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Review Article

An update of electro surgery devices options in minimal invasive surgery: a review

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ABSTRACT

The rate and variety of advances in energy sealing technology in the last two decades has heralded new opportunities in laparoscopic and minimally invasive surgery. Reduced operating times, lower postoperative pain scores, and shorter length of stay are offset by the additional cost of such instruments. Critical to obtaining optimal clinical effects and reducing potential complications, is a thorough understanding of the proper use of each energy modality. No single device has shown a significant superiority over the other. However best combination to have is harmonic along with ligasure or perhaps now the latest wireless sonicision with ligasure to undertake most of the surgeries. Thunderbeat has advantages like faster cutting speed and minimal instrument changes. Ferromagnetic wand is the fastest available instrument with unique features. Argon beam coagulation has certain specific uses and is best for fulguration and it is definitely advantageous to have it in OT. Sonicision offered wireless ergonomics and better manoeuvrability, cheapest VSD was the conventional bipolar.

Keywords: Vessel sealing technologies, Ligasure, Harmonic scalpel, EnSeal, Argon beam coagulation, Minimally invasive surgery

INTRODUCTION

Energy-based vessel sealing devices (VSDs) have been under constant evolution and enable surgeons to improve the efficiency and safety of procedures with decreased blood loss and operative times.[1] Continuous research and technological advancements have significantly improved contemporary VSDs. New design improvements have been developed to provide more consistent energy delivery and a feedback loop to optimize seal quality. There are many VSD available today claiming one's superiority over the other. The opinion of the best VSD sometimes are market driven. The user is left in dilemma as to what would be best VSD or combination of VSDs one should have in his/her surgical armamentarium so that it suits surgeon's operating style and ergonomics as well as keeping the cost implication of each VSD in mind. Advances, including the combination of ultrasonic and bipolar systems, the addition of cutting blades, ferromagnetic technology, tissue impedance sensors, and electrode configurations with reduced lateral thermal spread have heralded new opportunities in laparoscopic and minimally invasive surgery.

Through this review article we have tried to evaluate and compare the various commercially available VSDs w.r.t. the transection speed, jaw temperature, thermal spread, and seal burst pressures. We have also tried to introduce the mechanism of action of newly available VSDs and tried to decipher optimal use of each instrument to surgeon's best advantage.

METHODS

The review includes a thorough search of literature concerning the physics, applications, success, complications and comparison of various energy sources in surgery. Priority was given to human studies and laparoscopic procedures. However, the studies involving animals (both in vivo and in vitro) and open procedures which were unique and relevant to the assessment of the energy sources were considered. Emphasis was placed on more recent studies covering the latest techniques and studies conducted on live patients in the United States. The keywords used in the search were numerous and the websites such as Medline, PubMed, SpringerLink and Google were extensively covered along with various books published in the field.

RESULTS

Harmonic scalpel appears to be a versatile equipment which can be used and is a must have in today's modern surgery. With its better ergonomic design and least lateral spread harmonic scalpel is still the favourite among surgeons esp. for dissecting the peritoneum and retroperitoneal dissection of loose areolar tissue and lymph node dissection and sampling. However, to achieve best and faster haemostasis from a bleeding vessel ligasure appears to be a better choice than the harmonic and indeed many surgeons started using a combination of harmonic and ligasure for performing all types of laparoscopic surgery. The introduction of enseal by ethicon which now comes integrated with harmonic scalpel but still requires instruments to be changed and is slower as compared to ligasure. Thunderbeat offers the best combination of harmonic scalpel and bipolar vessel sealer in a single instrument and significantly reduces the operating time virtually eliminating the time required for changing the instruments from harmonic scalpel to bipolar. The cost of thunderbeat as a single instrument should be justified against the advantages it has to offer when there are more economical options of using harmonic scalpel and ligasure or combination of both are available with equal results. Best instrument to control the oozing from tissue bed viz the ovarian bed after cystectomy, presacral bleeding and in endometriosis, appears to be argon beam coagulation via fulguration. The cheapest energy source combination available in remote settings appears to be simple bipolar with cold scissors and monopolar hook/spatula; but again, the disadvantages like large lateral spread, ineffective haemostasis, charring of tissues, significant increase in operative time has to be considered keeping in mind the type of surgery, the tissue one is dealing with and the surgeon's experience.

