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ORIGINAL ARTICLE

Cordless ultrasonic dissector versus advanced bipolar vessel sealing device for laparoscopic ovariectomy in dogs*

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Abstract

Objective: To compare Sonicision cordless ultrasonic dissector (SCUD) to LigaSure vessel sealing device (LVSD) for laparoscopic ovariectomy (Lap OVE) in dogs.

Study design: Randomized, paired prospective clinical trial.

Animals: Client-owned dogs (n = 22) presented for elective Lap OVE.

Methods: Dogs were randomly assigned to one of two protocols: protocol 1 required the left ovary resected using SCUD and the right ovary using LVSD; protocol 2 required the left ovary resected using LVSD and the right ovary using SCUD. Duration of ovary excision, complications, surgical smoke production, and collateral thermal damage were compared between SCUD and LVSD. Total surgery duration, postoperative convalescence, obesity, mesovarial fat score, and technique-associated costs were also recorded.

Results: Ovary excision was significantly faster with LVSD than SCUD. Surgical smoke production was significantly greater for SCUD than LVSD. Minor pedicle hemorrhage occurred 3 times with SCUD and one time with LVSD (not significantly different) and was easily corrected intraoperative. Presence of hemorrhage significantly increased ovary excision time. Technique-associated costs were lower for SCUD than LVSD. No significant differences were found in collateral thermal damage between SCUD and LVSD. Total surgery duration and convalescence time were similar to previous reports of Lap OVE in dogs at the authors' institution.

Conclusions: SCUD is a cost-effective alternative for Lap OVE, taking into account differences in technique and user preference.

1 | INTRODUCTION

The technique of laparoscopic ovariectomy (Lap OVE) in dogs has improved with the development of advanced endoscopic vessel sealing and tissue dissection technologies.¹⁻⁵ These devices use a grasping forceps that create a tissue seal by a combination of pressure and thermal heating. The most

commonly employed energy types are bipolar radiofrequency electrical current combined with mechanical transection blade, and an ultrasonic vibrating active blade for both tissue sealing and cutting.⁶ The LigaSure (Valleylab/Covidien, Boulder, Colorado) vessel sealing device (LVSD) has been evaluated extensively for laparoscopic vessel sealing and dissection (Figure 1). It is a bipolar vessel sealing device using a pulsed radiofrequency (472 kHz) high-current and low-voltage to generate electrothermal tissue heating by inducing atomic vibrations in the electrical field. The result is denaturation of collagen and elastin in vessel walls resulting in a hemostatic seal.^{6,7} The effect can be controlled by

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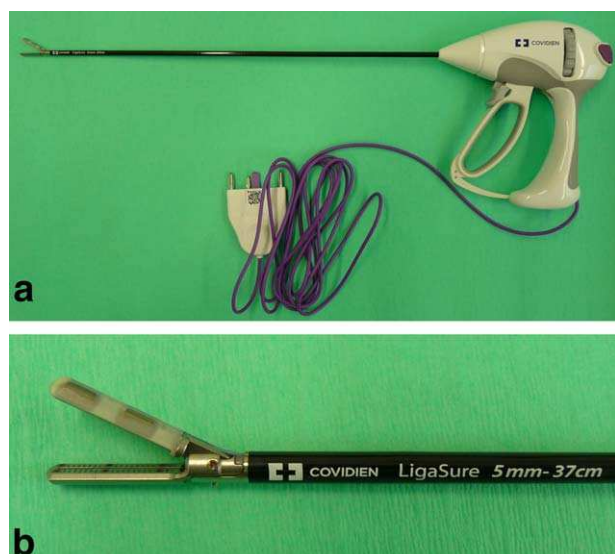


FIGURE 1 LigaSure blunt tip laparoscopic sealer/divider (5 mm diameter, 37 cm length). A, Overview. B, Close-up of blunt tip grasping forceps with 14.5 mm single-action jaw

choosing a power setting on a 1-5 scale. The unique real-time tissue-impedance-measuring feedback system enables sealing of vessels up to 7 mm in diameter.^{6,8}

Ultrasonic devices have a grasping forceps with an active and a passive blade. Electrical energy is converted to mechanical energy through a reverse piezoelectric technique, resulting in ultrasonic vibrations (55.5 kHz) of the active blade. On tissue contact, the ultrasonic vibrational energy induces thermal tissue heating.⁹ Consequently, coagulation and cutting of tissues is possible, allowing vessel sealing and hemostatic tissue transection. Ultrasonic devices can seal vessels up to 5 mm in diameter.⁸ Several types of endoscopic ultrasonic devices have been compared to endoscopic bipolar electrosurgical devices, including LigaSure, for vessel sealing capability, thermal heating, collateral thermal damage, and surgical smoke (also referred to as fume or plume) production. In vivo and ex vivo testing resulted in similar⁹⁻¹² or increased^{8,13,14} collateral thermal damage and increased vessel seal burst pressures for LigaSure compared to ultrasonic devices (Harmonic scalpel and Harmonic ACE). Harmonic scalpel generated significantly less surgical smoke compared to a standard bipolar grasping forceps.¹⁵ Surgical smoke production, objectively measured with a particle detection system, was comparable between LigaSure-V and Harmonic scalpel.⁹ On subjective evaluation by blinded review of videoclips, the Harmonic scalpel was reported to produce less surgical smoke than LigaSure-V.⁹

Such laboratory tests are important for evaluation of safety and function.⁸⁻¹³ However, translation to the clinical setting,¹⁶ where device settings and mode of application are determined by the user, is unclear. Furthermore, these tests do not evaluate a device's full clinical performance, in which ergonomics,

ease of use, application speed, and interaction with the tissues of interest may be more important than the ability to seal vessels >5 mm in diameter and to sustain supraphysiologic burst pressures. Thus, testing in clinical trials is important to fully assess performance of a surgical instrument.

