Bipolar electrosurgical devices and ultrasonic devices are routinely used for hemostasis in advanced laparoscopic or invasive surgeries in animals. A bipolar electrosurgical device reportedly achieves hemostasis of the ovarian pedicle during laparoscopic-assisted ovariohysterectomy. It can safely seal blood vessels with diameters as large as 7 mm. This technology can be used to permanently seal a blood vessel through inducing fusion of the vessel wall, without reliance on thrombosis in the blood vessel. The quality of the seal is affected by the content of elastin and collagen in the tissue.

Vessel sealant technology is used during laparoscopic-assisted ovariohysterectomies in veterinary surgery to seal ovarian pedicles. When used to perform an ovariohysterectomy with an open abdomen or with laparoscopy, the VSD is commonly applied to the uterine horn. Therefore, uterine horn closure relies only on the bursting strength of the seal created with the VSD. To the authors’ knowledge, no studies have been performed to evaluate the efficacy of a VSD seal on a uterine horn or body in dogs, nor have intrauterine pressures been sufficiently described.

**Objective**—To compare the bursting strength of a vessel sealant device (VSD) with that of an encircling suture on uterine horns and bodies from dogs.

**Sample**—Uteri from 34 shelter dogs with unknown reproductive histories.

**Procedures**—Uterine horns and bodies were allocated to groups to be sealed with suture or a VSD. Uteri were then infused with saline (0.9% NaCl) solution until the seals burst or the uteri reached a maximal pressure of 300 mm Hg. Variables recorded included dog age, uterine body and horn diameter, and maximal pressure.

**Results**—The median (range) bursting pressure reached in sealed uterine horns was 300 (0 to 300) mm Hg for the VSD group and 300 (200 to 300) mm Hg for the suture group. Within the VSD group, seals of 2 of 3 uterine horns with a diameter ≥ 9 mm burst before intraluminal pressure reached 100 mm Hg, compared with 1 of 21 uterine horns with a diameter < 9 mm. The median bursting pressure for uterine bodies was 237 (0 to 300) mm Hg for the VSD group versus 300 (175 to 300) mm Hg for the suture group. Within the VSD group, seals in uterine bodies with a diameter ≥ 9 mm failed at a significantly lower pressure (125 [0 to 125]) mm Hg than those with a diameter < 9 mm (275 [125 to 300]) mm Hg.

**Conclusions and Clinical Relevance**—The failure pressure for both sealing techniques was high, which indicated that the VSD may be a safe instrument for sealing the uterine horn in dogs. Given the low mean bursting pressure for seals in uterine bodies with large diameters, the VSD cannot be recommended for sealing uterine bodies ≥ 9 mm in diameter.

**Materials and Methods**

**Dogs and uteri**—Uteri were collected from 34 dogs immediately after euthanasia or elective ovario-
hysterectomy. The dogs were from animal shelters and some had been involved in another, unrelated research project. Uteri were used for uterine horn testing (both horns), for uterine body testing, or both; some had been transected at the bifurcation of the horns during ovariohysterectomy and therefore did not have a uterine body available for evaluation. After collection, uteri were immediately placed in saline (0.9% NaCl) solution and stored at 4°C. Those containing fetuses or gross lesions were excluded from the study. Dog age was recorded, and uteri were allocated to 2 groups on the basis of that age: ≥ 8 months or < 8 months. The study was performed in compliance with institutional guidelines for research on animals. The protocol was approved by the Institutional Review Board at the Colorado State University Veterinary Medical Center.

Uterine testing—Uterine testing began within 24 hours after collection. Each uterine horn from a given dog was randomly assigned via coin toss to be sealed with suture or a VSD. Uterine bodies from all dogs were similarly assigned. The broad ligament was dissected from the uterine horns and body. Diameter of the structure at the site to be tested was measured with calipers. For uterine horn testing, the ovary and proper ligament of each was amputated, leaving the horn with an open lumen. A 10F multipurpose polypropylene catheter was introduced into the lumen of the horn and advanced until the tip was 2 cm from the site at which the seal was to be applied. The catheter was secured inside the lumen with 1 encircling size-0 silk suture tied at the base of the catheter-horn combination.

For uterine body testing, the ovary and proper ligament were amputated from one horn, and the entire horn except for 1 cm was amputated from the opposite side. A 10F multipurpose catheter was introduced into the horn lumen and advanced until it was 2 cm from the uterine body site to be tested. The catheter was secured within the lumen of the horn as for the uterine horn testing. The opposite horn stump was sealed with 1 encircling size-0 silk suture.

Pressure testing for each sealing method was performed in an identical manner. A syringe containing saline solution was connected to a 3-way stopcock and a catheter prior to placement of the catheter in the structure, and the catheter was filled with saline solution. The syringe was placed in a syringe pump. The third port of the 3-way stopcock was connected to a mechanical pressure manometer. The uterine body or distal portion of the uterine horn was then sealed with 1 encircling suture of 3-0 glycomer 631 or the application of 1 seal cycle of a 10-mm VSD. If 1 cycle was not sufficient to grossly seal the body or horn lumen, the VSD was applied again until a macroscopic seal was obtained.