DISCUSSION

Traditional monopolar devices are associated with unpredictable and weak vessel sealing and increased lateral thermal spread.[2,3] Bipolar energy and ultrasonic devices are the most routinely used thermostatic energy devices in contemporary surgical practice.

Harmonic scalpel (ethicon endosurgery)

This device uses a high-frequency ultra-sonic transducer (55,000 cycles/second) to create mechanical vibration of one of the two jaws. The device can be used to vaporize tissue (cut) or achieve hemostasis by coagulation. As with the other devices, protein is denatured, and vessels are occluded by formation of a coagulum. With the Harmonic Scalpel, the surgeon can adjust the amount of energy delivered to tissue by selecting any one of five available settings. Coagulation is maximized when the setting is low and tissue is under minimal tension; a high setting and maximal tissue tension, on the other hand, disrupt tissue with minimal haemostasis. Tissue effects with this device can vary strikingly, depending on how the surgeon applies it.

EnSeal tissue sealing and hemostasis system and enseal ptc (surgrx)

EnSeal utilizes nanotechnology to control the energy at the electrode–tissue interface. The jaws contain a temperature-sensitive matrix with embedded conductive carbon spherules designed to "sense" tissue characteristics. It uses extremely high jaw compression to create uniform tissue effects. It does not require a dedicated electrosurgical unit for use; an adapter can be purchased that permits use with most generators.

Ligasure V (valleylab)

Ligasure is a bi-polar electrosurgical device designed to deliver high current and very low voltage to tissue. It monitors tissue impedance between the jaws of the instrument and continuously adjusts the delivery of energy. Ligasure seals vessels by applying high, uniform mechanical compression while monitoring and adjusting energy delivery to the tissue (Figure 1).[4] Collagen and elastin fibres in the compressed vessel walls are denatured; during the cool-down phase, cross-linking reoccurs, effectively creating a new, solid wall of collagen and elastin tissue.

An algorithm in the generator determines optimal time and energy delivery to achieve consistent seals for vessels as large as 7 mm in diameter. Because this product relies heavily on the collagen and elastin content of vessels to achieve hemostasis, it works well for arteries and veins but inconsistently in tissues where the blood supply is delivered predominantly by capillaries, which have a low collagen content.

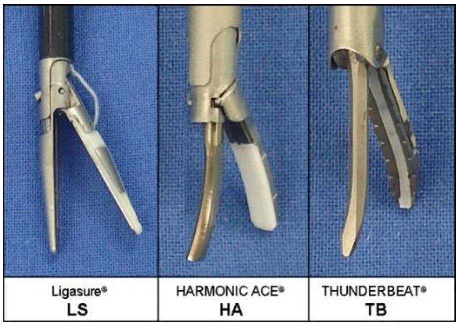

Figure 1: Detailed view of jaws of different devices.[5]

A combination of ultrasonic and bipolar energy sources within one device has been shown to reduce the need for instrument exchange and, with increased speed of cutting, dissection and tissue manipulation, reduce operating times when compared with devices that use either modality alone.[6] Hence the introduction of Thunderbeat.

The argon beam coagulator (ABC) delivers radiofrequency electrical energy to tissue across a jet of argon gas, providing noncontact, monopolar, electrothermal haemostasis. The ABC appears to be an excellent instrument for achieving haemostasis in solid organ injury and may be especially valuable in managing patients with coagulation deficits. The ABC stopped bleeding from 25/25 hepatic lacerations in 48±8 seconds (mean±SEM) and from 18/18 splenic lacerations in 28±3 seconds. The Nd:YAG laser, mattress sutures, and topical haemostatic agents failed to control bleeding in 14 of 15 applications after 3 minutes. The ABC successfully salvaged all failures in less than 1 minute. The depth of splenic and hepatic thermal injury with the ABC ranged from 2 to 7 mm and was proportional to the duration of application.[7] Presacral bleeding is a dreaded complication of pelvic surgery.