Ultrasonic devices and advanced vessel sealing devices have been evaluated in clinical settings and both significantly reduce surgical duration and intraoperative hemorrhage compared to mechanical surgical hemostasis (suture ligation or vascular clips).¹⁷⁻¹⁹ Sonosurg ultrasonic shears has been compared to LigaSure in Lap OVE in dogs, showing comparable efficacy.²

Most advanced energy-based hemostatic devices are relatively expensive to purchase and require ongoing costs with replacement of disposable hand pieces, thereby limiting their use in veterinary private practice. Consequently, there is a demand for more economical laparoscopic vessel sealing solutions. Recently, the Sonicision (Covidien) cordless ultrasonic dissector (SCUD) was marketed.²⁰ The SCUD is the first cordless energy-based hemostatic device for laparoscopic tissue dissection and vessel sealing. It has a disposable dissecting forceps combined with a detachable battery and ultrasonic generator, both reusable up to 100 times (Figure 2). The operator can choose between two power settings:

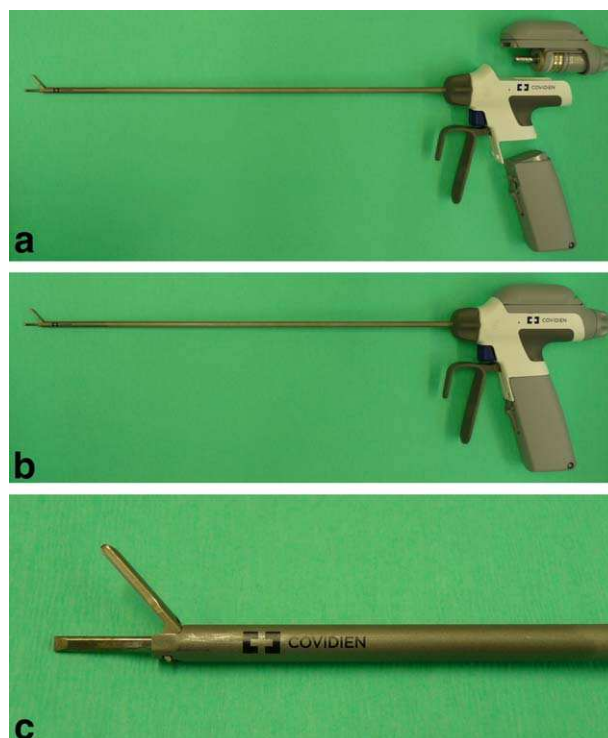


FIGURE 2 Sonicision cordless ultrasonic dissector. A, Overview showing disposable sonicision ultrasonic dissector (5 mm diameter, 39 cm length) with the detached reusable generator and battery. B, Overview of the sonicision cordless ultrasonic dissector. C, Close-up of the grasping forceps with 14.5 mm active blade

low for coagulation and high for incision, activated by manually pushing a button halfway or completely inward. Apart from being cordless and allowing freedom of movement during surgery, the major advantage of the SCUD is the reduced cost compared to more high-end endoscopic sealing devices. The SCUD performed similarly to the Harmonic ACE for vessel sealing times, burst pressures, collateral thermal damage, and seal failure rates in vivo in pigs.^{20,21} The SCUD had significantly decreased surgical smoke production compared to Harmonic ACE in ex vivo studies.^{22,23} Clinically, SCUD was successfully applied in a laparoscopic nephrectomy and a lymphadenectomy procedure in people.²⁴ No data are available on the use of SCUD in dogs.

The purpose of this study was to compare the SCUD with the new LVSD with ForceTriad generator in Lap OVE in client-owned dogs. We hypothesized that surgical performance of the SCUD would be comparable to the LVSD in surgery duration, efficacy, surgical smoke production, complications, and collateral thermal damage; however, at a lower cost. Based on this result, we would propose the SCUD would provide an economical alternative to other advanced hemostatic dissection devices for Lap OVE in dogs.

2 | MATERIALS AND METHODS

A prospective clinical trial was established to compare the SCUD with the LVSD in Lap OVE in dogs. To reduce inter-dog bias and allow paired observations, both techniques were applied in the same dog. Dogs were randomly assigned to one of two protocols: protocol 1 required the left ovary resected using the SCUD and the right ovary using the LVSD; protocol 2 required the left ovary resected using the LVSD and the right ovary using the SCUD. The random sequence was established prior to the trial and protocol assignment (1 or 2) was documented in a sealed and numbered envelope (1-22). Dogs were assigned consecutively on admission to the trial and the envelope was opened by the surgeon at the start of the surgery.

