**Advanced Electrothermal Bipolar Vessel Sealing**

 **In Small Animal Surgery**

En litteraturstudie

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**Advanced Electrothermal Bipolar Vessel Sealing**

**In Small Animal Surgery**

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**Objectives –** To review the use of advanced electrothermal bipolar vessel sealing in small animal surgery with its indications.

**Study design –** Literature review

**Results –** Vessel sealing is used in both open and minimally invasive small animal surgery. It is easy to learn and timesaving for sealing arteries ≤ 7 mm in diameter. Moreover it has advantages in sealing surrounding tissues like for example soft palate, lung lobes, liver, pancreas and uterine horns. Use of vessel sealing does not improve hemostasis over encircling suture but may decrease surgical time.

**Clinical Relevance –** In minimally invasive surgery vessel sealing should be favored over extracorporeal modified Roeder knot

**Abbreviations:** Electrothermal bipolar vessel sealing (device) - EBVS(D)

 LigaSure™ - LS

 Minimally invasive (surgery) - MI(S)

 Open surgery - OS

 Surgical time - ST

 Suture-fracture - SF

 Dissection-ligation - DL

 Ovariohysterectomy - OVH (laparoscopic = lapOVH, open = oOVH)

 Ovariectomy - OE (laparoscopic = lapOE, open = oOE)

**INTRODUCTION**

MIS and advanced soft tissue surgery are increasing fields in veterinary surgery38. This requires ST saving ligation methods without challenging safety, patient comfort and costs over time/patient. This article reviews the use of EBVS in veterinary surgery, its indications, benefits and complications.

**HISTORY**

The first report on initial surgical application of a direct current instrument by Becqueral in the early 19th century describes both heat formation and hemostasis1-2.Ten years after D´Arsonovals and Teslas invention of a high frequency alternating current device, in 1881 Negelsmith described the alternating current heating mechanism as “diathermy”1-2.

In the early 20th century Doyen improved Pozzys high frequency, high voltage alternating current technique termed *fulguration* by attaching a grounding plate to the patient and termed the effect *electrocoagulation*2.Around 1910 William Clark invented *dessication* with his device, but the precursor of modern electrosurgery, with an adjustable generator, instrument and grounding pad, was first achieved in the late 1920s by William T. Bovie and Harvey Cushing1-2.

In the 1990s methods were developed for MIS to seal larger blood vessels2.

**VESSEL SEALING DEVICES**

The goal with using EBVS is sealing arteries ≤7 mm diameter with reduced collateral thermal damage compared with conventional bipolar electrosurgery. EBVS systems achieves this by sensing tissue impedance and adjust energy output to gain hemostasis with less heat (50-80 °C compared to 100-300 °C with conventional biopolar electrosurgery) and minimal tissue carbonization2. This results in desiccation and denaturation of collagen and elastin in the vessel wall and surrounding tissue, reforming the vessel wall into a permanent seal3. EBVS is operating with high current and low voltage.

The generator has a feedback mechanism providing the surgeon with an audible tone when the sealing process is complete. The surgeon then divides the fused tissue manually, which operating surgeons experienced as having more control over the procedure4.

There are disposable and reusable systems on the market with the LS most often documented for use in veterinary medicine. Devices are designed for use in either MIS or OS and differ in cutting ability and cutting method.

The systems listed in *table 1* are those, that the author found available on market for sealing vessels ≤ 7 mm diameter.

**VESSEL SEALING PROCEDURES**

*HEAD*

*Soft Palate*

Brachycephalic dogs commonly show elongation of the soft palate. Sharp excision with scalpel and scissors followed by primary suture is the traditional method for removing the elongated portion. Use of CO2 laser resulted in shorter ST in one study6.

The use of EBVS was reported to be faster than CO2 laser with no difference in depth of tissue injury7.

