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VESSEL SEALERS IN LAPAROSCOPY – REVIEW OF LITERATURE

Gynecology

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ABSTRACT

Minimally invasive technology has revolutionalised the surgical approaches in the current century. Energy sources form a vital part of laparoscopic surgeries in achieving hemostasis and providing bloodless field to operate. The most common energy-based vessel sealing technologies are based on bipolar (BP) and ultrasonic (US) technology or both. An ideal vessel sealing device produces minimal thermal spread, is effective on vessels ≤7 mm in diameter, works quickly, produces consistent results, and can be used multiple time .The purpose of this study is to review the available literature and compare the safety ,utility ,reliability ,usage and efficacy of the available vessel sealing technologies.

KEYWORDS

vessel sealer , bipolar, ultrasonic technology, thermal spread

INRODUCTION

Minimally invasive technology has revolutionalised the surgical approaches in the current century, overpowering the open techniques even in some of the cancer surgeries. Energy sources form a vital part of laparoscopic surgeries in achieving hemostasis and providing bloodless field to operate. Complexity of the procedures performed laparoscopically has necessitated the need to develop better electrosurgical energy. Introduction of energy-based vessel sealing technologies has expanded the spectrum of potential techniques available for hemostasis during laparoscopic surgery. These devices allow for sequential tissue and vessel sealing, coagulation, and transection. Despite their widespread use, there has been a paucity of data comparing the relative safety and efficacy of each device or any recommendations endorsing one over the other.

AIMS AND OBJECTIVES:

This review article is designed to compare and highlight the similarities and differences between the various laporoscopic vessel sealing devices available.

MATERIALS AND METHODS:

An extensive literature search online was done through PubMed, Google scholar, Wikipedia, Research gate and the user manual of the individual vessel sealers.

FINANCIAL DISCLOSURE:

This current study was not financially assisted by any private groups or organisations.

DISCUSSION

Achieving good hemostasis is the corner stone of any successful surgery. At the advent of laparoscopy ,suturing ,titanium clips and laparoscopic stapling devices were used to achieve hemostasis. Use of electrosurgery for hemostatsis was a milestone in the history of laparoscopy.Success of any electrosurgical system as a vessel sealing device is decided by certain factors like:

- **Consistency:** Performance of the device should not be altered by the nature of the procedure or the user.
- **Utility:** Effective sealing and coagulation of vessels and tissues in different steps in different procedures
- **Reliability:** ability to seal vessels up to 7mm in diameter which is independant of times of usage.
- **Efficiency:** The treatment time needed to seal the tissue completely
- **Safety:** less lateral thermal spread

In short an ideal vessel sealing device produces minimal thermal spread, is effective on vessels ≤7 mm in diameter, works quickly, produces consistent results, and can be used multiple time.

The first electric modality introduced used was monopolar electrocurrent. However, this technology went out of favour for a variety of reasons like

-
- Ineffectiveness as vessel selaer
- The current passes through many other tissues outside the surgical field
- The risk of thermal injuries due to direct contact of instruments, faulty insulation or diffusion of the electrical current or due to the concept of capacitive coupling.

Various vessel sealers available and the various companies currently manufacturing it, is shown in Table 1

Table 1:

Device	Technology	Company manufacturing
Ligasure	Bipolar	Valleylab, Boulder,CO
Enseal	Bipolar	SurgRx, Inc. Palo Alto, CA
Gyrus	Bipolar	Gyrus Medical, Mineapolis, MN, Harmo
Harmonic scalpel	Ultrasonic	Ethicon endosurgery, Cincinati, OH,
Thunder beat	Bipolar plus ultrasonic	Olympus

The most common energy-based vessel sealing technologies are based on bipolar (BP) and ultrasonic (US) technology or both. Ferromagnetic heating is a new modality that has proven effective and is coming up.

BIPOLAR TECHNOLOGY

Bipolar technology, one of the most widely used energy sources , employs incorporation of both active and return electrode into a single electrosurgical instrument thus facilitating major flow of the alternating current through the target tissue. Advanced bipolar devices function as an excellent vessel sealers through a process of uniform compression and efficient energy delivery [1]. Surgical hemostasis with this technology is accomplished with precise delivery of high-frequency/low-voltage electric current to the compressed vessel wall which in turn is converted in to thermal energy [2]. This results in denaturation of collagen and elastin in the vessel followed by prompt renaturation ,which in turn forms a vascular seal with high tensile strength .

