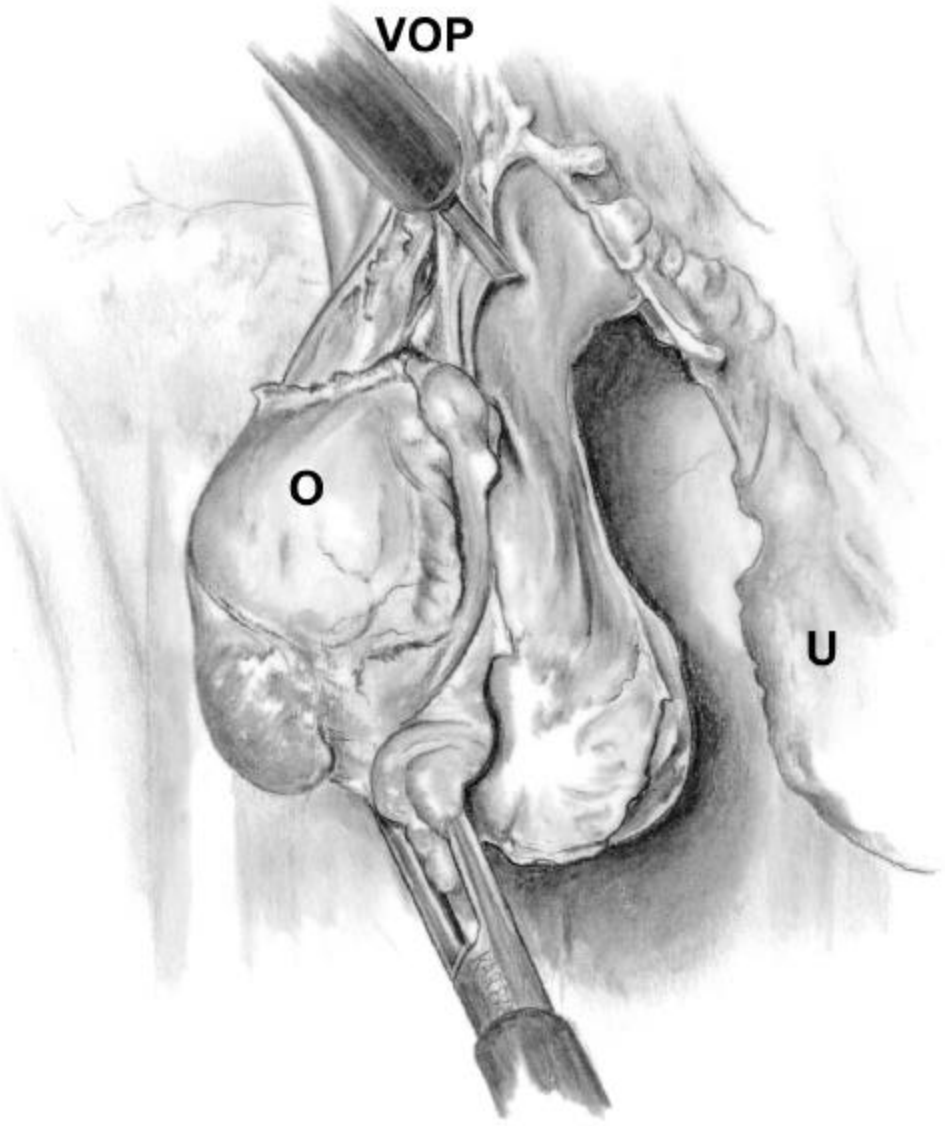

Figure 8: Transection of the lateral aspect of the remaining ovarian pedicle with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. (O – ovary, U – uterine horn)

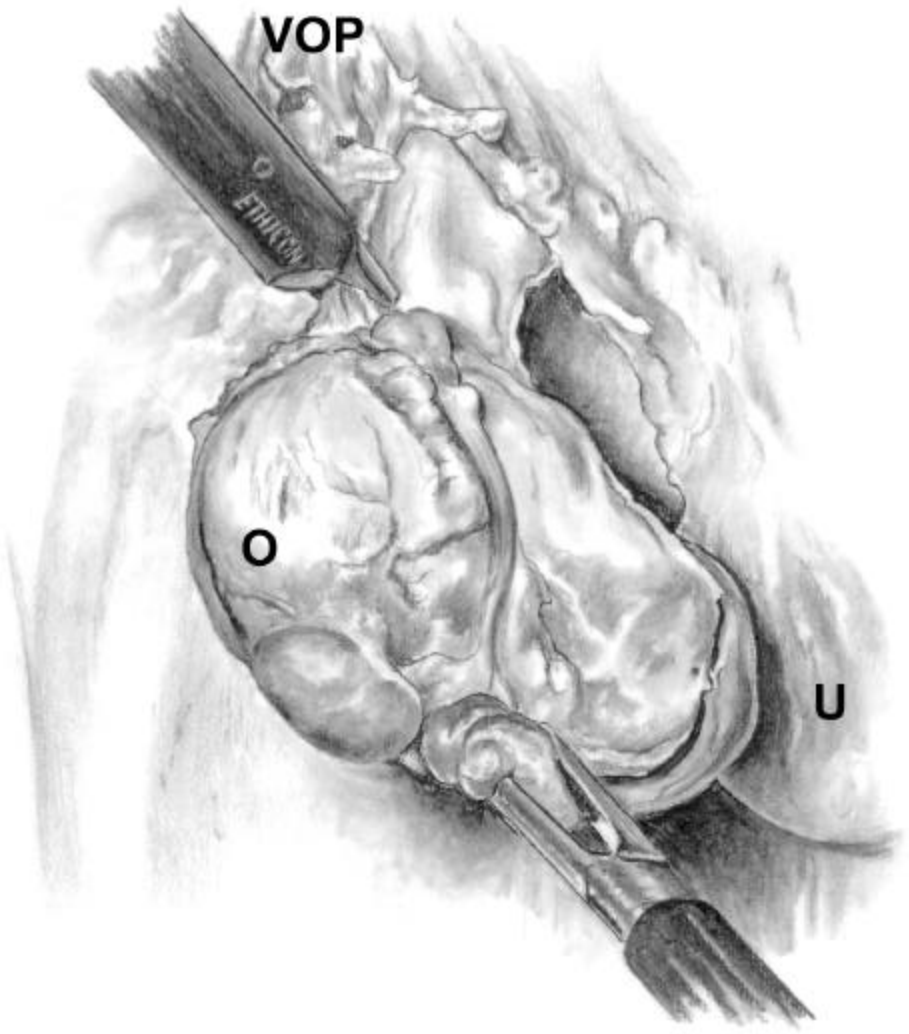

Figure 9: Transection of the medial aspect of the remaining ovarian pedicle with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. (O – ovary, VOP – vertical part of the ovarian pedicle, U – uterine horn)