In dorsal recumbency and with the mouth opened in fullest extend the soft palate was transected by EBVS at the level of the cranial commissure of the tonsillar crypt. No serious complications were identified and EBVS did not cause clinically important tissue injury or pharyngeal swelling. Despite that the soft palatine was resected more rostral than recommended, it has not been associated with more long-term complications8.

Results indicated that EBVS can be safely used for resection of the elongated portion of the soft palate 8.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Company****+ online referense** | **VESSEL SEALING DEVICE:** | **Energy platform** | **Re use** | **MIS/ open** | **hand activated** | **shaft dia meter (mm)** | **Instrum.length (mm)** | **seal witdh (mm)** | **seal length (mm)** | **cut length (mm)** | **dissection blade** | **jaw design** |
| **Aesculap®**  [www.caimansurgery.com](file:///C%3A%5CUsers%5CAlice%5CDocuments%5CDocuments%5CExamensarbete%5Cwww.caimansurgery.com) | **Caiman® 5**  |  |  | MIS |  | 5  | 360 | - | 26,5 | 23,5 |  | hinged jaw to close the tip first |
| **Caiman® 12** | Lektrafuse® RF Generator | no | both | no | 12 | 240 | - | 50 | 47 | yes | hinged jaw to close the tip first, 80° jaw articulation |
| **Caiman® 12 Plus** |  |  | MIS |  | 12 | 445 | - | 50 | 47 |  |  |
| **BOWA**  [www.bowa-medical.com/en/products/instruments/tissueseal-plus.html](file:///C%3A%5CUsers%5CAlice%5CDocuments%5CDocuments%5CExamensarbete%5Cwww.bowa-medical.com%5Cen%5Cproducts%5Cinstruments%5Ctissueseal-plus.html) | **TissueSeal Plus®** | BOWA ARC generator | yes | OS | no | - | 190, 230, 280 | - | - | - | no | curved, smooth |
| **Covidien**  <http://surgical.covidien.com/products/vessel-sealing>*Laparoscopic Instruments*   | **LigaSure™ 5mm Blunt**  |  |  |  |  | 5 | 370, 440 | - | 19,5 | 17,8 | no | straight, blunt, ridged |
| **LS Advance™** | ForceTriad™ |  |  |  | 5 | 440 | - | 18 | 15,5 |  | curved, bilateral with monopolar tip |
| **LSAtlas™** |  | no | MIS | yes | 10 | 370 | 2x3 | 22 | 20 | yes | straight, blunt |
| **LS DolphinTip**  | ForceTriad™ and LigaSure™ vessel sealing system (LS™VSS) |  |  |  | 5 | 370 | - | 18 | 12 |  | straight, dolphin-nose tip |
| *Open Instruments*   | **LS Impact™** |  |  | OS | yes | 13,5 | 180 | - | 36 | 34 |  | curved, smooth |
| **LS Small Jaw**  | ForceTriad™ |  |  |  by clos ing | - | 188 | 1-4 | 16,5 | 14,7 | yes | curved, smooth |