2.1 | Dogs

Client-owned, healthy female dogs, admitted for elective Lap OVE at the Department of Clinical Sciences of Companion Animals, Faculty of Veterinary Medicine, Utrecht University, from January 2014-July 2015 were enrolled. Owners completed a standard questionnaire about the dog (number of heat-cycles, date of last heat, presence of pseudopregnancy, general health, diet, and vaccination status). The breed, age, bodyweight, and obesity score (1-5)²⁵ of each dog was recorded. The study was approved by the institutional ethical committee and all owners provided informed consent for enrolling their dog in the study.

2.2 | Surgical procedure

Anesthesia was performed using a standardized ASA 1-2 protocol as described.³ All surgical procedures were performed by a single ECVS boarded surgeon experienced in endoscopic procedures. All dogs were positioned in dorsal recumbency and prepared for aseptic surgery. Video-assisted Lap OVE was performed through a standard 3 midline portal approach in 10° Trendelenburg position and 20° lateral tilt away from the ovary being removed.²⁶ A modified open approach was used for primary cannula insertion at the caudal portal before inducing a pneumoperitoneum.²⁷ An approximately 10 mm incision was made in the skin and subcutaneous tissues, midway between umbilicus and pubis, followed by placing bilateral stay sutures approximately 3 mm lateral to the linea alba. An approximately 4 mm stab incision was made in the linea alba between the stay sutures and a 6 mm outer diameter threaded cannula (Ternamian endotip; Karl Storz-Endoscopy, Vianen, The Netherlands) was inserted through the abdominal wall under endoscopic guidance while pulling the stay sutures upward to avoid damage of abdominal structures. After cannula insertion, the abdomen was insufflated at 3-5 L/min CO₂ flow to an intra-abdominal pressure of 8 mm Hg. A 5 mm, 0° telescope (Hopkins II, Karl Storz-Endoscopy) was inserted through the cannula and 2 additional 6 mm cannulas (Ternamian endotip; Karl Storz-Endoscopy) were inserted through approximately 5 mm stab incisions under laparoscopic guidance, 1-2 cm caudal and 1-2 cm cranial to the umbilicus. The telescope was redirected to the middle portal and a routine visual exploration of the abdominal cavity was performed. The left ovary was located by identifying and grabbing the round ligament at the inguinal ring and following it cranially toward the uterine horn using two endoscopic grasping forceps (CLICKline endoscopic Kelly forceps and self-retaining blunt grasper; Karl Storz-Endoscopy). The ovarian bursa was grasped with the self-retaining forceps through the cranial portal, by introducing one jaw into the bursal opening. Ovariectomy was performed using either the SCUD or the LVSD through the caudal portal, excising the complete ovarian bursa containing the ovary in a caudal-to-cranial direction. For the LVSD technique, a LigaSure Blunt Tip Laparoscopic Sealer/Divider (5 mm diameter, 37 cm length) was used with a Force Triad generator (Valleylab/Covidien) in a power setting of 2 bars to create the tissue seal which was subsequently divided using the incorporated mechanical knife blade. For the SCUD technique, a Sonicision Ultrasonic Dissector (5 mm diameter, 39 cm length; Covidien) was applied in either the “low” (coagulation) or the “high” (cutting) power setting by manually pushing the activation button halfway or completely in. After excision, the left ovary was placed next to the ventral bladder ligament to be retrieved subsequently, and searching and excision of the right ovary

was commenced. After excision of the right ovary, the caudal portal was enlarged to approximately 1–1.5 cm using Metzenbaum scissors for removal of both ovaries from the abdomen. After inspection of the abdominal cavity, CO₂ was expelled from the abdomen and the portals were closed routinely by a senior student or an attending resident.

2.3 | Data collection

Surgical time-intervals were recorded intraoperative using a stopwatch and categorized as followed: skin incision, trocar placement and exploration; localization of the left ovary; resection of the left ovary; localization of the right ovary; resection of the right ovary; removal of the ovaries from the abdomen; total surgery duration (excluding closure of the portals). Additional variables recorded were fat score of the ovarian pedicle (0 = no fat; 1 = minimal fat; 2 = moderate fat; 3 = abundant fat), accessibility of the ovaries (easy/difficult), occurrence of intraoperative hemorrhage (yes/no), tissue adherence to the device (yes/no), and abnormalities of ovaries or uterus. The amount of surgical smoke formation was subjectively scored (0 = minimal smoke, no impairment of visibility; 1 = moderate smoke, minimal impairment of visibility; 2 = large smoke, moderate impairment of visibility). All ovary resection intervals were recorded on video for standardized scoring of excision duration, surgical smoke production, and complications.