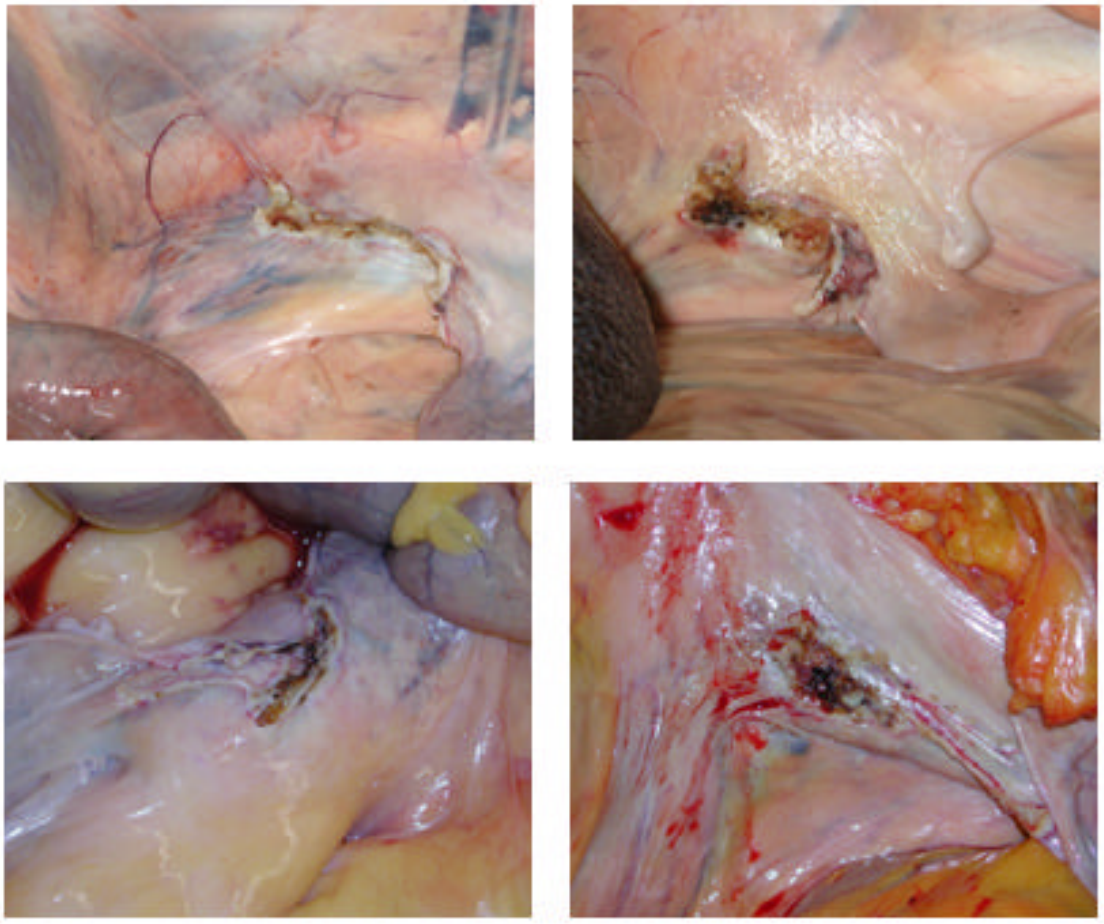

Figure 10: Photographs of transection sites of 4 different mares 3 days postoperatively.

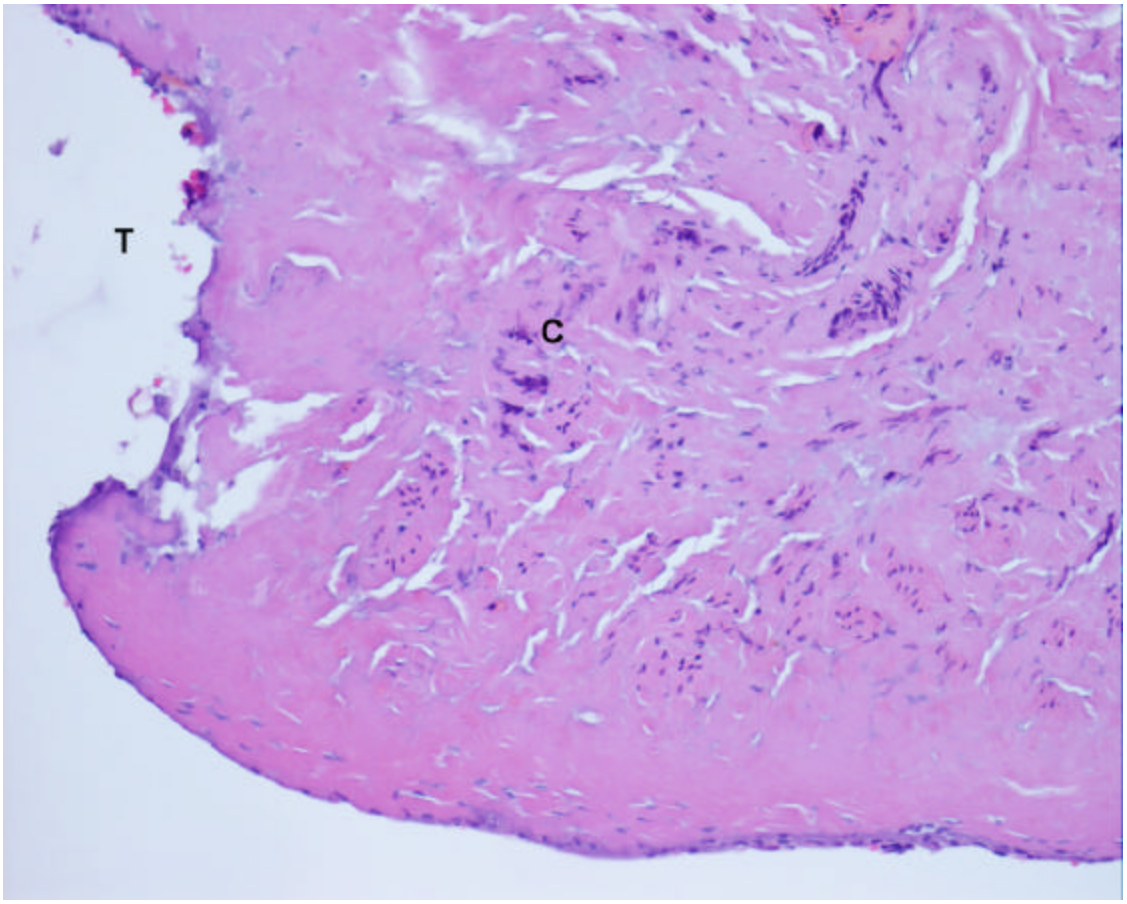

Figure 11: Photomicrograph of the ovarian pedicle, 3 days after transection with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. (C – coagulum, T – transection line)