| **LS 5mm Blunt** |  | no |  |  | 5 | 200 | - | 19,5 | 17,8 |  | straight, ridged |
| **LS Atlas™** |  |  | both | yes | 10 | 200 | 2x3 | 22 | 20 |  | straight, blunt |
| **LS DolphinTip**  |  |  |  |  | 5 | 200 | - | 18 | 12 |  | straight, dolphin-nose tip |
| **LS Precise™** |  |  |  | no | - | 16,5 | 1-3 | 15,5 | - |  | curved, smooth |
| **LS Max** | ForceTriad™ and LS™VSS |  |  | + | - | 230 | 3-5 | 25 | - |  | curved, ridged, grained |
| **LS Xdt** |  | yes  | OS | + | - | 280 | 2,5-5 | 28 | - | no | curved, ridged, grained |
| **LS Sdt** |  |  |  | no | - | 180 | - | 25 | - |  | pyan-styled, curved |
| **LS Axs** |  |  |  | no | - | 200 | - | 23 | - |  | angled 60° |
| **Erbe** www.erbe-med.com/us/medical-technology/public/7000\_vesselsealing/BiClamp-- | **BiClamp® Ceramic** | VIO® System |  | OS | - | - | 200, 260, 270 | - | - | - |  | curved |
| **BiClamp® LAP** |  | yes | MIS | - | 5 | 340 | - | - | - | no | Maryland (serrated/smooth), Fenestrate (serrated/ smooth) |
| **Ethicon**  [http://gb.ethicon.com/healthcare-professionals/products/energy-devices/enseal-tissue-sealing-devices](http://gb.ethicon.com/healthcare-professionals/products/energy-devices/enseal-tissue-sealing-devices%20)  | **EnSeal® G2 Super Jaw Tissue Sealer**  |  |  |  | - | 12 | 220 | 6,7 | 40 | - |  | curved, atraumatic teeth for grasping |
| **EnSeal® TRIO Tissue Sealing Device**  | Ethicon Generator G11 | no | both | - | 5  | 140, 250, 350, 450 | 3 | - | - | I-Blade™ | curved, smooth |
| **EnSeal® Tissue Sealing Device** |  |  |  | - | 6  | 140, 250, 350 | - | - | - |  | round, smooth |
| **KLS Martin Group** [www.klsmartin.com/products/electrosurgery/electrosurgical-instruments/bipolar-instruments/?L=2](file:///C%3A%5CUsers%5CAlice%5CDocuments%5CDocuments%5CExamensarbete%5Cwww.klsmartin.com%5Cproducts%5Celectrosurgery%5Celectrosurgical-instruments%5Cbipolar-instruments%5C%3FL%3D2) | **marSeal IQ** |  |  | both |  | 10 | 200, 370  | 6 | 22,8 | 18 |  | blunt, straight |
| **marSeal Slim IQ** | maximum® high-frequency generator | yes |  | yes | 10 | 200, 370 | 3 | 22.5 | 18 | non-sterile disposable | slim, curved |
| **marSeal 5 IQ** |  |  | MIS |  | 5 | 370 | 3 | 17 | 13 |  | straight with curved tip |
| **Olympus**  <http://medical.olympusamerica.com/products/thunderbeat> | **Thunderbeat** | ESG-400 generator, USG-400 generator | no | both | yes | 5 | 100, 200, 350, 450 | - | - | - | ultrasonic | - |
| **PKS SEAL (GYRUS PK)** | G400 PK | - | OS |  | - | 250 | - | - | - | none | curved |