2.4 | Histology

Resected ovaries were fixed in 10% formaldehyde. Samples were trimmed to and sections perpendicular to 3 distinct locations of the surgical transection area were taken: the proper ligament/uterine attachment site, the mesovarial/pedicle area, and the suspensory ligament. Trimmed tissues were embedded in paraffin according to standard procedures and cut into 4 µm tissue sections and stained with hematoxylin and eosin (H & E; Klinipath 64089, Duiven, The Netherlands) for histologic examination of collateral thermal damage.^{27,28} Tissue slides were coded and randomized to blind the histologic assessment to the ovariectomy technique. Sections from the 3 selected tissue sites were qualitatively scored for thermal damage which accounted for coagulation necrosis, loss of cellular detail, formation of an eosinophilic or amphophilic coagulum, and nuclear streaming. Each section was scored on a scale from 0 to 3 in 3 high-power fields in the most affected areas of each tissue section: 0 (not affected)–3 (most affected). Collateral thermal damage was quantitated by measuring the distance of visible thermal tissue damage perpendicular to the thermal tissue seal in digitalized images at 40× magnification using CellB software (CellB Olympus, Zoeterwoude, The Netherlands), at ±50

µm precision. Any tissue shrinkage during fixation was not taken into account.

2.5 | Cost

Total costs of investment for both techniques were evaluated and costs per year were calculated based on approximate selling prices, accounting for given life-span of the device's generator and power supply, costs of disposable parts, and estimated life span of disposable parts after re-sterilization (known to not significantly affect function and common practice in veterinary surgery for such devices).²⁹ Cleaning of the SCUD and LVSD disposable forceps was performed using an automatic ultrasonic decontaminator washer (G7826, Miele, Vianen, The Netherlands) at 60°C. Re-sterilization for both SCUD and LVSD was by ethylene oxide. Directly after surgery, the reusable battery and reusable generator of the SCUD were cleaned manually using an enzymatic detergent solution and subsequently put in 90% isopropyl alcohol for at least 20 minutes before storage and again after recharging the battery before a new surgery.

2.6 | Statistical analysis

Statistical analysis was performed using SPS Statistics 23. A power analysis was performed prior to the study, using estimated values to determine the number of dogs needed in the experiment (paired test; $\beta = 0.10$; $\alpha = 0.05$; standard deviation of 25%; estimated difference of 20%, based on previous studies).³ The minimal number of dogs needed was 19.³⁰ All responses were tested for their distribution using a Shapiro-Wilk test. A paired *t* test (normal distribution) or a Wilcoxon signed ranks test (non-normal distribution) was used to compare the duration of surgical stages and histologic scores between LVSD and SCUD, and between left and right OVE. Other unpaired parameters were compared between LVSD and SCUD using unpaired *t* test or ANOVA with post hoc comparisons. Frequency data were compared using chi-square test. Significance was considered at $P < .05$ (2-tailed) and normal data are reported as mean (95% CI) and non-normal data as median (interquartile range [IQR]).

3 | RESULTS

Twenty-two dogs of various breeds with normal health status were included. Mean bodyweight was 24.7 kg (95% CI 20.9–28.5) and median age was 14.0 months (IQR 13.3). Eighteen percent of dogs were considered obese and 1 dog had a history of pseudopregnancy. Mean total surgery time was 28.4 minutes (95% CI 25.4–31.4).

TABLE 1 Mean (95% CI) ovariectomy time (minutes) for LigaSure (LVSD) and Sonicision (SCUD) and total surgical time by fat score levels

Fat score	0	1	2	3	P value (ANOVA)
LVSD	1.7 (0.0-0.0)	1.8 (1.2-2.5)	1.9 (1.6-2.2)	2.5 (1.5-3.5)	.202
SCUD	2.7 (0.0-0.0)	2.7 (1.2-4.2)	2.6 (2.1-3.2)	4.3 (1.0-6.9)	.046
Total surgery time	24.1 (0.0-0.0)	24.9 (17.9-31.8)	28.4 (24.7-32.2)	35.7 (16.9-54.5)	.115
Fat score	0-2	3			
LVSD	1.9 (1.6-2.1)	2.5 (1.5-3.5)			.032
SCUD	2.6 (2.2-3.1)	4.3 (1.0-6.9)			.004
Total surgery time	27.1 (24.3-30.0)	35.7 (16.9-54.5)			.030

3.1 | Surgical parameters

No difficulties were noticed in accessibility of the ovaries and no abnormalities were detected on any ovary. Ovariectomy was significantly faster for LVSD than SCUD (LVSD 2.0 minutes [95% CI 1.8-2.2]; SCUD 2.9 minutes [CI 2.4-3.3], $P < .001$ paired t test). Three small hemorrhages occurred with SCUD, which did not significantly affect total surgery duration ($P = .46$ unpaired t test), but did result in significantly increased ovary excision time (SCUD hemorrhage 4.4 minutes [95% CI 2.4-3.2]; SCUD no hemorrhage 2.7 minutes [95% CI 3.2-5.3], $P = .012$ unpaired t test). All hemorrhages were easily managed using SCUD. One small hemorrhage occurred with LVSD, which did not significantly affect total surgery duration ($P = .13$ unpaired t test) or ovary excision time ($P = .38$ unpaired t test). Frequency of hemorrhage was not significantly different between SCUD and LVSD ($P = .61$ chi-square test). Surgical smoke production was significantly greater with SCUD than LVSD ($P < .001$ ANOVA) and did not depend on the duration of SCUD ($P = .08$ ANOVA), LVSD ($P = .58$ ANOVA), or total surgery duration ($P = .23$ ANOVA). Ovary excision time significantly increased with higher mesovarial fat score for SCUD ($P = .046$ ANOVA), but not for LVSD ($P = .20$ ANOVA) or total surgery duration ($P = .12$ ANOVA). Post hoc comparisons between fat score levels showed a significant increase in OVE duration only for fat score 3 (Table 1). No significant differences were found in any outcomes between obese and non-obese dogs.