Before testing, the pressure manometer system was zeroed to the level of the uterine horn or body. Saline solution was then infused via the syringe pump into the lumen of the uterine horn or body at a rate of 5 mL/min to a maximal pressure of 300 mm Hg. Pressure within the uterine horn or body was constantly recorded. Leakage was recorded if the pressure reached a plateau or if the pressure suddenly dropped on the manometer tracing as well as with visual inspection of the seal. Bursting pressure was defined as 0 mm Hg if the seal was visibly open and saline solution immediately leaked from the opening. Variables recorded were size (diameter) of the structure at the site to be tested and bursting strength (pressure reached prior to seal failure). Nonfailure was defined as an instance in which the seal allowed the pressure to reach 300 mm Hg without failing.

Statistical analysis—One-way ANOVA was used to compare age of dogs between the suture and VSD groups. Because bursting pressure data were not normally distributed, nonparametric tests were used to compare bursting pressures between groups. The Wilcoxon signed rank test was used to compare the bursting pressure of matched pairs of uterine horns in the suture and VSD groups. The Fisher exact test was used to compare proportions of uterine horns ≥ or < 9 mm that burst at a pressure < 100 mm Hg. The Kruskal-Wallis test was used to compare the bursting pressure of uterine horns ≥ or < 9 mm within VSD groups. A Kruskal-Wallis test was used to compare the bursting pressure of the uterine body between the VSD and suture groups. The effect of dog age (≥ or < 8 months) on the proportion of uterine horns and bodies in the aforementioned size categories was evaluated with the χ² test. Values of P < 0.05 were considered significant. All analyses were performed by use of statistical software.

Results

Dogs and uteri—Uterine horns from 24 dogs were used, providing 48 uterine horns for use in the study. Twenty-four uterine horns (1 from each dog) were assigned to be sealed with a VSD, and the remainder were assigned to be sealed with suture. The mean ± SD age of the dogs with uterine bodies assigned to the VSD group (11.1 ± 1.8 months) did not differ significantly (P = 0.92) from that of dogs with uterine bodies assigned to the suture group (11.3 ± 1.9 months). Mean uterine horn diameter was 5.70 ± 3.9 mm for the VSD group and 5.71 ± 4.04 mm for the suture group (P = 0.95; power = 95%).

Eighteen uterine bodies were used; of these, 10 were assigned to the VSD group and 8 were assigned to the suture group. With respect to age of the dog of origin, the mean age was 17.3 ± 5.9 months for the VSD group and 7.0 ± 7.3 months for the suture group (P = 0.35; power = 56%). Mean uterine body diameter was 8.2 ± 4.1 mm for the VSD group versus 7.6 ± 2.6 mm for the suture group (P = 0.71; power = 82%).

Seal strength—The median bursting pressure for the 24 uterine horns sealed with a VSD was 300 mm Hg (range, 0 to 300 mm Hg) and that for the 24 sealed with suture was 300 mm Hg (range, 200 to 300 mm Hg). This difference was significant (P = 0.018). Seals in 21 (42%) horns did not burst, of which 3 were sealed with the VSD and 18 were sealed with suture. Seals in 2 of 3 uterine horns with a diameter ≥ 9 mm burst before intraluminal pressure reached 100 mm Hg, compared with 1 of 21 horns < 9 mm (P = 0.034). In the VSD group, the bursting pressure of uterine horns with a diameter ≥ 9 mm was not significantly (P = 0.11) different than that of uterine horns < 9 mm (Table 1). None
of the seals in uterine horns ≥ 9 mm in diameter burst before the intraluminal pressure reached 100 mm Hg in the suture group.

Dog age had no effect on the distribution uterine horns by diameter (P = 0.56). For 4 uterine horns, the VSD had to be applied twice to obtain a macroscopic seal. The diameter of the horn did not have a significant (P = 0.22) effect on the number of applications of the VSD required to attain a macroscopic seal (power = 51%).

Testing of uterine bodies showed the bursting pressure was 237 mm Hg (range, 0 to 300 mm Hg) for the VSD group and 300 mm Hg (range, 175 to 300 mm Hg) for the suture group (P = 0.25; power = 60%). Three uterine bodies (17%) did not burst; 1 of these was sealed with the VSD and 2 were sealed with suture. Seals in the remaining uterine bodies were able to sustain pressures ≥ 100 mm Hg even when they were ≥ 9 mm in diameter. In the VSD group, the bursting pressure for seals in uterine bodies ≥ 9 mm in diameter was significantly (P = 0.03) lower than that of seals in uterine bodies < 9 mm (Table 1). One uterine body could not hold a seal at any pressure because the seal spontaneously opened without manipulation; the bursting pressure was then recorded as 0 mm Hg. For 3 uterine bodies, the VSD had to be applied 2, 3, or 5 times to obtain an observable seal. The diameter of the body had a significant (P = 0.002) effect on the number of VSD applications required to achieve a macroscopic seal.