*Table 1*

THORAX

*Mediastinum*

LS and EnSeal ® can be used effectively for section of the ventral mediastinal attachments, after having established access to the thoracic cavity in thoracoscopy for patients placed in dorsal recumbency. EBVS is recommended because any haemorrhage can result in significant loss of visualization10, 15.

EBVS can be used to initiate dissection of cranial mediastinal masses from surrounding tissue11.

*Thoracic duct*

Idiopathic chylothorax in two cats was treated with thoracic duct sealing with an EBVSD and partial pericardectomy. The procedure was performed without surgical complications. No long term (two years) recurrent thoracic effusion and no clinical signs occurred12.

*Pericardium*

For treatment of several cardiac and noncardiac diseases pericardectomy is indicated. Thoracoscopic procedures have limited objective comparison to open thoracotomy in veterinary literature, but advantages of thoracoscopy in small animals are likely to be similar to those in people13.

Using a fine-tipped EBVSD facilitates both the initial incision in pericardial windowing and subphrenic pericardectomy and the final cutting procedure in subphrenic pericardectomy11.

*Lung*

Peripheral lung resection is indicated for lung biopsies for diagnosis of diffuse lung disease as well as for resection of small peripherally located mass lesions or bullae.

The LS Atlas 10 mm was used to collect biopsy samples from the periphery of a lung lobe. One lung ventilation was used, but histology of the samples revealed that aeration of the lung provides a protective effect with regard to thermal damage. Two dogs where pulmonary parenchyma was atelectatic at time of resection had a greater transaction zone than the four dogs with aerated parenchyma.

There were no surgical complications and thoracic radiographs taken 1, 2, 4, and ~180 days after surgery did not reveal air leakage or other complications. The use of LS Atlas appears to be safe for peripheral lung biopsy in healthy dogs, but further studies are required to evaluate efficacy in dogs with parenchymal disease15.

In porcine lung the LS showed to be superior to conventional electrocautery for parenchymal resection because of significantly lower blood loss and lower degree of thermal injury which was confirmed by histological examination16.

In one human study on comparing EBVS with endostapler in endoscopic lung wedge resection, the LS Atlas is found eligible for pulmonary wedge resection and mobilization of tumors, which cannot be accessed by staplers. It leaves no foreign material in the cut surface and its smaller head can facilitate approach in difficult situated areas. A disadvantage however is sticking of tissue to the device´s head, but it can be handled with regular mechanical cleaning during the surgery. EBVS is more favorable in a financial aspect 17.

*ABDOMEN*

*Liver*

Liverlobectomy is a common procedure in dogs, more often as partial than complete. In a study devices developed for MIS were used for open liver surgery. Five surgical techniques (SurgiTie™, LS, Ultracision® Harmonic Scalpel, Suction+Clip and Suction+TA [thoracoabdominal] stapler) were compared in regards to ST and intraoperative blood loss.

The highest amount of blood loss as percentage of blood volume was as follows: SurgiTie™ 2,43%, LigaSure™ 4,10%, Ultracision® Harmonic Scalpel 3,37%, Suction+Clip 7,44% and Suction+TA stapler 4,3%. Suction+Clip had significantly higher blood loss than the other four techniques. Having to apply additional hemostasis in 3 of 10 liver lobes transected with Ultracision® Harmonic Scalpel, indicated that careful application of the device and avoiding grasping too much parenchyma at once is important.

There was no significant difference in ST 18.

In a swine model, stapling and EBVS were compared for parynchemal transection in laparoscopic liver surgery. No evidence of biliary leakage or haemorrhage was found in either of those two methods. A trend toward shorter transection time was seen for the stapled group compared to the LS group, but no difference in serial liver enzymes and liver histopathology. Both techniques are considered safe and effective, but using the endomechanical staplers is associated with increase in cost19.

*Spleen*

Splenectomy in dogs is performed for a variety of reasons, including trauma, torsion, neoplasia and autoimmune disease23, and in cats most frequently for primary and metastatic neoplasia, hyperplasia, hematomas and splenitis22.

MI splenectomy is gold standard for treatment of hematologic disorders of the spleen in people25.

In a comparison between single and three portal approaches in dogs, single incision laparoscopy considers available, feasible and safe for dogs undergoing elective splenectomy, because it presents advantages in operative time and surgical scar20.

Laparoscopic splenectomy for treatment of splenic hemangiosarcoma in one dog is presented in a clinical report. In this case vessels were sealed as close as possible to the parenchyma with a LS device, which facilitated the procedure due to the fact that isolation of individual spenic vessels was not needed. Major contraindication for laparoscopic splenectomy is hemoabdomen because of limited visibility as well as the necessity for rapid control of actively bleeding vessels. Attempting MI splenectomy is recommended for tumors with a diameter ≤ 5 cm23.

Three-portal laparoscopic splenectomy was performed in three cats using LS and EnSeal™ VSD to transect the splenic pedicle along the hilus, moving from the tail up to the head of the spleen. The challenging part of the dissection was the area of the head of the spleen as the feline pancreas is closely located to this area22.

Two studies illustrate the use of EBVS for OS for canine splenectomy21, 24.