Tissue sticking is known to be a significant concern in the usage of electrosurgery energy [3]. When heated tissues adheres to the blades of the device, electrical resistance is increased, which in turn hampers the energy delivery to targeted tissue making the sealing less effective,more time consuming and inadequate hemostasis .Other shortcomings noted are uneven compression from the proximal to the distal tip of the instrument's end effector, which tends to affect the consistency of the vessel sealer [4] and difficulty to approach the target

tissue perpendicularly ,with the use of such vessel sealers during laparoscopy thus affecting the seal strength [5].

ENSEAL TISSUE SEALING SYSTEM

The Enseal is based on the nanotechnology and functions by incorporating nanopolar thermostats in to the jaws of the device which controls the amount of energy delivered to the electrode-tissue interface.The Enseal contains an offset electrode configuration with the positive temperature coefficient(PTC) nanoparticles fixed in the jaw(figure 1A). When the temperature in the jaw and tissue rises (100°C), this PTC polymer expands and the breaks the conductive chain, thus interrupting the flow of electrical current and preventing further increases in temperature. This configuration and working minimizes thermal spread and sticking, while allowing for a complete hemostatic seals .

Uniform compression along the length of the jaw is mandatory to produce strong vessel seals and adequate surgical hemostasis. The ability to maximize the use of compression in combination with optimal heat transfer leads to collapse of the vessel wall, collapse of the lumen, and eventually a complete collagen seal as in figure 1B. Reyes et al [6] observed that variations in apposition force (compression force) along the length of the instrument had a major effect on sealing strength in ex vivo sheep carotid arteries and found that vessels were optimally sealed with pressures of 2.4–3.8 MPa (which equates to 348–551 psi), at 90°C and a clamp time of 10 seconds.

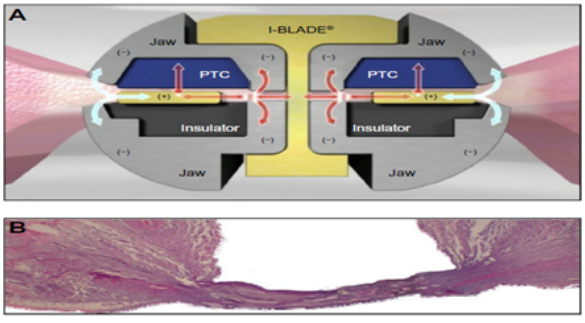


Figure 1A[7]: Jaws and i-blade are illustrated in cross-section. Positive temperature coefficient material (PTC), energy transfer (arrows), and offset electrode configuration, which confine current flow between the device jaws.

Figure 1B [7] :Hematoxylin And Eosin (H&E) Stained image of a well sealed porcine carotid artery

LIGASURE VESSEL SEALING SYSTEM:

Ligasure has a unique property of active tissue response which is a feedback from the tissue being sealed , that modifies the energy delivery and automatically discontinues it, when the seal cycle completes. The Ligasure generator detects the characteristics of the tissue in the jaws of the instruments and delivers energy accordingly This technique is different from the conventional coagulating methods that achieve vessel sealing by tissue carbonization.The Ligasure melts the collagen and elastin in the wall of the vessel forming a seal. This seal zone shows a translucent appearance that is easily recognized by the operating surgeon and thus making the process operator independent. However, the Ligasure produces smoke which may affect visibility.

Several types of variation of the instrument are manufactured to cater the needs of different surgeries from various fields. They are ligasure atlas ,ligasure v,ligasure lap, ligasure precise and ligasure advanced pistol grip.all of the ligasure variants are effective in sealing vessels up to 7 mm as reported in previous studies based on the use of the system in abdominal and gynecological surgery.

Ligasure advanced pistol grip mode is a widely used vessel sealer (figure 2).It has a monopolar tip for fine dissection and spot coagulation.The wide bilateral jaw facilitate effective access to target structures and tissue separation.insulated jaw reduces the heat transfer and lateral thermal damage.Valley lab mode provides a unique combination of momopolar hemostasis and dissection using a low power setting which produces less char ,less thermal damage than the traditional coagulation mode.