Saurabh et al reported using the argon beam coagulator (ABC) to control presacral bleeding and found that ABC is a simpler, equally effective and expeditious way of addressing presacral bleeding.[8] ABC performs faster than conventional coagulation systems and provides a more uniform and shallower coagulation region which results in faster dispersion thus minimizing tissue damage. It also produces less smoke than the conventional system. The protection of the active electrode tip from exposure to oxygen also results in less charring.[9,10]

To date one of the best article comparing the various VSDs come from Okhunov et al, who evaluated various available Vessel sealing devices (VSD) in 15 Yorkshire pigs in three categories of vessels: small (2-5 mm), medium (5.1-7 mm) and large (7.1-9 mm) according to scoring criteria and definitions (Table 1). Five VSDs which were evaluated were: the Caiman 5 (C5; Aesculap, Inc., Center Valley, PA), Harmonic Scalpel Ace Plus (HA; Ethicon Endosurgery, Cincinnati, OH), Harmonic Ace +7 (HA7; Ethicon Endosurgery), Ligasure (LS; Covidien, Mansfield, MA), and Enseal G2 (ES; Ethicon Endosurgery); according to the settings recommended by the manufacturer. In additional, they measured the maximum jaw temperature for each VSD using a thermal camera (FLIR E5; FLIR Systems). Their findings are summarized in Table 1 and 2.

Table 1: Scoring criteria and definitions.

	Definition
Score	**Charring/carbonization**
1	No charring/carbonization
2	Slight charring/carbonization that does not interfere with sealing/transection
3	Slight charring/carbonization on upper or lower jaw requiring cleaning
4	Moderate charring/carbonization on one or both jaws requiring cleaning
5	Significant charring/carbonization on both jaws requiring cleaning
Score	**Tissue sticking**
1	No tissue sticking
2	Slight sticking requiring activation of the device to release tissue
3	Tissue sticking requiring counter tension to gently remove tissue
4	Tissue sticking requiring counter tension and extensive force to remove tissue
5	Tissue sticking such that tissue is damaged or torn during the removal process
Score	**Seal quality**
1	Excellent, no bleeding
2	Blood oozing at tissue site
3	Blood oozing at tissue site at 5 seconds
4	Moderate bleeding requiring intervention
5	Bleeding without evidence of tissue sealing
Score	**Transection quality**
1	Complete tissue transection from proximal to distal end of the jaw
2	Incomplete tissue transection cut proximally, not distally

Continued.

	Definition
3	Incomplete tissue transection cut distally, not proximally
4	Incomplete tissue transection with bleeding
5	No tissue transection occurred

Table 2: Comparison of tissue transection time, charring and carbonization, tissue sticking, and maximum jaw temperature measurements between Caiman 5, Enseal G2, Harmonic Ace Plus, Harmonic Ace +7, and Ligasure.

Variables	C5	ES	HA	HA7	LS	P	Pairwise t-tests
Transection time	67.3 (3.9)	96.5 (3.9)	61.6 (3.9)	60.8 (3.9)	91.1 (3.9)	<0.001a	ES>C5(<0.001); ES>HA (<0.001); ES>HA7(<0.001) LS>C5(0.001); LS>HA (<0.001): LS>HA7(<0.001)
Charring/carbonization -up median (range)	1 (1–1)	1 (1–2)	1 (1–2)	1 (1–1)	1 (1–3)	0.429b	No pairwise differences are significant
Charring/carbonization —low, median	1 (1–1)	1 (1–1)	1.5 (1–3)	1 (1–1)	1 (1–3)	<0.001b	HA>C5(0.001); HA>ES(0.001); HA>HA7(0.001); HA>LS(0.001)
Tissue sticking, median (range)	1 (1–1)	1 (1–1)	1 (1–3)	1 (1–3)	4 (3–5)	<0.001b	LS>C5(<0.001); LS>ES(<0.001); LS>HA(<0.001); LS>HA7(<0.001)
Transection quality, median (range)	1 (1–1)	1 (1–1)	1 (1–1)	1.2 (1–2)	1.2 (1–2)	0.170b	No pairwise differences are significant
Maximum jaw temp mean (SD)	109 (3.4)	114 (3.4)	195.6 (3.4)	260.1(3.4)	95 (3.4)	<0.001a	HA7>C5(<0.001); HA7>ES (<0.001); HA7>HA (<0.001); HA7>LS (<0.001); HA>C5(<0.001); HA>ES(<0.001); HA>LS (<0.001); C5>LS(0.043); ES>LS (0.002)