**Discussion**

Findings of the study reported here suggest a VSD can be used to seal uterine horns in dogs during ovarioectomy. The VSD is also likely safe for use on uterine bodies < 9 mm in diameter that have grossly normal texture. However, given the unreliability in bursting strength achieved and our experience during the study, use of the VSD on uterine bodies ≥ 9 mm in diameter during ovariohysterectomy is not recommended because its seal is unpredictable and likely related to the macroscopic nature of the uterus such as texture or previous pathological conditions. The uteri used for technique testing were from dogs with a wide age range. The uteri were also likely from dogs in various stages of the estrus cycle, influencing uterine texture but representing a general rather than specific canine population.

Uterine horns sealed with the VSD failed at a lower pressure than did uterine horns ligated with an encircling suture. However, the pressure at which the failure occurred was likely higher than the physiologic pressure in a nonpregnant uterus. Pressures between 69 and 80 mm Hg have been reported for a nonpregnant bitch given oxytocin during diestrus to simulate uterine contractions during labor. To the author’s knowledge, no studies of intrauterine pressure in dogs with disease such as pyometra have been reported. However, it is unlikely that a healthy uterus sealed with a VSD or an encircling suture would contain pressure nearing or ≥ 80 mm Hg, such as the pressure in oxytocin-stimulated uteri. Therefore, we believe that a VSD can be used to seal canine uterine horns at the level of the proper ligament.

When a seal was visibly achieved in the present study, the bursting strength of the uterine body did not differ on the basis of sealing technique used. For 3 uterine bodies, the VSD needed to be applied up to 5 times to acquire a macroscopic seal, making the application of the VSD unpredictable for sealing the uterine body. The impact of multiple applications of the VSD on tissue healing was not evaluated. A uterine horn or body diameter ≥ 9 mm significantly reduced the bursting strength of the seal obtained with the VSD. When a macroscopic seal was obtained, the bursting pressure was at least 75 mm Hg, which may be the pressure reached during labor.

Although they may visibly appear to seal, uterine horns > 9 mm in diameter may not be able to sustain an intraluminal pressure > 100 mm Hg in the immediate postoperative period. The limit of 100 mm Hg was chosen for the present study because the intraluminal pressure after oxytocin injection during labor can reach 80 mm Hg. Uterine bodies < 9 mm in diameter that were sealed with the VSD had a bursting pressure > 255 mm Hg. Only 1 uterine body ≥ 9 mm in diameter failed to seal appropriately, and this was obvious macroscopically before it was pressurized. Uterine bodies ≥ 9 mm in diameter that were sealed with the VSD burst at pressure that may be too low to recommend device use for this application. Uterine bodies that were subjectively turgid in texture and sealed with the VSD failed at low pressures, even when their diameter was < 9 mm. This discrepancy in size and subjective texture assessment was not apparent in uterine horns. For these reasons, we do not recommend sealing the uterine body with vessel sealant technology.

A 10-mm vessel sealant clamp was used in our study because this is the clamp most commonly used during laparoscopic ovarioectomy. The clamp had to be applied 2 or 3 times across the body in the largest uterine body to achieve a complete seal. Such repeated application may have influenced the strength of the seal because of local heat production. Other clamps of different sizes exist but are usually not used during ovariohysterectomy.

Several points must be considered when determining whether a VSD should be used for ovarioectomy or ovariohysterectomy in dogs. During such surgeries, the objective of the VSD or suture is to seal not only the organ lumen but also the associated vasculature, and vascular bursting pressure was not evaluated in our study. However, the vessel sealant technology can seal blood vessels with a diameter as large as 7 mm. In addition, the specimens used in

**Table 1—Median (range) in vitro bursting pressures (mm Hg) of canine uterine horns and bodies < 9 or ≥ 9 mm in diameter that were sealed with an encircling suture or VSD.**

<table>
<thead>
<tr>
<th>Uterine site</th>
<th>VSD</th>
<th>Encircling suture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 9 mm</td>
<td>275 (0–275)</td>
<td>225 (0–225)</td>
</tr>
<tr>
<td>≥ 9 mm</td>
<td>300 (125–300)</td>
<td>250 (175–300)</td>
</tr>
<tr>
<td>Body</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 9 mm</td>
<td>275 (0–125)</td>
<td>225 (0–125)</td>
</tr>
<tr>
<td>≥ 9 mm</td>
<td>300 (175–300)</td>
<td>250 (175–300)</td>
</tr>
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*Value differs significantly (P < 0.05) from corresponding uterine horn value.*

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our study were cadaveric; therefore, it is unknown how tissue healing might affect the integrity of the seal. Breeding and estrus cycle history were unknown for most dogs because they originated from a shelter. The stage of estrus cycle may have an effect on the strength of the initial seal as well as influence on the number of applications required to seal some uterine bodies. We did not perform any histologic evaluations of tissues used. In an in vivo situation, histologic evaluation would ideally be performed because inflammation and debridement may contribute to seal breakdown in the days following seal application.

Findings of the present study suggest the VSD is safe for sealing uterine horns, even when their diameter exceeds 9 mm. Vessel sealant devices can be applied to the uterine body; however, caution should be used for uterine bodies ≥ 9 mm in diameter. It is likely that the uterine body of dogs that have not been gravid and have not been through an estrous cycle would be safely sealed with a 10-mm VSD.

References