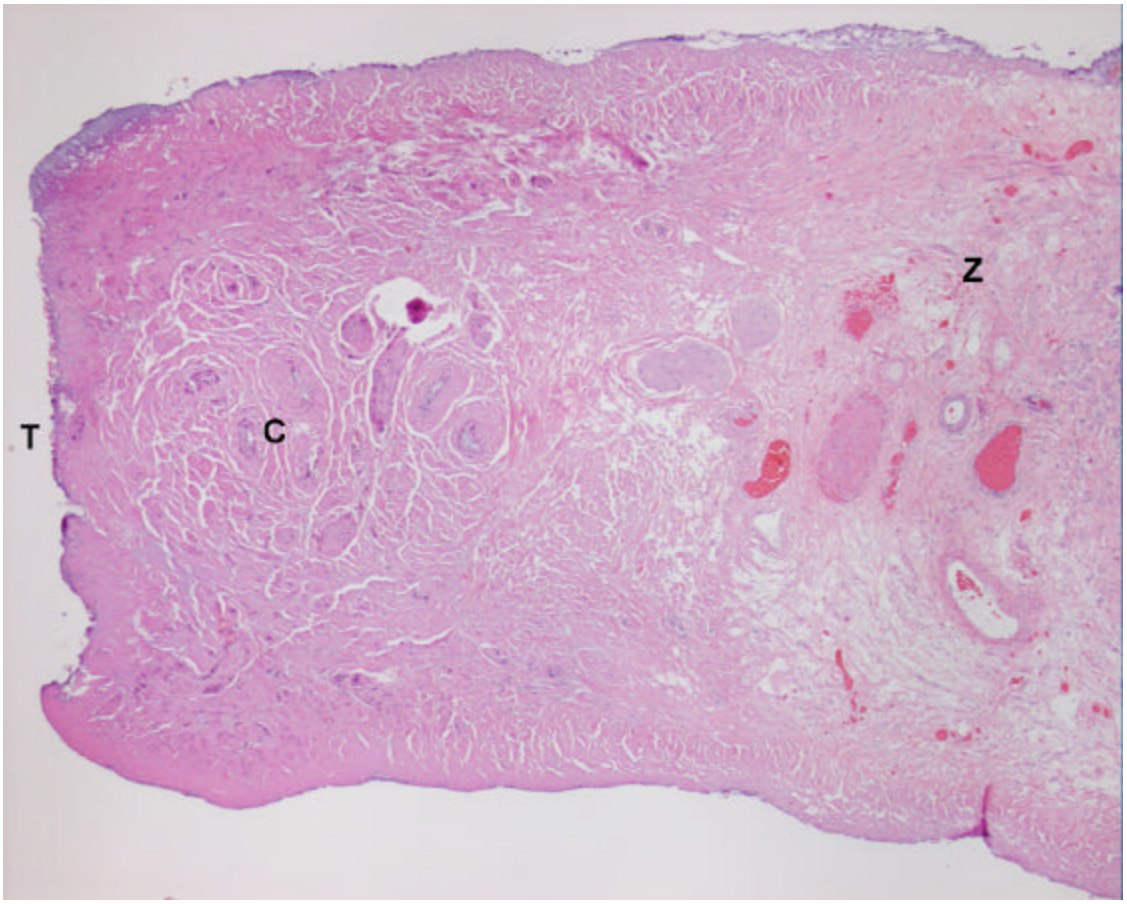

Figure 12: Photomicrograph of the wall of the ovarian bursa 3 days after transection with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. (C – coagulum, T – transection line, Z – zone of congested vessels)

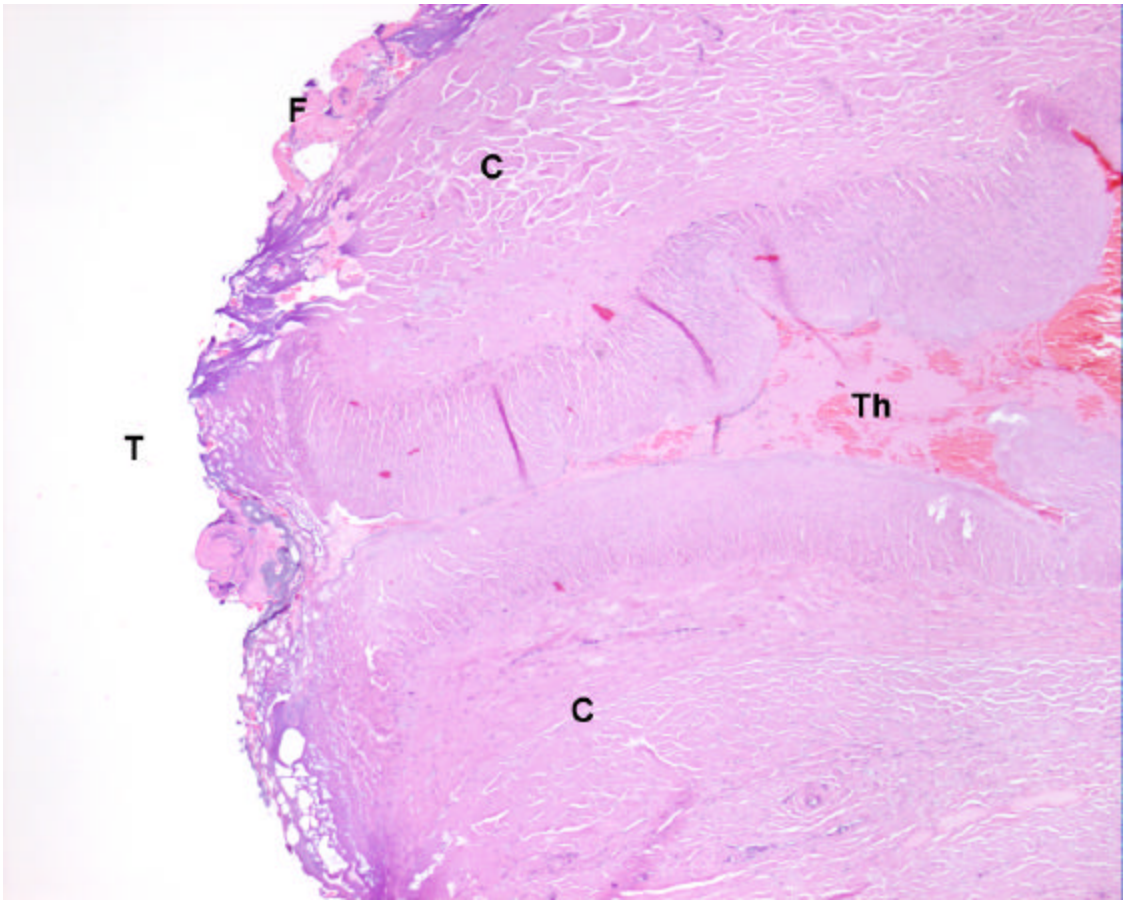

Figure 13: Photomicrograph of a muscular artery 3 days after being sealed with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. (C – coagulum, F – fibrin, T – transection line, Th – thrombus within the muscular artery)