Comparison of vessel sealing devices

HA7 demonstrated the fastest mesenteric transection time with the mean of 60.8 seconds, followed by HA, C5, LS, and ES demonstrating 61.5, 67.3, 91, and 96.5 seconds, respectively. Maximum jaw temperature recorded during the mesenteric transections was highest for HA7 followed by HA, ES, C5, and LS. Transection quality was equal among all VSDs. The median tissue sticking scores were 1.0, 1.2, 1.6, 1.0, and 4.2 for C5, HA, HA7, ES, and LS, respectively. There were no differences in the median charring/carbonization scores. For small arteries, seal quality scores were equal for distal and proximal C5, HA, HA7, and LS, which were superior to ES. The LS resulted in significantly more charring and carbonization than the other devices.[11]

Bursting pressure failure was defined by threshold of 300 mm Hg for arteries and 30 mm Hg for veins.[12,13] Again, C5, HA7, and LS were all able to effectively seal arteries and veins up to 9 mm with no failures. HA and ES performed slightly less favourably.

Uniform compression is very much related to the jaw configuration of the VSD. Most contemporary VSDs utilize either a scissor-like or pivoting jaw design. It has been shown that the scissor-like design is associated with a less uniform distribution of compressive forces with decreasing pressure force from the proximal to the distal end of the jaws, resulting in a weaker sealing quality at the tip of the instrument.[14,15] C5 is designed with a novel pivoting jaw to address the limitations of the scissor-like jaw configuration. Specifically, the C5 device evaluated in this study consists of a novel pivoting jaw design and closing mechanism with the sealing electrodes distributed in both the upper and lower jaws.[16] This mechanism allows for a more homogeneous pressure distribution in the entire jaws.

A margin of at least 5 mm is recommended to avoid any thermal damage.[17] For both mesenteric and vessel tissues, ES and LS demonstrated the lowest jaw temperatures, whereas HA and HA7 consistently demonstrated the highest jaw temperatures across all vessel sizes. These data are consistent with previously reported studies.[17-19] HA and HA7 had the least thermal spread for both veins and arteries compared with the other three VSDs.

It may seem counterintuitive that the devices with the highest jaw temperature resulted in the least energy damage on histopathology. However, it is clear that many factors affect tissue response. The advantage of high energy is because of a feedback loop that delivers fast and highly efficient energy with the least amount of transection time. Reyes and colleagues evaluated optimal temperature and duration of clamp time to achieve a complete vessel seal. These investigators concluded that average of 2.4–3.8 MPa (348–551 psi) pressure force with 90DEGREESC with at least 10 seconds of clamp time is required for optimal and reliable vessel sealing.[20]

Tissue sticking on the instrument's jaws can create increased resistance to energy transmission, thereby prolonging the sealing time and subsequent coagulation necrosis on either side of the jaws. C5, in both proximal and distal jaw positions, had the lowest tissue sticking scores followed by HA, ES, LS, and HA7 when used on small and medium vessels. However, for large arteries, ES and HA7 demonstrated best results followed by C5, LS, and HA. Milsom and colleagues, also demonstrated that LS had poor tissue sticking results compared with ES and HA.[21]

Overall, all VSDs created a reliable seal for small and medium size arteries. For large arteries, C5, HA7, and LS were the most reliable VSDs with the highest bursting pressures and no bursting failures <300 mm Hg. HA and HA7 are associated with highest jaw temperatures but both provide the fastest sealing and transection time with less thermal damage.

Table 3: Arteries.