In the first study ST decreased significantly with EBVS compared to surgical staplers, despite that there were more gastropexies and liver biopsies performed in the EBVS group. Frequent cleaning of the jaws is recommended to prevent char buildup21.

The second study evaluated the use of EBVS for splenectomy, including measuring of the splenic artery diameter, in 27 dogs. Splenectomy was performed using a LS system for ligation of all major vessels. The splenic artery was sealed three times with an overlap of seals, while the splenic vein was sealed twice. Transection was performed across the most distal seal. No failure of the device occurred during surgery. One dog was readmitted four days after surgery with haemoabdomen. Manipulation of the splenic artery too close to the pancreas might have triggered local pancreatitis, which possibly caused resorption of the seal from the EBVSD and induced bleeding in this case. The seal created by the EBVSD was found to be stronger than those of other energy-based ligation methods and comparable in strength to mechanical ligation. Authors recommend measuring the diameter of the splenic artery in large breed dogs to ensure that the artery is ≤ 7 mm diameter. Their impression is that it is important to avoid any tension on the major vessels when the seal is performed. EBVS is found to be safe for performing canine splenectomy 24.

*Pancreas*

Partial pancreatectomy or local enucleation is performed for removing insulinomas. Insulinomas are insulinproducing pancreatic β-cells tumors and commonly observed in middle-aged to older dogs of medium to large breed. Insulinomas are often malignant, and at the time of diagnosis 40 to 50% have macroscopically visible metastases in the regional lymph nodes and liver. Traditional techniques for partial pancreatectomy are suture-fracture (SF) and dissection-ligation (DL) technique 26.

Earlier, coagulation of the pancreas had been discouraged, because of the potential development of pancreatic irritation.

LS was used because of its documented limited collateral thermal spread of 0,5 to 2 mm. Mean ST of the EBVS group was significantly shorter compared to the SF group. Intraoperative complications occurred in none of the groups. Mean hospitalization period was significantly shorter for EBVS group compared with SF group. None of the dogs in the EBVS group developed clinical signs of pancreatitis, whereas three dogs treated using SF did. EBVS prevents leakage of the pancreatic juices by creating a seal right at the dissection site. Tumor size or location is considered less important when using EBVS for partial pancreatectomy because even located in the pancreatic corpus they can be relatively easy removed by placing the device on the healthy pancreatic tissue surrounding the tumor26.

*Adrenal Glands*

An innovative approach for adrenalectomy was designed for dogs in sternal recumbency to allow gravitational displacement of the abdominal viscery in one study. Adrenalectomy was performed by dissection with a curved dissecting forceps and a 5 mm LS. The phrenicoabdominal vein was easily sealed. ST for the sternal approach was significantly shorter than historic control data and for this the use of LS should be taken to account 27.

*Small Bowel*

Feasability and effectiveness of LS was studied dividing porcine small bowel. Staples, LS Atlas (single and double sealed) and LS XDT were compared by measuring burst pressure. Burst pressure for stapled bowel was significantly higher than for LS segments with no significant difference among the LS groups. The result therefore shows that LS not safely seals small bowel28.

*Kidneys*

Various conditions are indications for canine ureteronephrectomy including primary renal neoplasia, hydronephrosis, chronic or unresponsive pyelonephritis, renal dysplasia, polycystic kidney disease, ureteral atresia, nephrolithiasis, trauma and idiopathic renal hematuria.

Surgical technique for transperitoneal laparoscopic ureteronephrectomy is described in an experimental study and case series using EBVS for dissection and hemoclips for renal hilar vessel ligation in dogs. In small dogs use of EBVS alone could be considered 29.

In people complications and costs are compared for open and MI nephrectomy. MIS is used with increasing frequency because of improved patient comfort, better cosmetic results, less postoperative pain, lower transfusion rates and earlier return to daily activities. Difference in costs compared to OS is negligible30.