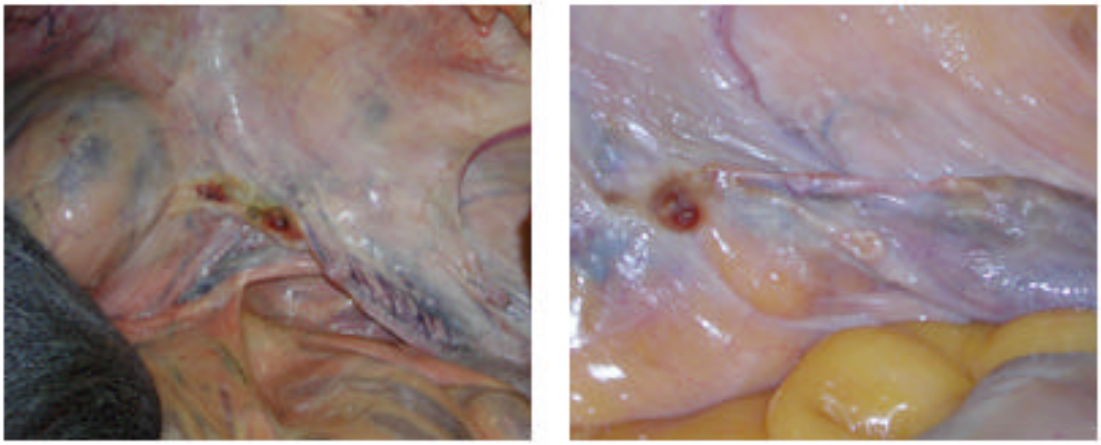

Figure 14: Photographs of transection sites of 2 different mares 30 days postoperatively.

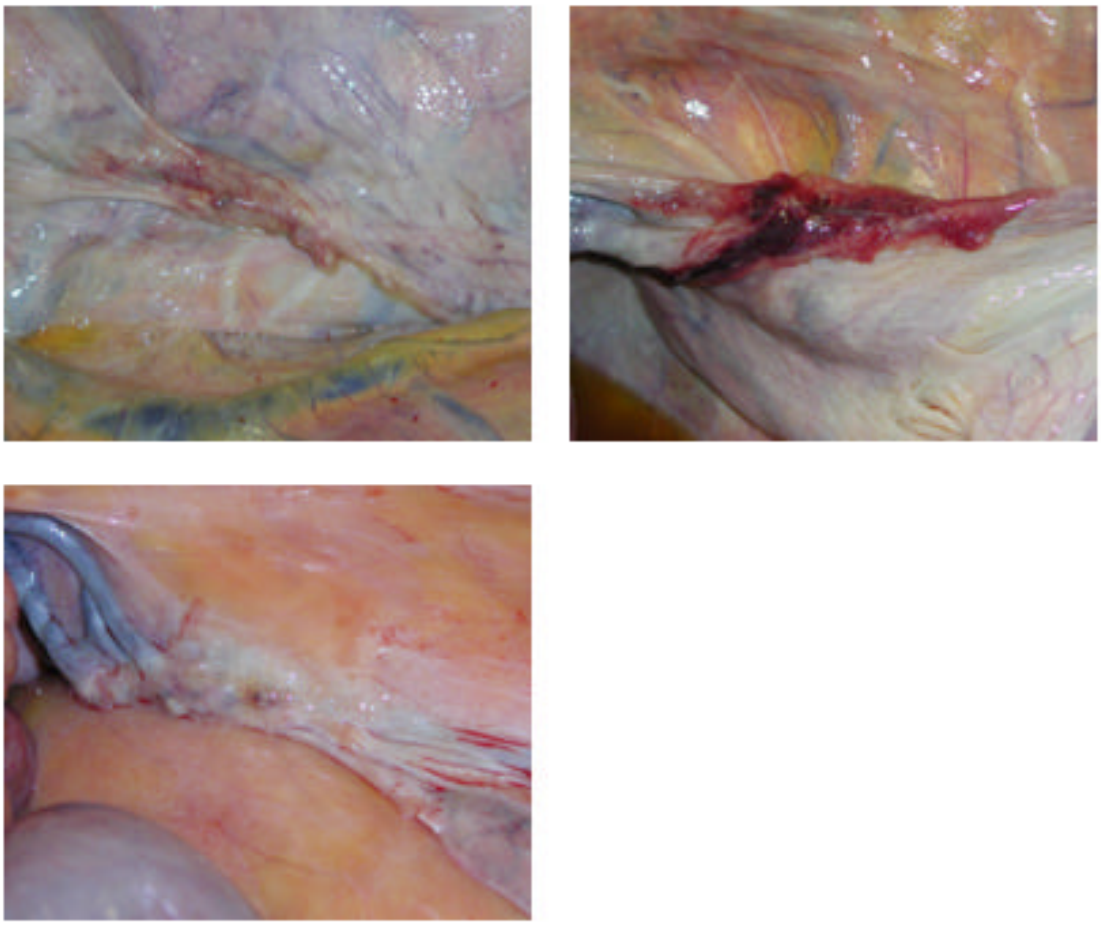

Figure 15: Photographs of transection sites of 2 different mares 30 days postoperatively. Note the vascularized fibrous tags in the area of the transected ovarian pedicle.