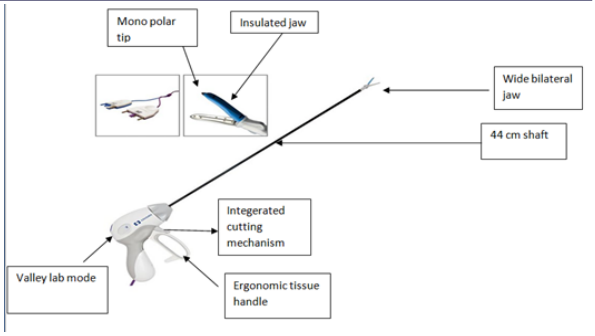


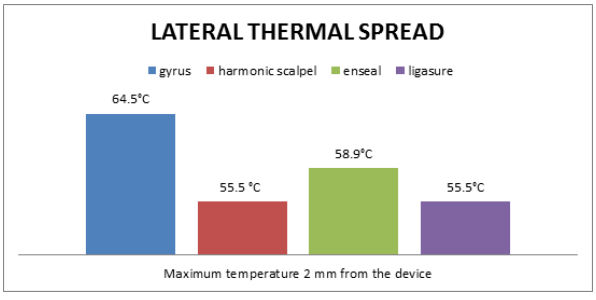
Figure 2:Ligasure advanced pistol grip model

Hrurby and co-workers [8] found a high burst pressure with the Ligasure and a rapid sealing time. The best sealing was seen with the Ligasure device and the poorest with the HS. The mean arterial burst pressure for arteries was 536 mm Hg and time to seal for vessels 3.1-5.0 mm was 5.7 sec. Hefni et al [9] studied ligasure for securing the pedicles during vaginal hysterectomy in comparison with the conventional suture ligation. There was no statistically significant difference between the two groups in terms of operative blood loss ,but peri-operative haemorrhagic complications were less frequent in the Ligasure group

GYRUS:

This bipolar electrosurgical device uses plasma kinetic technology and was designed to deliver energy in a series of rapid pulses. The pulse-off periods, theoretically allows cooling to occur at the tissue site and decrease the thermal spread. Pietrow et al [10] evaluated the thermal spread produced by the gyrus, and reported that the instrument had damage ranging from 2.7-4.7 mm from the cut surface with a mean of 3.6 mm. The study also found that though it had the fastest sealing times, larger vessels cannot be controlled consistently and effectively using the harmonic scalpel or gyrus. In order to assess the lateral thermal spread of the vessel sealers, Lamberton et al [11] measured the maximum temperatures 2 mm from the devices and found that gyrus had the maximum temperature of 64.5°C as shown in chart 1.

Chart -1



Jaws of GP are designed in such a way to get a good hold on the tissue being desiccated without slipping. However, in areas where careful dissection may be needed, it can also be traumatic.

ULTRASONIC TECHNOLOGY

Ultrasonic technology for vessel sealing was introduced more than 20 years ago as a safer alternative to electrosurgery.The advantages of ultrasonic technology over conventional electrosurgery were excellent hemostasis with minimal thermal damage [12] and low visual obstruction from mist or smoke [13]. Sealing vessels with this technology depends mainly on three main interdependent variables: compression, heat, and time[(14,15).] Since coagulation and cutting occurs simultaneously, unlike with bipolar technologies, geometry the frequency, and compression of the device are critical determinants of seal strength as well as cutting ability

HARMONIC SCALPEL :

The Harmonic scalpel is a vessel sealer based on ultrasound energy. It works at a frequency of 55,500 vibrations/sec. The ultrasound transducer located in the handpiece is composed of piezoelectric crystal sandwiched under pressure among metal cylinders (figure 3). It utilise adaptive tissue technology with the addition of predictive analytics to alter the energy delivery during the sealing cycle [16.] Vessel coagulation is then performed in a similar method to electrosurgery by

tamponading and sealing with a denatured protein coagulum by using ultrasonic vibration to denature hydrogen bonds. Since the heat productionis minimal , incisions made with ultrasonic devices resulted in less inflammation with enhanced revascularization and faster fibrosis remodelling [17]