There were no significant differences in duration between left and right ovary localization (left 1.9 minutes [95% CI 1.6-2.2]; right 1.8 minutes [95% CI 1.6-2.0], $P = .56$ paired t test) and ovary excision (left 2.4 minutes [95% CI 2.1-2.8]; right 2.4 minutes [95% CI 1.9-2.8], $P = .35$ paired t test). Operation of the SCUD compared to LVSD was different. Grasping, sealing, and cutting tissue with the LVSD was straightforward and highly automated. Grasping tissue is

done by locking the hand piece in the closed position. Sealing is performed by activating the device, which results in a device-calculated duration of activation. In contrast, the SCUD has no built-in feedback mechanism to calculate sealing duration, which is completely determined by the user. Furthermore, the “low” power setting of the SCUD sometimes had the tendency to cut through tissue, especially with the forceps completely closed over thicker tissues (high fat score) and the “high” power setting was often not needed to cut through the tissue. The absence of a power cord was a subjective advantage of the SCUD. The frequency of tissue adherence to the device was not significantly different between techniques ($P = .75$ chi-square).

Owner-perceived recovery duration was a mean (SD) of 1.4 (0.9) days. Minor postoperative swelling or discharge, none of which required treatment, was seen in 3% of wounds.

3.2 | Cost

Cleaning and re-sterilization of the Sonicision disposable forceps was straightforward and seemingly without affecting function. No dysfunction or defects occurred during the study with SCUD devices being re-sterilized up to 7 times. This is comparable to the reuse of the LVSD, which is re-sterilized up to 6 or 7 times before we note instrument malfunction.

At the time of this report, the veterinary selling price for the SCUD is \$USD 850 for the battery, \$USD 850 for the generator, \$USD 850 for the battery station, and \$USD 525 per disposable forceps. The veterinary selling price for the LVSD are \$USD 25 000 for the ForceTriad Generator and \$USD 625 per disposable forceps. The SCUD generator and battery can be used 100 times. Selling prices may vary per country and hospital, based on a hospital's contract with Covidien and the number of disposable pieces used per year.

The annual procedural costs are calculated based on a 10-year cost depreciation of the ForceTriad Generator

TABLE 2 Median (interquartile range) histologic scores of collateral thermal damage for LigaSure (LVSD) and Sonicision (SCUD)

	LVSD	SCUD	<i>P</i> value ^a
Uterine stump serosa	3.0 (2)	3.0 (2.0)	.86
Adipose tissue mesovarial ligament	1.0 (1.0)	1.0 (1.0)	.42
Suspensory ligament	3.0 (1.0)	3.0 (1.0)	.71

^aWilcoxon signed ranks test.

(\$USD 2500 per year) and the SCUD battery station (\$USD 85 per year) and a hand instrument reuse frequency of 6-7 times. The resulting costs per year over a 10-year period estimating 100 Lap OVE per year are \$USD 9660 for Sonicision and \$USD 11 875 for LigaSure, excluding possible service costs.

3.3 | Histology

There were no significant differences in qualitative tissue damage scores or quantitative measurements of collateral thermal damage between SCUD versus LVSD at any location (Table 2). The likely point of contact of the instrument showed formation of a heterogeneous coagulum in which there was loss of cellular and nuclear detail and chromatin streaming. Muscular tissue showed similar changes with occasionally formation of a cavity filled by amphophilic granular material. There was preservation of the cellular detail of submucosal connective tissue (Figure 3).

No significant differences were seen in collateral thermal damage depth between SCUD and LVSD at any location (Table 3, Figure 4). Mean collateral thermal damage depth was 0.98 mm (95% CI 0.89-1.07) for proper ligament/uterine attachment site, 0.93 mm (95% CI 0.86-1.01) for mesovarial/pedicle area, and 0.89 mm (95% CI 0.82-0.96) for suspensory ligament.

4 | DISCUSSION

We hypothesized that the SCUD would be comparable to the LVSD in performance for Lap OVE in dogs. Our findings support the use of SCUD as a cost-effective alternative for LVSD although there were some differences observed between the 2 techniques.

Although LVSD was significantly faster than SCUD, the mean difference between the two was less than 1 minute and did not influence total surgery duration. This difference in vessel sealing speed is comparable to previous studies comparing LigaSure-V to Harmonic ACE for vessel sealing.^{9,10} A previous study comparing the 10 mm LigaSure-Atlas to the SonoSurg ultrasonic device in Lap OVE in dogs found no significant difference in duration of ovary excision.²

However, we used the newer generation Blunt Tip LigaSure forceps with the ForceTriad generator, which has been shown to significantly improve surgery speed compared to its predecessor, the LigaSure generator, which may explain the difference found in ovary excision time.