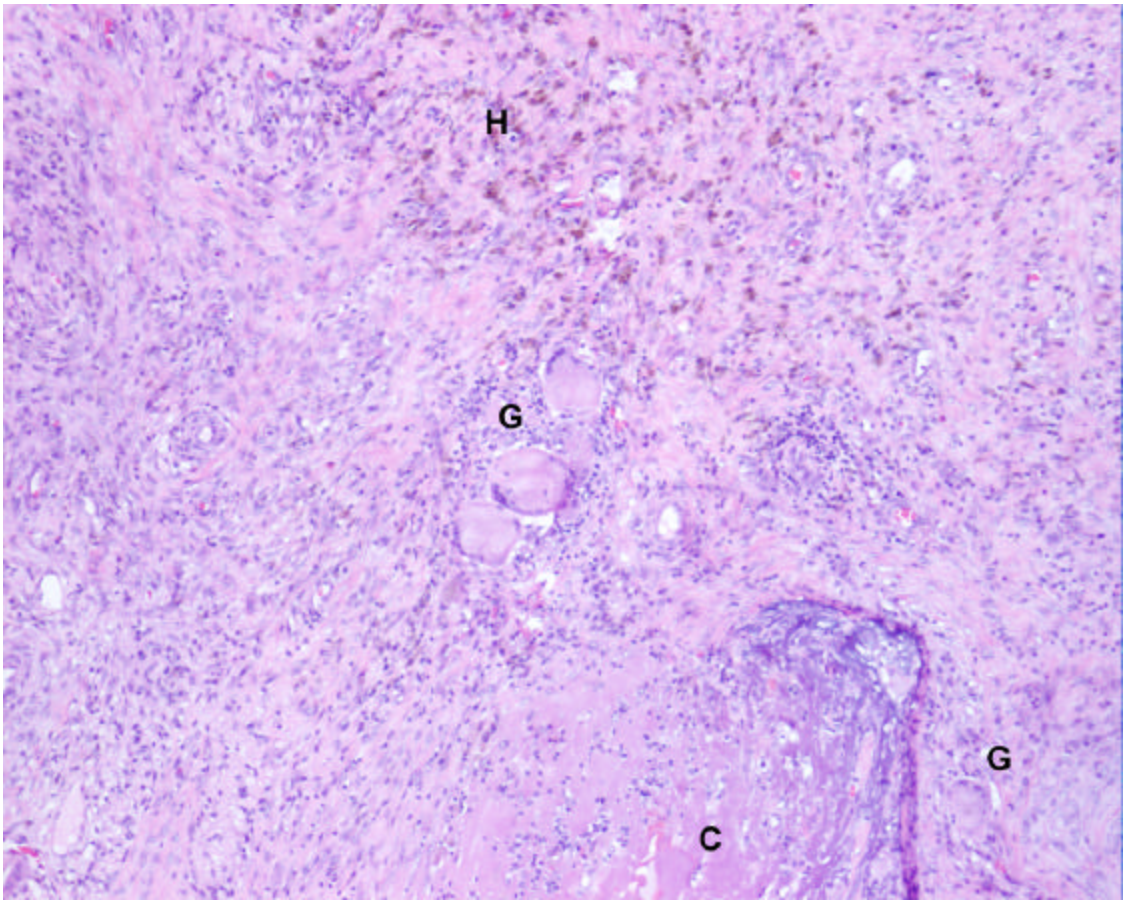

Figure 16: Giant cells, hemosiderin, and remaining coagulum within maturing fibrous tissue in the area of the ovarian pedicle 30 days after transection with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. (C – remaining coagulum, H – hemosiderin, G – giant cells)

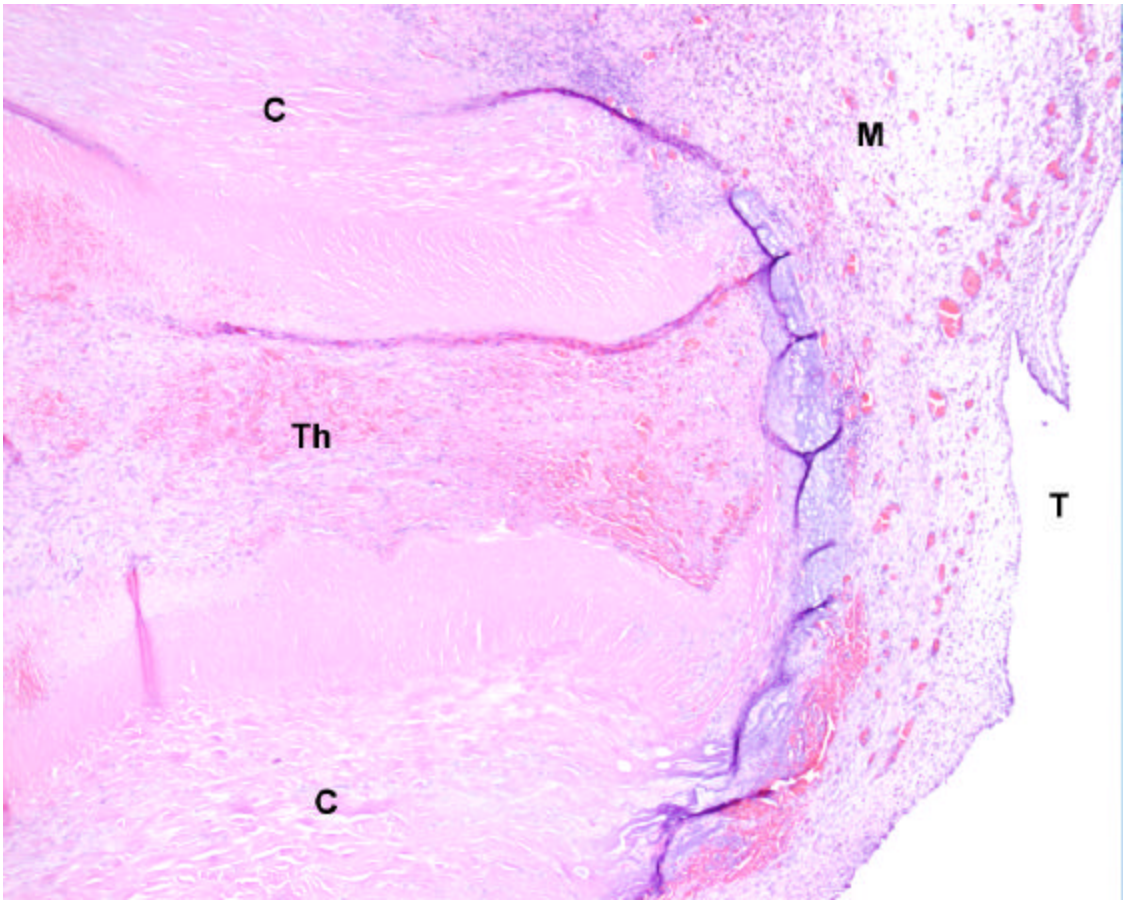

Figure 17: Photomicrograph of a muscular artery 30 days after transection with the Harmonic Scalpel™ Laparosonic® Coagulating Shears. (C – coagulum, M – maturing fibrous tissue, T – transection line, Th – thrombus within the muscular artery)

10. Appendix

Table 1: Animals

Horse	**Age in years**	**Weight in kg**	**Breed**	**Maiden mare**	**Cycling at time of surgery**	**Follow-up period in days**	**Reason donated**
Luv Flower	2	410	THB	X	X	3	Lameness
Granny	20	543	THB		X	3	Chronic laminitis
Babe	16	445	APH	X		3	Degenerative suspensory desmitis
Bugs	17	522	THB		X	3	Chronic weight loss
Asian Rose	7	509	THB		X	30	Lameness, fungal endometritis
Keebler	17	418.5	Arabian		X	30	Lameness
Lulu	9	540	THB	X	X	30	Behavioral abnormalities
Don't Devil Me	13	520	THB			30	Chronic weight loss

Table 2: Preoperative physical exam information

Horse	**Rectal temperature in °C**	**Heart rate in beats/min**	**Respiratory rate in breaths/min**	**Mucous membranes**	**CRT in sec**
Luv Flower	37.3	36	12	pink, moist	<2
Granny	37.3	40	12	pink, moist	<2
Babe	37.2	36	12	pink, moist	<2
Bugs	37.5	40	14	pink, moist	<2
Asian Rose	37.4	36	12	pink, moist	<2
Keebler	37.2	40	32	pink, moist	<2
Lulu	37.8	36	12	pink, moist	<2
Don't Devil Me	37.4	36	12	pink, moist	<2

Horse	**Cardiac auscultation**	**Pulmonary auscultation**	**Gastrointestinal auscultation**
Luv Flower	WNL, 2nd degree AV block	WNL	WNL
Granny	WNL	WNL	WNL
Babe	WNL	WNL	WNL
Bugs	WNL	WNL	WNL
Asian Rose	WNL	WNL	WNL
Keebler	WNL	WNL	WNL
Lulu	WNL	WNL	WNL
Don't Devil Me	WNL	WNL	WNL

Table 3: Preoperative complete blood count information

Horse	HCT in %	PP in g/dl	Fibrinogen in mg/dl	WBC /µl
Luv Flower	35.1	6.2	200	7,320
Granny	36.2	6.5	200	7,280
Babe	34.2	6.2	200	5,280
Bugs	46.2	7.4	300	9,800
Asian Rose	38.5	6.0	100	7,170
Keebler	38.8	6.9	300	6,900
Lulu	44.6	7.3	200	10,200
Don't Devil Me	35.7	6.6	300	5,420

Horse	Seg /µl	Band /µl	Lymph /µl	Mono /µl	Eos /µl	Baso /µl
Luv Flower	4,612	0	2,416	220	0	73
Granny	4,805	0	2,184	291	0	0
Babe	3,062	0	1,901	264	53	0
Bugs	5,586	0	3,332	98	490	294
Asian Rose	3,011	0	3,728	359	72	0
Keebler	4,002	0	2,070	276	483	69
Lulu	5,304	0	4,284	408	204	0
Don't Devil Me	3,577	0	1,680	108	54	0

Table 4a: Amounts and time intervals of detomidine hydrochloride administered IV during the surgery.