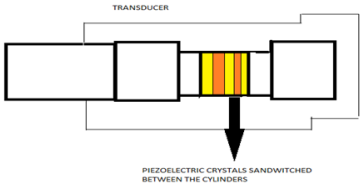


Figure 3: Transducer of harmonic scalpel

Harmonic scalpel has three compatible probes, that are the shear, blade and a hook. The shear can coagulate vessels up to 5 mm, whereas the hook and blade onlyup to 2 mm in diameter. It has the least thermal spread and smoke production of all the devices The latest one of the harmonic devices is harmonic ace 7 Shears with advanced hemostasis with purely ultrasonic energy device can seal vessels up to 7mm diameter.

The purely mechanical action of ultrasonic devices, without the use of electrical current as in electrosurgery, allows usage of the devices in the vicinity of nerves, with reduced risk of injury [12]. Nanduri et al [18] examined the differences between ultrasonic and electrosurgery at a molecular level via transcriptomics and proteomics. It demonstrated that in the acute phase of wound healing ultrasonic energy produced lower levels of immunological and inflammatory mediators, indicating a reduced amount of iatrogenic trauma .In addition, there was an early shift to wound-healing proteins with ultrasonic energy. This is well evident according to Timm et al [19] and the figure 4 in the study which compares the extend of collagen denaturation in vessel wall with harmonic scalpel and ligasure.

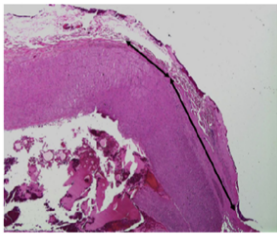


Figure 4A: H&E staining of goat carotid artery sealed with harmonic acE®+7 at 40× magnification. Black lines shows the extent of collagen denaturation.

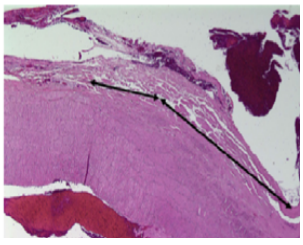


Figure 4B: H&E staining of goat carotid artery sealed with ligasure™ at 40× magnification.Black lines shows the extent of collagen denaturation.

Surgical smoke limits visualization of the surgical field ,lengthens the surgical time and potentially aerosolizes the harmful viruses .Clearly in the study by Smith et al [20] the harmonic scalpel had the least subjective and objective degradation of video image

THUNDER BEAT:

Thunderbeat is a single multi-functional instrument, integrating ultrasonic and advanced bipolar energies, allowing simultaneously sealing and cutting of the vessels up to 7 mm with minimal thermal spread [21]. It provides faster dissection and cutting with immediate sealing of the blood vessels [22] Surgeons don't have to go through a dilemma whether to go for rapid dissection or reliable hemostasis when selecting an advanced energy device,as thunderbeat provides both.



Figure 5A: Modes in thunderbeat

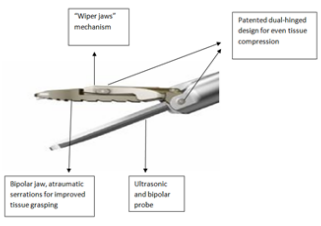


Figure 5B: Jaw of Thunderbeat

Thunderbeat features a patented center-pivot jaw design having a "wiper jaw " mechanism(Figure5B) ,which allows for even distribution of closing pressures onto the tissue while at the same time improving grasping forces with precise, controlled dissection and a more reliable vessel seal. When compared to the electrosurgical instruments, thunderbeat instruments have similar technological features, such as the shaft length, shaft rotation and shaft diameter, while they also have properties like number of instrument sockets, footswitch options, output levels and waveforms similar to the ultrasonic technology.[23] High frequency bipolar output enables vessels sealing and hemostasis,while the ultrasonic output enables to cut and coagulate soft tissues. It has 2 modes(figure 5A):

- Seal & Cut Mode : Utilisation of both bipolar energy and ultrasonic energy
- Seal mode: Utilisation of only bipolar energy

Fagotti et al [24] compared the usage of thunderbeat over the standard electrosurgery in laparoscopic radical hysterectomies with bilateral pelvic lymphadenectomy and found that thunderbeat is associated with shorter operative time and less post-operative pain than standard technique in patients with uterine cancer The median operative time was 85 min vs. 115 min for thunderbeat and standard electrosurgery respectively .