Surgical smoke production caused by the action of energy-based hemostatic devices can reduce laparoscopic visibility. A device with minimal surgical smoke production is therefore desirable in laparoscopic surgery. Although the SCUD generated less smoke than other ultrasonic devices (Harmonic ACE) in a study using digital image processing techniques,²² it generated more smoke compared to the LVSD in our study. Therefore, LVSD (with ForceTriad generator) probably also produces less fume compared to other ultrasonic devices. However, visibility during ovariectomy was considered acceptable for both devices and did not significantly affect surgery times.

The cordless feature is a major advantage of the SCUD, improving portability and freedom of movement. All other laparoscopic hemostatic energy devices currently available are connected to a generator by a cable, which can limit mobility, can result in contamination of the operating field, or become entangled with other instruments or cables.²⁰ The advantage of a fully independent power source in surgical equipment is already utilized in certain third-world settings and trauma units in human medicine.²⁰ When extrapolating this to veterinary medicine, a battery-powered cordless solution may be efficient in operating rooms without the need of expensive power sources. Considering the mobility of the unit, it may be convenient for mobile veterinary surgeons if proper sterilization facilities are available. We found a cost advantage of the SCUD over the LVSD based on 100 uses per year. However, selling prices vary per country and may depend a hospital's contract with Covidien. An important factor for veterinary practices is the almost 10 times higher initial investment cost for the LVSD over the SCUD. Apart from frequency of use, costs may be affected by several other factors, of which reduction in surgery duration may be important.³¹

Cleaning and re-sterilization of the SCUD disposable forceps was performed up to 7 times without noticeable changes in function. This is comparable to the LVSD, which is