Horse	# of drug administrations	Time interval between administrations in minutes	Detomidine in mg/kg
Luv Flower	1	N/A	0.0073
	2	37	0.0049
	3	23	0.0049
	4	29	0.0049
	5	43	0.0049
	6	33	0.0049
Granny	1	N/A	0.0055
	2	35	0.0037
	3	7	0.0037
	4	5	0.0037
	5	41	0.0037
	6	33	0.0037
	7	26	0.0037
	8	26	0.0037
	9	37	0.0037
Babe	1	N/A	0.0067
	2	25	0.0045
	3	40	0.0045
	4	23	0.0045
	5	26	0.0045
	6	28	0.0045
Bugs	1	N/A	0.0057
	2	41	0.0057
	3	21	0.0057
	4	26	0.0057
	5	35	0.0057
	6	30	0.0057
	7	24	0.0038

Table 4a (continued): Amounts and time intervals of detomidine hydrochloride administered IV during the surgery.

Horse	**# of drug administrations**	**time interval between administrations in minutes**	**detomidine in mg/kg**
Asian Rose	1	N/A	0.0039
	2	41	0.0039
	3	13	0.0039
	4	55	0.0039
	5	34	0.0039
	6	20	0.0039
Keebler	1	N/A	0.0060
	2	19	0.0048
	3	34	0.0048
	4	49	0.0048
	5	36	0.0048
	6	27	0.0048
Lulu	1	N/A	0.0056
	2	34	0.0037
	3	33	0.0046
	4	44	0.0037
Don't Devil Me	1	N/A	0.0058
	2	31	0.0038
	3	27	0.0038
	4	25	0.0058
	5	42	0.0038
	6	25	0.0038
	7	27	0.0038
	8	36	0.0038

Table 4b: Amounts and time intervals of butorphanol tartrate administered IV during the surgery.

Horse	**# of drug administrations**	**Time interval between administrations in minutes**	**Butorphanol in mg/kg**
Luv Flower	1	N/A	0.0073
	2	37	0.0049
	3	23	0.0049
	4	29	0.0049
	5	43	0.0049
	6	33	0.0049
Granny	1	N/A	0.0055
	2	35	0.0184
	3	86	0.0037
	4	26	0.0037
Babe	1	N/A	0.0067
	2	25	0.0045
	3	40	0.0045
	4	23	0.0045
	5	26	0.0045
	6	28	0.0045
Bugs	1	N/A	0.0057
	2	41	0.0057
	3	21	0.0057
	4	26	0.0057
	5	35	0.0057
	6	30	0.0057
	7	24	0.0038

Table 4b (continued): Amounts and time intervals of butorphanol tartrate administered IV during the surgery.

Horse	**# of drug administrations**	**time interval between administrations in minutes**	**detomidine in mg/kg**
Asian Rose	1	N/A	0.0039
	2	41	0.0039
	3	13	0.0039
	4	55	0.0039
	5	34	0.0039
	6	20	0.0039
Keebler	1	N/A	0.0060
	2	19	0.0048
	3	34	0.0048
	4	49	0.0048
	5	36	0.0048
	6	27	0.0048
Lulu	1	N/A	0.0056
	2	34	0.0037
	3	33	0.0046
	4	44	0.0037
Don't Devil Me	1	N/A	0.0058
	2	31	0.0038
	3	27	0.0038
	4	25	0.0019
	5	42	0.0019
	6	25	0.0019
	7	27	0.0019
	8	36	0.0019

Table 5: Total doses of detomidine hydrochloride and butorphanol tartrate administered IV during the surgery.

Horse	weight in kg	total dose of detomidine in mg	total dose of detomidine in mg/kg	total dose of butorphanol in mg	total dose of butorphanol in mg/kg
Luv Flower	410	13.0	0.032	13.0	0.032
Granny	543	19.0	0.035	17.0	0.031
Babe	445	13.0	0.029	13.0	0.029
Bugs	522	20.0	0.038	20.0	0.038
Asian Rose	509	12.0	0.024	12.0	0.024
Keebler	419	12.5	0.030	12.5	0.030
Lulu	540	9.5	0.018	9.5	0.018
Don't Devil Me	520	18.0	0.035	12.0	0.023

Table 6: Time used to transect the ovarian pedicles and achieve complete hemostasis with the Harmonic Scalpel™ Laparosonic® Coagulating Shears and occurrence of bleeding.

Horse	**Left ovarian pedicle**	**Occurrence of bleeding (left)**	**Right ovarian pedicle**	**Occurrence of bleeding (right)**
Luv Flower	36		29	
Granny	51	X	62	X
Babe	29		23	X
Bugs	28	X	20	X
Asian Rose	40	X	28	
Keebler	15	X	25	X
Lulu	22	X	18	X
Don't Devil Me	21		48	X

Table 7a: Findings on physical exam postoperatively (Luv Flower)

Time post-op	**Attitude**	**Appetite**	**Rectal temperature in °C**	**Heart rate in beats/min**
1 hour	QAR, shivering	very good	37.1	36
3 hours	BAR	good	38.8	48
4 hours	BAR	very good		44
8 hours	QAR	good	39.7	44
10 hours	BAR	very good	38.8	
1 day (morning)	BAR	good	38.3	36
1 day (evening)	BAR	good	38.3	40
2 days (morning)	BAR	good	37.7	38
2 days (evening)	BAR	slightly decreased	37.7	36
3 days (morning)	BAR	slightly decreased	37.3	40

Time post-op	**Respiratory rate in breaths/min**	**Gastrointestinal auscultation**	**Other**
1 hour	12	decreased	
3 hours	18	increased	Incisional serous discharge
4 hours	12	decreased	Incisional serous discharge
8 hours	12	increased	
10 hours			
1 day (morning)	12	decreased	Incisions slightly swollen
1 day (evening)	12	decreased	Incisions slightly swollen
2 days (morning)	12	WNL	Incisions less swollen
2 days (evening)	12	WNL	Incisions less swollen
3 days (morning)	12	WNL	Incisions less swollen

Table 7b: Findings on physical exam postoperatively (Granny)

Time post-op	Attitude	Appetite	Rectal temperature in °C	Heart rate in beats/min
1 hour	QAR, shivering	very good	37.1	36
3 hours	BAR	very good	37.8	40
4 hours	BAR	very good	37.7	36
7 hours	QAR	very good	38.3	40
1 day (morning)	QAR	good	37.7	34
1 day (evening)	QAR	good	38.4	40
2 days (morning)	BAR	good	37.1	38
2 days (evening)	Excited	good	38.0	44
3 days (morning)	BAR	very good	37.6	36