	C5 distal	C5 proximal	HA	HA7	LS	ES	p	P value for pairwise comparisons
Small (2-5 mm), N	5	5	10	10	10	10		
Vessel size (mm)	3.6	2.8	2.9	2.4	3.1	2.9	0.153	None significant
Bursting pressure (mmHg)	1580	1405	1189	1506	1311	1506	0.273	None significant
Maximum jaw temperature	130	126	162	171	81.5	98	<0.001	LS<HA (0.002); LS<HA7 (0.002); ES<HA (0.017); ES<HA7 (0.015)
Percentage of burst pressure failure	0	0	0	0	0	10	<0.001	
Medium (5.1–7 mm), N	5	5	10	10	10	10		
Vessel size (mm)	5.6	5.2	5.7	5.8	5.9	6.1	0.09	None significant
Bursting pressure (mmHg)	1600	1740	571	1165	981	1165	<0.001	HA<C5-D (<0.001); HA<C5-P (<0.001); HA<ES (0.002); HA<HA7 (0.002); HA7<C5-P (0.026); ES<C5-P (0.026); LS<C5-P (0.001); LS<C5-D (0.014)
Maximum jaw temperature	120.6	123.4	151.8	130.4	87	111.7	<0.001	LS<C5D (<0.001); LS<C5P (<0.001); LS<HA (<0.001); LS<HA7 (<0.001); LS<ES (0.001); ES<HA (<0.001); ES<HA7 (0.023); C5D<HA (0.001); C5P<HA (0.002); HA7<HA (0.006)
Percentage of burst pressure failure	0	0	20	0	0	40	<0.001	
Large (7.1–9 mm), N		5	5	5	5	4		
Vessel size (mm)		7.6	7.7	7.8	7.2	7.4	0.765	None significant
Bursting pressure (mmHg)		1676	254	467	530	467	<0.001	C5<HA (<0.001); C5<HA7 (0.006); C5<ES(0.006); C5<LS (0.012)

Continued.

	C5 distal	C5 proximal	HA	HA7	LS	ES	p	P value for pairwise comparisons
Maximum jaw temperature		125	213	156	91.3	121	<0.001	C5<HA (0.001); HA7<HA (0.014); LS<HA (<0.001); ES<HA (<0.001); LS<HA7 (0.006)
Percentage of burst pressure failure		0	40	0	0	80	<0.001	

Table 4: Veins.

	C5 distal	C5 proximal	HA	HA7	LS	ES	p	P value for pairwise comparisons
Small, N	5	5	10	10	10	10		
Vessel size (mm)	3.0	3.1	2.9	2.8	3.3	2.8	0.647	None significant
Bursting pressure (mmHg)	743	1048	447	533	730	533	0.009	HA<C5P (0.02); HA7<C5P (0.001); ES<C5P (0.001)
Maximum jaw temperature	128	125	162	164	90	100	0.022	LS<HA7 (0.001); LS<HA (0.012); ES<HA7 (0.001)
Medium (5.1–7 mm), N	5	5	10	10	10	10		
Vessel size (mm)	5.9	5.4	5.9	5.7	5.9	5.7	0.554	None significant
Bursting pressure (mmHg)	704	730	271	560	464	560	<0.001	HA<C5P (0.022); HA<C5D (0.017; LS<C5P (0.010); LS<C5D (0.018)
Maximum jaw temperature	126	123	170	184	89	104	<0.001	LS<HA7 (0.001); LS<HA (0.001); ES<HA7 (0.001); ES<HA (0.001); C5P<HA7 (0.001)
Large (7.1–9 mm), N		5	5	5	5	5		
Vessel size (mm)		8.9	8.6	8.6	8.2	8.6	0.833	None significant
Bursting pressure (mmHg)		449	336	446	364	446	0.877	None significant
Maximum jaw temperature		123	193	186	96	118	<0.001	LS<HA7 (0.021); LS<HA (0.001); ES<HA7 (0.001); ES<HA (0.001); C5<HA7 (0.001); C5<HA (0.012)

Table 5: Thermal spread measurements devices.

Devices	C5	HA	HA7	LS	ES	P	P value for pairwise comparisons
Arteries, N	5	5	5	5	5		
Size in mm	4	4.6	3	3.3	3.5	0.275	None significant
Jaw temperature	114	166	168	87	98.3	<0.001	C5<HA (0.001); LS<C5 (0.001); LS<LS (0.002); LS<HA7 (0.001)
Thermal energy spread, mean (mm)	3.0	3.2	2.9	3.8	4.2	0.721	None significant
Veins, N	5	5	5	5	5		
Size in mm	3.8	4.2	3.6	3.5	4	1.348	None significant
Jaw temperature	108	162	158	94	92	<0.001	LS<HA(0.001); LS<HA7(0.001); C5<HA(0.04); C5<HA7(0.001)
Thermal energy spread, mean (mm)	2.1	2.9	2.3	3.4	3.9	0.281	None significant