*Female reproductive tract*

Unsurprisingly most studies are made for comparing several techniques for spaying bitches, both healthy dogs and dogs with pyometra, due to the fact that ovariohysterectomy (OVH) and ovariectomy (OE) are the most common surgical procedures performed in veterinary medicine31.

When not using EBVS for laparoscopic OVH surgical times increase significantly compared to open OVH, while pain still is lower for lapOVH 32.

When comparing three techniques for lapOVH, including extracorporeal modified Roeder knot application, metal clip application using a multifire 10 mm laparoscopic clip applier and a 5 mm EBVSD, the use of EBVS significantly shortens ST and provides excellent hemostasis. A learning curve exists for clip and suture methods33.

LapOVH is documented for uterine diameters up to 4 cm in dogs with pyometra. A 5 mm LS was used for the suspensory ligament, ovarian vessels and mesovarium, while the uterine body was double ligated using 2-0 polydioxanone after being exposed through the most caudal portal incision34.

Bursting pressures for sealing uterine horns and bodies with EBVS versus an encircling suture were the concern of another study. The failure pressure for both techniques was high which indicates that EBVS of uterine horns in dogs may be safe. However, given the low mean bursting pressure for seals in uterine bodies with large diameter, EBVS cannot be recommended for sealing uterine bodies ≥ 9 mm in diameter 35.

Ovariectomy (OE) is less invasive than OVH and not associated with increased risk of complications36. With use of EBVS in laparoscopic OE, postoperative activity is not significantly changed from preoperative in small dogs measured with an accelerometer, compared to significant change in activity after open OE performed with suture technique. LS is easy to use and results in excellent hemostasis37.

In two studies LS was used for single portal lapOE38, 39. EBVS was found to facilitate sealing and dividing ovarian pedicles. The amount of fat in the ovarian ligament correlated negatively with ST. Big amounts of fat could result in an overload of jaws and increase the likelihood of bleeding. Other facts, like dirty clamps for coagulation, could preclude correct vessel sealing 39.

In cats, oOE, lapOE with extracorporeal modified Roeder knot and lapOE with LS, were compared. ST was significantly longer for the Roeder knot group than for the other two methods which were not different.

*Male reproductive tract*

Cryptorchism is the most common congenital defect of testes. MIS offers advantages in animals with nondescended testes because it permits rapid exploration of the inguinal ring with a minor incision (0,5 cm)41.

In one case report laparoscopic crypotorchidectomy is performed in a cat using bipolar cauterization42.

**DISCUSSION**

EBVSD are developed primary to facilitate ligation in MIS procedures. The biggest disadvantage of both EBVS and MIS procedures is expense for equipment, thus the methods are not widely spread within veterinary medicine today. Case load is needed to develop important skills for performing MIS procedures, but seems not to be important for EBVS.

EBVS should be considered as a dissecting complement and ligation method not only for MIS but also for open surgery. EBVS is not leaving foreign body material, while being easy to use, fast to learn and timesaving.

Studies showed that EBVS could be useful sealing different tissues like soft palate7, lung15, 16, 17, liver18, pancreas26, and uterine horns ≤ 9 mm in diameter beyond EBVS being safe for sealing arteries ≤7 mm diameter.

EBVS does not achieve an appropriate seal for small bowel28.

Weakness of many studies is, that they are based on a small number of cases12, 15, 22, 23, 42 and when comparing OS to MIS different ligation methods are used37. This makes it difficult to illustrate, if it is the approach or the ligation method responsible for the differences in results.

**CONCLUSION**

The use of EBVS is timesaving and easy to learn. It can be used for lots of different procedures due to the fact that it was found to be safe for sealing arteries up to 7 mm diameter and has some other advantages in sealing surrounding tissue, like for the soft palate, lung lobs, liver, pancreas and uterine horns.

EBVS is feasible for both MIS and OS and is most likely to increase in use for small animal surgery.

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