Time post-op	Respiratory rate in breaths/min	Gastrointestinal auscultation	Other
1 hour	8	decreased	
3 hours	8	decreased	
4 hours	8	WNL	
7 hours	8	slightly decreased	Moderate subcutaneous emphysema (right side)
1 day (morning)	8	WNL	Moderate subcutaneous emphysema (right side)
1 day (evening)	8	slightly decreased	Moderate subcutaneous emphysema (right side)
2 days (morning)	8	WNL	Moderate subcutaneous emphysema (right side)
2 days (evening)	8	WNL	Moderate subcutaneous emphysema (right side)
3 days (morning)	8	slightly decreased	Mild subcutaneous emphysema (right side)

Table 7c: Findings on physical exam postoperatively (Babe)

Time post-op	Attitude	Appetite	Rectal temperature in °C	Heart rate in beats/min
1 hour	QAR, shivering	very good	36.9	32
2 hours	QAR	very good	37.0	36
4 hours	BAR	very good	37.4	40
7 hours	BAR	good	38.3	40
1 day (morning)	BAR	good	38.4	42
1 day (evening)	BAR	good	38.2	36
2 days (morning)	BAR	very good	37.7	40
2 days (evening)	BAR	good	37.9	40
3 days (morning)	BAR	very good	37.9	38

Time post-op	Respiratory rate in breaths/min	Gastrointestinal auscultation	Other
1 hour	12	absent	
2 hours	12	decreased	
4 hours	12	WNL	Incisional serous discharge
7 hours	12	WNL	Incisional serous discharge
1 day (morning)	36	slightly decreased	
1 day (evening)	16	WNL	
2 days (morning)	16	WNL	
2 days (evening)	12	WNL	
3 days (morning)	10	WNL	

Table 7d: Findings on physical exam postoperatively (Bugs)

Time post-op	Attitude	Appetite	Rectal temperature in °C	Heart rate in beats/min
1 hour	QAR	good	36.6	30
2 hours	BAR	good	37.4	36
4 hours	QAR	good	38.1	44
7 hours	QAR	slightly decreased	38.8	40
1 day (morning)	QAR	good	38.1	40
1 day (evening)	QAR	good	38.4	32
2 days (morning)	QAR	good	37.8	32
2 days (evening)	QAR	good	37.7	32
3 days (morning)	QAR	good	36.9	32

Time post-op	Respiratory rate in breaths/min	Gastrointestinal auscultation	Other
1 hour	10	absent	Incisional serous discharge
2 hours	12	decreased	Incisional serous discharge
4 hours	16	slightly decreased	Incisional serous discharge
7 hours	16	decreased	Incisional serous discharge
1 day (morning)	14	decreased	
1 day (evening)	12	WNL	
2 days (morning)	14	WNL	
2 days (evening)	12	WNL	
3 days (morning)	12	WNL	

Table 7e: Findings on physical exam postoperatively (Asian Rose)

Time post-op	Attitude	Appetite	Rectal temperature in °C	Heart rate in beats/min	Respiratory rate in breaths/min	Gastrointestinal auscultation	Other
1 hour	QAR	very good	37.2	42	12	decreased	
3 hours	BAR	very good	37.8	44	12	decreased	
4 hours	BAR	very good	38.2	40	12	WNL	
8 hours	QAR	good	38.6	36	12	WNL	
1 day (morning)	BAR	good	38.3	36	12	WNL	
1 day (evening)	QAR	good	38.0	36	12	WNL	
2 days (morning)	BAR	good	37.5	32	12	WNL	
2 days (evening)	QAR	slightly decreased	37.6	36	12	WNL	
3 days (morning)	BAR	slightly decreased	37.6	32	12	slightly decreased	
3 days (evening)	BAR	slightly decreased	37.8	32	12	WNL	
4 days (morning)	BAR	slightly decreased	37.7	24	12	WNL	
5 days (morning)	BAR	slightly decreased	37.4	30	12	WNL	
6 days (morning)	BAR	good	37.6	32	12	WNL	
7 days (morning)	BAR	good	37.3	24	12	WNL	
8 days (morning)	BAR	very good	37.4	28	12	slightly decreased	seroma on right lowest incision
9 days (morning)	BAR	good	37.5	24	12	slightly decreased	seroma on right lowest incision
10 days (morning)	BAR	good	37.3	28	12	slightly decreased	seroma on right lowest incision
11 days (morning)	BAR	very good	37.4	24	8	WNL	seroma getting smaller
12 days (morning)	BAR	good	37.2	28	8	WNL	seroma getting smaller
13 days (morning)	BAR	good	37.2	32	10	WNL	seroma getting smaller
14 days (morning)	BAR	very good	37.2	36	8	WNL	seroma getting smaller

Table 7f: Findings on physical exam postoperatively (Keebler)

Time post-op	Attitude	Appetite	Rectal temperature in °C	Heart rate in beats/min	Respiratory rate in breaths/min	Gastrointestinal auscultation	Other
1 hour	still sedated	no food offered	35.9	36	12	absent	
2 hours	very quiet	good	36.3	36	12	decreased	
4 hours	QAR	good	37.3	42	12	slightly decreased	
6 hours	QAR	slightly decreased	37.3	36	12	slightly decreased	
7 hours	QAR	slightly decreased	37.4	36	16	slightly decreased	
1 day (morning)	QAR	slightly decreased	37.5	34	20	slightly decreased	
1 day (evening)	BAR	slightly decreased	37.7	36	12	slightly decreased	
2 days (morning)	BAR	good	37.1	36	18	slightly decreased	
2 days (evening)	BAR	good	37.6	40	20	WNL	
3 days (morning)	BAR	good	37.1	32	14	WNL	
3 days (evening)	BAR	good	36.9	36	12	WNL	
4 days (morning)	BAR	good	36.6	34	12	WNL	
5 days (morning)	BAR	very good	36.8	34	10	WNL	
6 days (morning)	BAR	very good	37.2	36	12	WNL	
7 days (morning)	BAR	good	37.1	34	12	WNL	
8 days (morning)	BAR	slightly decreased	36.8	34	12	WNL	
9 days (morning)	BAR	very good	37.4	32	8	WNL	
10 days (morning)	BAR	very good	37.0	32	10	WNL	
11 days (morning)	BAR	good	36.8	32	12	WNL	
12 days (morning)	BAR	very good	36.7	30	10	WNL	
13 days (morning)	BAR	good	37.1	34	8	WNL	
14 days (morning)	BAR	good	36.9	36	12	WNL	

Table 7g: Findings on physical exam postoperatively (Lulu)