Two studies highlight vessel ligation Newcomb and Lamberton et al.[12] Used on medium and large vessels, the Harmonic Scalpel and Gyrus products had significant failure rates: 8% to 22% for the Harmonic Scalpel and 41% to 92% for the pulsed, bipolar Gyrus systems. The shortest sealing times for medium to large vessels were achieved with the Ligasure V using the Force Triad Generator. The Gyrus systems were the fastest devices when vessels were 2 to 3 mm in diameter. The Harmonic Scalpel produced the lowest thermal spread and least smoke, but also had the lowest mean burst pressure. The Gyrus PK generated the most smoke and had variable burst pressure. Although it had the fastest sealing times, in three of 10 trials there was a completely open arterial lumen following transection. In addition, 50% of applications involved burst pressures below 50 mm Hg. Maximum temperatures 2 mm from the device were 49.9ºC for the Harmonic Scalpel, 55.5ºC for Ligasure, 58.9°C for EnSeal, and 64.5°C for Gyrus PK. Ligasure was the highest-rated device overall, with the highest burst pressure and fastest sealing time. EnSeal was the slowest and had variable burst pressures.[4]

Table 6: Rating vessel-sealing devices: 5 measures of success. These ratings were devised by the author based on data from independent studies in living tissue models.[4]

Device	Safety: minimal thermal spread	Reliability: efficacy on vessels ≤7 mm	Efficiency: treatment time	Consistency: independent of user	Utility: multiple uses
Harmonic scalp	Excellent	Poor	Excellent	Poor	Excellent
Gyrus PK	Poor	Poor	Excellent	Fair	Fair
LigaSure V	Good	Excellent	Good	Excellent	Fair
EnSeal	Fair	Excellent	Poor	Excellent	Poor

Bindu et al showed that changes in gene transcript and protein levels after incisions with energized devices were observable at three days after surgery, and that differences exist between energized devices. The HARMONIC Blade appeared to produce better haemostasis, less inflammatory/immune response, less blood loss and reduced pain, and more advanced wound healing than electrosurgery. Evaluation of molecular functions using Gene Ontology showed that gene expression changes for the energized devices reflected the start of wound healing, including immune response and inflammation, while protein expression showed a slightly earlier stage, with some remnants of haemostasis. For both transcripts and proteins, ES exhibited a greater response than HB, especially in inflammatory mediators. This study has shown that transcriptomics and proteomics can monitor the wound healing response following surgery and can differentiate between surgical devices. In agreement with clinical observations, electrosurgery was shown to incur a greater inflammatory immune response than an ultrasonic device during initial iatrogenic wound healing.[22]

Electrothermal bipolar methods have been shown to be safe and effective when used to divide lymphatics in modified radical mastectomy and axillary dissection, and compared to conventional or harmonic scalpels, offer reduced operative time, perioperative blood loss, drain-age volume and duration, and incidence of seroma or lymphedema.[23] Histological analysis of lymph node biopsy slides is facilitated by ultrasonic dissection rather than electro- thermal methods. “The reading of histology slides is easier after ultrasonic dissections because of the greater depth of thermal injury in the lymphatic tissue” among electrosurgery patients.[24]

Table 7: A comparison of three commercially available vessel sealing devices: Harmonic ACE (Ethicon Endo-Surgery, Cincinnati, USA), Ligasure/ ForceTriad (Covidien, Mansfield, USA), THUNDERBEAT (Olympus, Tokyo, Japan).[25]

	Harmonic ACE	Ligasure/ForceTriad	Thunderbeat
Vessel sealing (FDA approval)	5 mm	7 mm	7 mm
Cutting speed (10 cm bowel mesentery)	26 sec	TissueFect (sensing tech)	20 sec
Burst pressure (5–7 mm)	454 mmHg	615 mmHg	734 mmHg
Haemostasis action	Ultrasonic	Bipolar	Ultrasonic/bipolar
Lateral thermal spread	2–3 mm	<1 mm	2–3 mm
Ergonomic	Excellent	Poor	Excellent
Cabling usage	10 cycles	Nil`	100 cycles