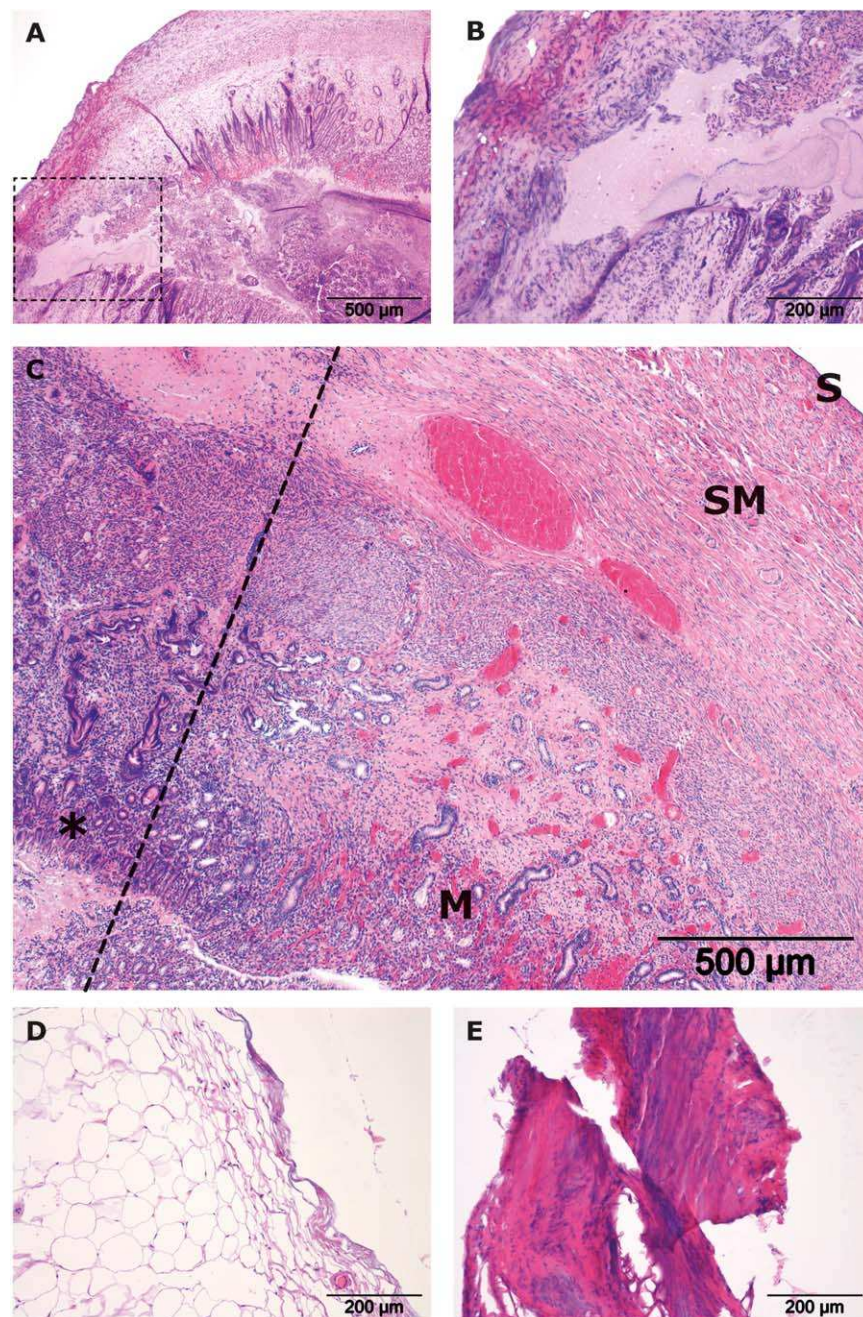


FIGURE 3 A, Uterus wall shows focally extensive collateral thermal damage characterized by loss of cellular detail in serosa, muscularis, and mucosal layers (hematoxylin and eosin x40). B, Higher magnification of image of the uterus wall showing the loss of cellular detail, hyperchromatic chromatin with nuclear streaming and formation of a homogenous coagulum (hematoxylin and eosin x100). C, Uterine wall showing the margin between affected and non-affected tissue (dashed line). The presumed point of contact with device is to the left of the image. Note the nuclear streaming, which is particularly evident in the mucosa (*). S (serosa); SM (smooth muscle); M (mucosa) (hematoxylin and eosin x40). D, Ligamentous tissue showing moderate to severe collateral thermal damage indicated by condensation of nuclear chromatin, hypereosinophilia of proteinaceous material (predominantly collagen), and loss of cell and nuclear detail (hematoxylin and eosin x100). E, Of the 3 tissue types, adipose tissue consistently showed the least signs of collateral thermal damage; compression and mild to moderate damage characterized by increased nuclear streaming as seen by the basophilic coagulum (hematoxylin and eosin x100)

cleaned and re-sterilized for 6-7 times before we notice malfunction at our institution. We acknowledge the re-sterilization process of the reusable battery and generator of

the SCUD in our study was suboptimal but was the only economical option at the time since low temperature hydrogen gas plasma sterilization, as recommended by the

TABLE 3 Mean (95% CI) histologic measurement (mm) of thermal tissue damage LigaSure (LVSD) and Sonicision (SCUD)

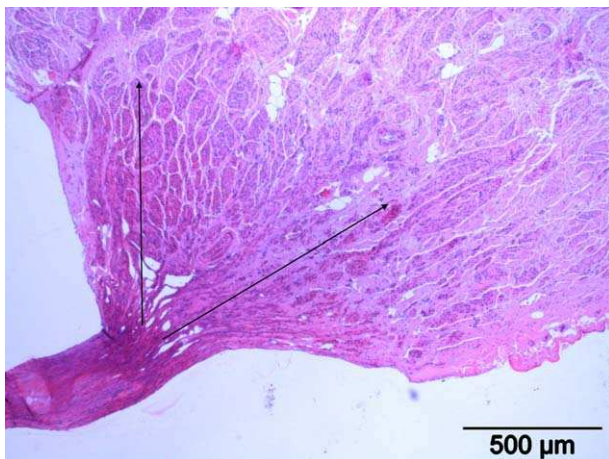
	LigaSure	Sonicision	<i>P</i> value ^a
Uterine stump	1.00 (0.87-1.13)	0.96 (0.79-1.11)	.60
Adipose tissue mesovarial ligament	0.90 (0.82-0.98)	0.88 (0.75-1.02)	.70
Suspensory ligament	0.91 (0.78-1.03)	0.96 (0.86-1.06)	.50

^aPaired *t* test.

manufacturer of Sonicision,³² was unavailable.³³ Accessibility to gas plasma sterilization in nearby human hospitals or academic centers may be an option for private practices. An autoclavable hemostatic device is ideal but availability is limited and function is variable compared to high-end disposable devices. One example is the MarSeal reusable and autoclavable vessel sealing instrument and generator (MarSeal; KLS Martin, Tuttlingen, Germany). The MarSeal does have the same minimally invasive device characteristics as the SCUD and the LVSD, being a 10 mm diameter instrument. The required disposable blades cost \$USD 200, the investment cost for the generator is \$USD 17 000 and disposable hand piece cost \$USD 4900 (can be reused up to 50 times), which cumulates in considerable costs per use³⁴ and any cost-advantage is not clear.

The extent of collateral thermal damage determines the risk for injury to surrounding tissues. When comparing published results of collateral thermal damage between different vessel sealing devices, differences in methods such as tissue type, in vivo or ex vivo, used power settings, application durations, and methods of damage measurement should be taken into account. We found no significant differences in qualitative or quantitative collateral thermal damage on histologic examination between SCUD and LVSD. Furthermore