Time post-op	Attitude	Appetite	Rectal temperature in °C	Heart rate in beats/min	Respiratory rate in breaths/min	Gastrointestinal auscultation	Other
1 hour	QAR	good	38.1	38	16	decreased	Incisional serous discharge
2 hours	BAR	slightly decreased	37.9	32	16	decreased	Incisional serous discharge
4 hours	BAR	very good	38.3	36	12	WNL	Incisional serous discharge
7 hours	BAR	good	38.2	40	16	slightly decreased	Incisional serous discharge
1 day (morning)	BAR	slightly decreased	38.5	34	12	slightly decreased	
1 day (evening)	BAR	good	38.3	32	16	decreased	
2 days (morning)	BAR	slightly decreased	38.0	34	12	WNL	
2 days (evening)	BAR	good	38.1	36	12	decreased	
3 days (morning)	BAR	slightly decreased	37.8	32	10	decreased	
4 days (morning)	BAR	good	37.6	28	10	slightly decreased	
5 days (morning)	BAR	good	37.2	36	12	WNL	
6 days (morning)	excited	decreased	37.6	38	16	WNL	
7 days (morning)	BAR	slightly decreased	37.7	32	10	decreased	
8 days (morning)	BAR	slightly decreased	37.5	30	12	slightly decreased	
9 days (morning)	BAR	good	37.8	32	12	WNL	
10 days (morning)	BAR	good	37.8	36	12	slightly decreased	
11 days (morning)	BAR	good	37.6	28	12	decreased	
12 days (morning)	BAR	very good	37.4	32	14	WNL	
13 days (morning)	BAR	good	37.4	32	10	slightly decreased	
14 days (morning)	BAR	very good	37.7	36	12	WNL	

Table 7h: Findings on physical exam postoperatively (Don't Devil Me)

Time post-op	Attitude	Appetite	Rectal temperature in °C	Heart rate in beats/min	Respiratory rate in breaths/min	Gastrointestinal auscultation	Other
1 hour	QAR	very good	35.0	24	12	decreased	Incisional serous discharge
3 hours	BAR	very good	36.1	28	12	decreased	Incisional serous discharge
5 hours	BAR	very good	37.1	34	10	WNL	Incisional serous discharge
8 hours	BAR	very good	38.2	38	12	decreased	Incisional serous discharge
1 day (morning)	BAR	very good	38.0	36	10	WNL	
1 day (evening)	BAR	very good	37.1	34	12	WNL	
2 days (morning)	BAR	very good	37.4	34	12	WNL	
2 days (evening)	BAR	very good	37.6	36	12	WNL	
3 days (morning)	BAR	very good	36.7	34	10	WNL	
4 days (morning)	BAR	good	36.6	28	10	WNL	
5 days (morning)	BAR	good	36.9	32	12	WNL	
6 days (morning)	BAR	very good	36.7	26	10	WNL	
7 days (morning)	QAR	decreased	36.8	28	12	WNL	
8 days (morning)	BAR	very good	36.2	32	12	WNL	
9 days (morning)	BAR	very good	36.2	34	10	WNL	
10 days (morning)	BAR	very good	36.6	32	12	WNL	
11 days (morning)	BAR	very good	36.7	36	12	WNL	
12 days (morning)	BAR	very good	36.8	34	10	WNL	
13 days (morning)	BAR	very good	36.8	32	12	WNL	
14 days (morning)	BAR	very good	37.2	32	12	WNL	

Table 8: Gross pathology findings 3 days postoperatively (4 mares)

Horse	Operating portals	Abdominal fluid	General peritonitis	Adhesions	Transection sites	Other
Luv Flower	healing, serosa not closed, subserosal hematoma, 9 cm in diameter (left proximal portal)	brownish yellow	none	none	firm lines of white, desiccated tissue (width 1.5 mm, height 2 mm), no char, erythematous margin (width 1 mm), mild local edema	9x10 cm areas of erythema (mild) on mesentery of small colon (left and right)
Granny	healing, serosa not closed	yellow	none	none	firm lines of white, desiccated tissue (width 1 mm, height 2 mm), minimal amount of char, erythematous margin (width 1 mm)	
Babe	healing, serosa not closed, subserosal hematoma, 4 cm in diameter (left distal portal)	brownish yellow	none	none	firm lines of white, desiccated tissue (width 1 mm, height 2 mm), minimal amount of char, erythematous margin (width 1 mm), mild local edema	moderate retroperitoneal emphysema around right ovarian pedicle
Bugs	healing, serosa not closed	brownish orange	none	none	firm lines of white, desiccated tissue (width 1 mm, height 2 mm), moderate amount of char, erythematous margin (width 1 mm)	

Table 9: Maximum coagulation depth in mm measured 3 days postoperatively

Horse	**Left cranial ovarian pedicle**	**Left caudal ovarian pedicle**	**Left cranial ovarian bursa**	**Left caudal ovarian bursa**
Luv Flower	2.4	2.8	5.0	2.8
Granny	2.9	1.4	3.3	3.6
Babe	2.9	4.1	3.5	3.0
Bugs	3.4	4.2	3.4	3.1

Horse	**Right cranial ovarian pedicle**	**Right caudal ovarian pedicle**	**Right cranial ovarian bursa**	**Right caudal ovarian bursa**
Luv Flower	3.0	2.7	3.4	0.9
Granny	2.6	0.8	2.4	0.2
Babe	4.4	2.8	2.8	2.9
Bugs	3.5	2.3	3.1	1.7

Table 10: Gross pathology findings 30 days postoperatively (4 mares)

Horse	**Operating portals**	**Abdominal fluid**	**General peritonitis**	**Adhesions**	**Transection sites**	**Other**
Asian Rose	Right lowest portal: resolving seroma, others healed	WNL	none	none	pedicles: firm, nodular tissue (1x2 cm, raised 7 mm), brownish red discoloration, bursa: brownish yellow discoloration	
Keebler	healed	WNL	none	none	pedicles: firm, nodular tissue (1x1.5 cm, raised 7 mm), brownish red discoloration, bursa: brownish yellow discoloration	
Lulu	healed	WNL	none	none	pedicles: firm, nodular tissue (1x2 cm, raised 4 mm), yellowish red discoloration, right pedicle: 1 vascular fibrous tag 1 cm in length, bursa: brownish yellow discoloration	
Don't Devil Me	healed	WNL	none	none	pedicles: firm, nodular tissue (2x10 cm, raised 5 mm), brownish red discoloration, covered with vascular fibrous tags 1 cm in length, bursa: brownish yellow discoloration	mature, non-vascular fibrous tags over large and small colon

10. Vita

Katja Düsterdieck was born in Hamburg, Germany and grew up on the island of Föhr in Germany. She attended the Veterinary University Hanover, Germany and the University Bern, Switzerland for her veterinary degree. Following, she performed postgraduate studies at the Institute for Animal Nutrition, Veterinary University Hanover, Germany and obtained a Dr. med. vet. degree in 1999. During this time she spent one year at the College of Veterinary Medicine of the Michigan State University as a Visiting Research Scholar and performed research in the area of equine exercise physiology. In 1998, she was accepted into a Large Animal Medicine and Surgery Internship at the Virginia-Maryland Regional College of Veterinary Medicine. Following she started her Large Animal Surgery Residency at the Virginia-Maryland Regional College of Veterinary Medicine. In 2003 she passed the certifying exam of the American College of Veterinary Surgeons.