Fagotti et al compare operative time with use of THUNDERBEAT (TB) vs standard electrosurgery (SES) during laparoscopic radical hysterectomy and pelvic lymphadenectomy to treat gynaecologic tumors and found that the median operative time was 85 minutes for TB vs 115 minutes for SES (p=0.001). TB is associated with shorter operative time and less postoperative pain than is the standard technique (SES) in patients with uterine cancer.[26]

Chen, et al validated Ferromagnetic heating, a new electrosurgery energy modality that has proven effective in hemostatic tissue dissection as well as sealing and dividing blood vessels and vascularized tissue. A laparoscopic vessel sealing device, Laparoscopic FMsealer (LFM), was studied for efficacy in sealing and dividing blood vessels and comparative studies against predicate ultrasonic, Harmonic Ace+(US), and/or bipolar, Ligasure 5 mm Blunt Tip and/or Maryland (BP), devices in vivo using a swine model and in vitro for comparison of seal burst pressure and reliability. In division of 10cm swine small bowel mesentery in vivo, the laparoscopic FMsealer [12.4±1.8 sec (mean±SD)], was faster compared with US (26.8±2.5 s) and BP (30.0±2.7 s), p<0.05 LFM versus US and BP. Blinded histologic evaluation of 5mm vessel seals in vivo showed seal lateral thermal spread to be superior in LFM (1678±433 mm) and BP (1796±337 mm) versus US (2032±387 mm), p<0.001. In vitro, seal burst strength and success of sealing 2 to 4mm arteries were as follows (mean±SD mm Hg, % success burst strength >240 mm Hg): LFM (1079±494mm Hg, 98.1% success) versus BP (1012±463, 99.0%), P=NS. For 5 to 7 mm arteries: LFM (1098±502 mmHg, 95.3% success) versus BP (715±440, 91.8%), p<0.001 in burst strength and P=NS in % success.[27]

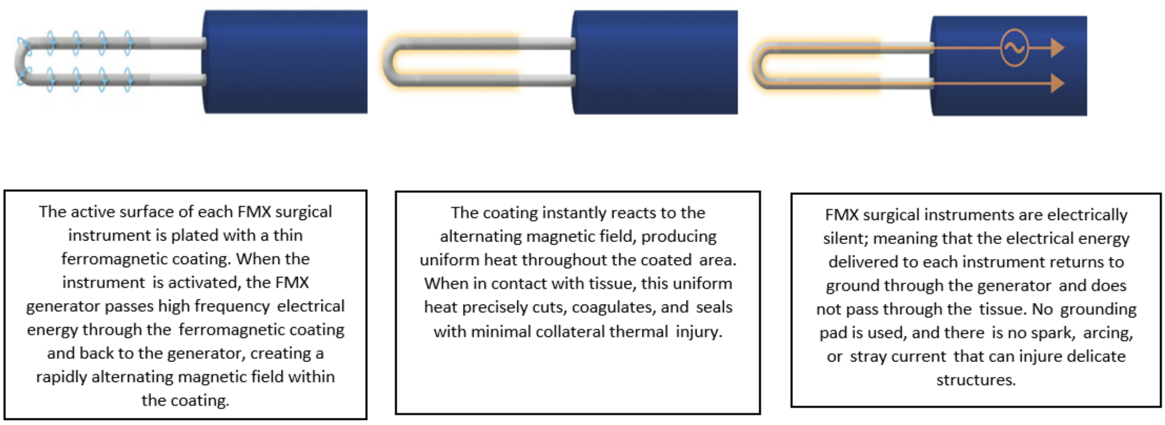

Figure 2: Structure and mechanism of action of ferromagnetic sealer.