REVIEW OF LITERATURE:

Table 2 comprises of summary of the studies available in the literature comparing different aspects of various vessel sealers.

TABLE 2:

Author	Devices Compared	Vessels Tested	Properties Compared	RESULTS
Chekan et al [7]	Enseal and LigaSure	5mm,6mm and 7mm porcine carotid vessels	compression uniformity, vessel sealing strength, and consistency	Enseal was better than ligaSure in terms of uniformity of jaw compression, reduced tissue sticking, and increased burst pressures in sealed vessels.
Person et al [25]	Harmonic scalpel LigaSure and EnSeal	variable	Bursting pressure, sealing time,lateral thermal spread	The bursting pressures with enseal was higher than with all the other devices Harmonic scalpel was the fastest sealing instrument. EnSeal created less radial thermal damage to the adventitial collagen of the vessels.
Lamberton et al [11]	LigaSure Gyrus, Harmonic Scalpel and EnSeal	5mm bovine arteries	sealing time, burst pressure, lateral thermal spread, and smoke production, as well as both subjective and objective effects on visibility.	Though enseal has smoke production and burst pressure similar to other vessel sealers ,the time to seal was statistically longer with enseal than the rest. Gyrus had higher temperatures and generated maximal smoke with variable burst pressure than the other tested devices Harmonic scalpel had the lowest thermal spread and smoke production, but was slow and had the lowest mean burst pressure

Newcomb et al [26]	Gyrus PK,Harmonic Scalpel EnSeal and LigaSure	Medium to large vessels	Failure rate and sealing time	Harmonic Scalpel and Gyrus had significant failure rates: 8% to 22% for the Harmonic Scalpel and 41% to 92% for the Gyrus systems. The shortest sealing times was achieved with the LigaSure V. The Gyrus were the fastest devices when vessels were 2 to 3 mm in diameter.
Carbonell et al [27]	Gyrus and Ligasure	Arteries in three sizes (2-3 mm, 4-5 mm, and 6-7 mm) from domestic pigs	the burst pressure and extent of thermal injury	Gyrus system has lower burst pressures when compared to the ligasure system with comparable thermal spread The ligasure produces supraphysiologic seals with significantly higher bursting pressures than the gyrus in vessels ranging from 4 to 7 mm..
Seehofer et al [22]	Thunderbeat ,ligasure and harmonic scalpel	5-7mm vessels in domestic pig	Efficacy parameters, seal failures and the maximum burst pressure (BP)	Using the thunderbeat, the burst pressure in larger arteries was significantly higher (734 ± 64 mm Hg than that of the Harmonic scalpel (453 ± 50 mm Hg). The cutting speed of the thunderbeat was significantly higher than that of all other devices.
Milsom J et al [21]	Thunderbeat, Harmonic scalpel, LigaSure and EnSeal	small (2–3 mm), medium (4–5 mm)-, and large (6–7 mm)-diameter vessels of pig	versatility, bursting pressure, thermal spread, and dissection time	Versatility score was higher and dissection time was shorter using thunderbeat compared with the other three devices. No statistically significant difference in thermal spread between thunderbeat and the other vessel sealers.

SUMMARY:

After reviewing the literature we were able to draw the following conclusions:

- Thunderbeat is more versatile than Ligasure and Enseal
- Harmonic scalpel had the lowest thermal spread and smoke production with lowest burst pressure
- Fastest sealing time ,best reliablilty and highest burst pressure was with ligasure.
- Larger vessels cannot be controlled consistently and effectively using the Harmonic Scalpel or Gyrus systems
- Gyrus has a fast sealing time and the highest smoke production while the Enseal had the slowest sealing time.

Due to the differing demands of various surgical procedures performed laporoscopically and the operating surgeons familiarity and instrument preferences, we cannot endorse one device as the best vessel sealer. According to Andrew Brill, MD, past president of AAGL, "it's not the wand, it's the magician."

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