collateral thermal damage was <1 mm. This is comparable to several studies comparing advanced bipolar vessel sealing devices to ultrasonic devices.^{9-11,35} Importantly, the extent of collateral thermal damage in the present and several other studies is less than the 2-4 mm reported for LigaSure.^{11,35} This can be partly explained by differences in study methodology. Studies use different activation duration, power settings, and in vivo versus ex vivo methods but also incorporate the vessel seal in the measured damage distance. We measured only collateral thermal damage outside of the tissue seal as done in several other studies and this represents true collateral thermal damage.^{9-11,35} Furthermore, the only study to date comparing thermal damage of the LigaSure-V to the LVSD with ForceTriad energy generator indicated significantly decreased collateral thermal damage spread for the ForceTriad system (1 mm vs 2 mm),³⁷ comparable to the results of our study.^{8,13} In general, the collateral thermal tissue damage caused by hemostatic energy devices depends on the temperature increase and duration at any point surrounding the instrument. This depends on multiple variables, including the application duration, applied power (the amount of energy transformed into heat), thermal conductivity of the tissue and the instrument tip, dimensions of the instrument tip, the thermal effect (coagulation vs vaporization), and the heat sink effect in perfused tissue. Although the temperature at the tip of the device itself can become much higher for ultrasonic devices (including SCUD ~200°C), compared to the LVSD (<100°C), this does not mean that the temperature distribution in the surrounding tissue is necessarily different between these techniques.³⁸ Tissue temperatures at 2 mm distance from the instrument tip were comparable for Harmonic Scalpel (49.9°C) and LigaSure-V (55.5°C) in an ex vivo model.⁹ Furthermore, maximum local temperatures were almost twice as high for the Harmonic Focus compared to LigaSure Precise, both slim-design precision instruments, using infrared thermography in an in vivo model. However, collateral temperature distributions were not different between devices for temperatures ≤ 60°C.³⁹ Because the threshold for acute thermal tissue damage varies around 60°C to 70°C for most tissues, differences in temperature distributions above this threshold, in case of a comparable spatial temperature distribution

**FIGURE 4** Uterus wall with a clear grasped part, and histological collateral thermal changes visible (hematoxylin and eosin x40). Black arrows show the measured distance

below this threshold, are probably less important for collateral damage extent.²⁷ Furthermore, since ultrasonic dissectors do not carry knife blades for sharp transection their cutting action depends on tissue disruption, while creating a hemostatic seal, which is a combination of mechanical and vaporizing effects involving high local temperatures. Thus, higher instrument tip temperatures may be expected.³⁸ The relatively shallow extent of collateral thermal damage in this study is typical for advanced vessel sealers, placing both SCUD and LVSD among the safest and most efficient methods for hemostasis in endoscopic surgery today.⁴⁰

Heat production is directly proportional to the power setting and the activation time of advanced vessel sealing devices.⁴¹ The feedback system of the LVSD reduces the likelihood of prolonged activation and limits heat production to that necessary for its intended goal: a reliable tissue seal.⁶ Since there is no automatic feedback mechanism to indicate seal establishment using the SCUD, the duration of activation of the device can be overestimated, resulting in more collateral thermal damage. The surgeon decides when to stop in coagulation mode and start in cutting mode of the instrument, based on subjective observations.⁶ Therefore, it has been proposed that no more than 5 seconds of activation of the Sonicision device should be the goal for tissue transection.⁴¹ In this study ovaries with a high fat score needed significantly more time for excision using the SCUD compared to low/moderate fat scores. Increased ovariectomy durations with increasing mesovarial fat score have also been found in a previous study using laser surgery and bipolar electrosurgery.³ This is probably due to increased tissue thickness and decreased heat conductivity and electrical conductivity because of the increased fat content of the tissue, resulting in increased duration for coagulation and dissection.⁴² Fat score only prolonged surgery duration for SCUD and not LVSD. This may be due to differences in technique since heat production occurs at the tissue-device contact area at the active blade only of the Sonicision forceps versus an alternating current that traverses the tissue within the LigaSure forceps. This feature of the LigaSure has already been shown to have improved tissue sealing ability compared to other bipolar devices.³⁴

Furthermore, the size and the high fat content of such ovarian pedicles results in friable tissue and it is our subjective observation that the Sonicision forceps may cut through the tissue when still in coagulation mode. This required the surgeon to take special care during the coagulation step, with gradual closure of the forceps to prevent early incision, which could result in inadequate vessel sealing leading to hemorrhage. In turn, this cautious approach may lead to a prolonged dissection time, especially with high mesovarial fat score. However, lack of significance of fat score affecting LVSD or total surgery duration may be explained by the rel-

atively few ovaries per fat score. Collapsing levels of fat score to 0-2 versus 3, both SCUD, LVSD, and total surgery duration are significantly increased for fat score 3 (Table 1).

Assessment of collateral thermal damage is difficult to determine macroscopically during surgery.⁴¹ Since the LVSD incorporates a real-time tissue effect feedback system, it is considered superior to all other surgical energy devices that rely on the surgeon's macroscopic evaluation of the tissue. As for other ultrasonic devices, the SCUD should therefore be used with caution to prevent overzealous tissue damage.³⁶ However, occurrence of hemorrhage and collateral thermal damage extent did not significantly differ between techniques, and tissue adherence to the device, which has been ascribed to prolonged activation time, was also comparable between SCUD and LVSD.

In conclusion, the overall function of the SCUD was considered excellent but did not outperform the ease of use of the LVSD. Although the absence of an electrical cord was a big advantage of the SCUD, the most important difference in ease of use according to the authors was the advantage of the feedback controlled reliable vessel sealing by the LVSD. This probably caused the difference in ovary transection speed, which largely depends on the SCUD ultrasonic tissue sealing duration estimated by the surgeon versus bipolar sealing duration calculated by the LVSD. Hemorrhage during SCUD use was considered minimal and easily corrected using the SCUD instrument. We conclude that the SCUD is a cost-effective alternative to more expensive high-end bipolar endoscopic dissection devices for Lap OVE in dogs.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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