Using light microscopy and morphometric imaging analysis, the width of tissue lateral thermal damage was measured from the point of Harmonic Scalpel incision. Perko et al showed lateral thermal damage over a mean width of 0.0522±0.0097 mm after a 5 s Harmonic Scalpel application, a damage width of 0.1544±0.0419 mm after a 10-s application, and a damage width of 0.1020±0.0430 mm after a 5 s application followed by 5 s of inactivity and another 5 s of activity.[28] The findings lead to the conclusion that tissue lateral thermal damage after Harmonic Scalpel application at standard output power is greater when a longer sustained period of application is used. Lateral thermal damage also is greater if the Harmonic Scalpel application time is continuous rather than of the same total duration with a brief midpoint interruption.[28]

The superiority of Ligasure over bipolar electrocautery is that the tissue fusion is created by the denaturation of proteins, thus forming a true seal rather than creating a proximal thrombus. Its lateral thermal spread is reported to be less than 1 mm.[29]

After a peritoneal incision, the mean lateral thermal damages of monopolar diathermy, Harmonic scalpel (output power 3), Harmonic scalpel (output power 5), and Ligasure were 215.79, 90.42, 127.48, and 144.18 µm, respectively. The conclusion of this study showed that the degree of lateral thermal spread varied by instrument type, power setting, and application time. Ligasure and Harmonic scalpel were the safest and most efficient methods of tissue coagulation. Monopolar diathermy resulted in the greatest degree of thermal damage in tissues.[30]

Latest in the field of technology appears to be a cordless harmonic scalpel which is a Covidien product and goes by the brand name Sonicision TM. The Sonicision cordless ultrasonic dissection device is a three-piece system that includes an ultrasonic dissector hand piece, a reusable generator, and a reusable battery. The hand piece is single-patient-use (disposable) device with a 39 cm, 5 mm diameter 360°; rotational shaft that culminates in a 14.5 mm active blade with an inactive cutting anvil. Both the generator and battery are snap-in components that fit into the handle and can be reprocessed and reused for up to 100 sterilization cycles. The handle is a traditional pistol-grip style with a depressible lever to open and close the device's jaws and a single dual-mode energy button that operates the device at minimum energy when minimally depressed and maximum energy when maximally depressed. The company claims to have better mobility, thinner jaws and faster cutting times than Harmonic ACE+7TM.

Figure 3: Comparison of Sonicision and Harmonic ACE+7™.

Greenberg has reviewed the device and has compared it with Ethicon's Harmonic scalpel and given the following score to the Sonicision. Design/functionality: 4.5, Innovation: 4.0, Value: 4.0, Overall Score: 4.5.

In a comparative study of performance in ultrasonic tissue dissection for sleeve gastrectomy: Wired versus Cordless, there was no significant difference in duration of the procedures. The assembly and installation time of the Sonicision™ were significantly shorter; however, the dismantle time was not. No difference in plume formation or dissection failures was found between the devices. Scrub nurses scored the Sonicision™ significantly clearer and easier in use and more reliable. The surgeons, however, did not find one of the devices easier in use, more reliable or precise, but they did report better manoeuvrability of the Sonicision™. Conclusion: In comparison to the wired HARMONIC ACE®+, during sleeve gastrectomy, the cordless Sonicision™ was considered easier to use, faster during assembling and installation, and more reliable with better manoeuvrability. Surgeons scored both devices equally effective. Both ultrasonic devices can be used easily and safely for a sleeve gastrectomy.[31]

In a comparison of Surgical Plume Generation of First Generation Cordless (sonicision) Versus Traditional Laparoscopic Harmonic Scalpel Devices Using a Novel Real-time Digital Quantification Technique. During 2 seconds of max activation, the average plume formation was highest with Ace compared to other devices.[32]

Temperature was measured after calibration and revealed that Ace had the highest temp during min activation and Sonicision obtained the highest during max. Histological analysis of tissue confirmed activation of the devices determined by coagulative necrosis at the edges, cautery effect, and inflammatory reaction compared to normal tissue.

CONCLUSION

No one energy device has been able to show its superiority over the other. Competition among available devices is fierce especially after introduction of newer modalities like Thunderbeat, ferromagnetic wand and argon beam coagulation. It appears that to successfully navigate the varied surgical situations and variety of tissue dealt with, one requires more than one energy device. Indeed, the newer VSDs are better and safer options but it is still the preference of the operating surgeons and how much one is ready to invest. Now with the latest introduction of Sonicision which is a cordless device and have better ergonomics and ease of use it can possibly be the best bet along with ligasure to have in OT. So, what's the bottom line? In the end, according to Andrew Brill, MD, past president of AAGL, "it's not the wand, it's the magician".

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