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Laparoscopic Surgical Devices: A Review of the Newest Energies and Instruments

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Precis: Newer ultrasound, plasma, advanced bipolar, ferromagnetic heat and combined energy devices are available in laparoscopic surgery. The basic principles and safety use issues are specific for each one.

Abstract

The present review aims to analyze the current information on basic principles, applications, advantages and risks of the main surgical devices used in laparoscopic surgery. A comprehensive review of literature was made of existing english language publications on databases Pub med and Google Scholar following a Mesh and key word searching. The studies were finally selected by one author according to the aim of this review. Currently, different kinds of devices using electrical, mechanical, plasma and ferromagnetic heat energy are available in laparoscopic surgery. New advanced bipolar instruments, using a tissue impedance measure, vessel sealing technologies and positive temperature control allows the surgeon an effective, safe and faster surgery, with less thermal spread. Ultrasound apply to surgery offer the surgical team (using a combination of high speed mobilization and cavitation principles) a faster and safest surgery parameters, but with the highest device tip heating. Thunder beat™ is a unique instrument that combines the cutting efficiency of the ultrasound with the coagulation advantages of bipolar energy, and appears to be the fastest and more versatile device available. Using ionized inner gas with minimal electricity flow, plasma devices allows cutting, coagulation and fulguration in the same instrument, but probably with the higher thermal spread among all. Employing pure thermal heat due the conduction of radio-frequency current, ferromagnetic heat energy devices are the newest instruments that can safety seal vessels up to 7 mm.

Keywords: Electro surgery, Ultrasound energy, Advanced bipolar, Plasma, Thunde beat, Ferromagnetic energy.

Abbreviations: ESU: Electrosurgical Unit; **PS:** Power setting; **US:** Ultrasound; **ACE:** Harmonic ACE; **JJ:** Jhonson and Jhonson; **LS:** Ligasure; **ES:** EnSeal PTC; **GP:** Gyrus PK ; **HS** ;Harmonic Scalpel ; **MP:** Monopolar; **BP:** Bipolar; **US:** Ultrasound ; **ABD:** Advanced bipolar devices; **OP:** Output power level; W: Watts.

Introduction and Basic Principles of Surgical Energies

Laparoscopic surgery requires instruments that provide an effective cut, dissection and hemostasis functions. The optimal device will be the one that provides a good cut and hemostatic effect with no thermal energy spread beside the area where it is initially applied.

Currently, five types of energy are commonly used: Mechanical, Electrical, Plasma, Laser and Ferromagnetic heat. Basic principles of these energies are presented in **Table 1.**

Table 1. ***Basic Principles of Surgical Energies***

Type of Energy	*Principles*
Electrical	*High frequency alternated current*
Mechanical	*No electrical current . High speed mobilization and cavitation principle - Piezoelectric effect - 22.500 to 55.000 Hertz*
Plasma	*Stream of Ionized Gas - Minimal electrical current*
Ferromagnetic heat	*Pure heat production - Radio frequency through ferromagnetic coated material - Ohmic heating and magnetic hysteresis.*
Laser	Thermal effect by conversion of light to heat, transfer of heat and tissue reaction

Since Philipe Bozzini started the era of Electro-Surgery in 1877 describing the first device for electro-cauterization, the process continue for decades until 1928 when Bovie organized a formal production of electrosurgical equipment, establish the fundamentals of modern electro-surgery allowing to convert diagnostic into operative laparoscopy.[1,2] The electrical current could determine three major effects: Thermal, Electrolysis and Faraday. The objective of the electro surgery is to achieve the thermal and avoid the other two, obtaining cutting and coagulation effects using alternated - high frequency current.

All devices can be used with three major current waveforms: cutting, coagulation and blended, generating different tissue effects during application. The cutting waveform uses non modulated high frequency-low voltage current, generating a quick rise in the temperature with a sudden tissue heat over 100 º C and a explosive vaporization of the cells, resulting in an acoustic vibration and a cutting effect. Meanwhile, coagulation is a less safe waveform because use modulated low frequency-high voltage current, producing a slow rise in tissue temperature (between 70 - 85 º C) leading to protein denaturation, desiccation and constriction of the cell with more thermal spread. In the blend mode, alternation in between the cut and coagulation waveform is applied, classified in three groups varying in the time spend of activation (50% - 40% - 25%). Other variables under the surgeon control that can modify the tissue effect are the setting of the electrosurgical unit (ESU), the total time of activation, the size and shape of the tip and the contact or not of the device tip with the tissue.

Concerns related to the morbidity due to thermal injuries on using monopolar energy contributed to the develop of bipolar devices in around 1970 by Frangenheim in Germany and by Rioux and Cloutier in North America. [3,4]

Mechanical energy is based on two major principles: higher speed mobilization and cavitation. With the use of a piezoelectric part, the electrical energy from the wall outlet is transformed to a mechanical movement, transmitted to the tip of the instrument. The high speed vibration (over 18.000 Hz) will determine heat and formation-explosion of air cavities within the tissue, determining destruction of the cells.

Ferromagnetic heat energy is obtained by conducting radio-frequency in a loop coated with thin micron thick ferromagnetic coating materials, with couples to the high frequency current. As the radio-frequency passes through this loop, pure thermal heat is generated by magnetic hysteresis losses and ohmic heating relayed to skin effect, finishing in a sudden and precise rise and fall of temperature.

Plasma is the fourth state of the matter and is created by adding energy to gas, resulting in a high energy- low density state. Using ionized inner gas with minimal electricity flow, plasma devices allows cutting, coagulation and fulguration in the same instrument. Tissue effects of this and other energies are show in **Table 2.**

Table 2. ***Tissue effects of surgical energies***

Type of Energy	***Tissue Effect***
Electrical	
Monopolar	*Vaporization - Fulguration - Dessication - Coaptation*
Bipolar	*Dessication - Coaptation*
Advanced Bipolar	*Dessication - Coaptation - Tissue Transection*

Ultrasonic	*Dessication - Coaptation - Mechanical Tissue Transection*
Plasma	*Vaporization - Fulguration - Desiccation - Coaptation*
Ferromagnetic heat	*Desiccation - Coaptation - Tissue Transection*
Laser	Hypertermia - Coagulation – Vaporization

It is paramount to understand the effect of the temperature on tissues. From 41 ºC protein starts denaturation, and when this injury (43 to 60 ºC) is maintain for at least 6 minutes, irreversible damage is established. Temperature between 60 to 80 ºC leads to "white coagulation" breaking the protein and hydrogen bonds, unwinding of cellular DNA and collagen denaturation (with preservation of elastin networks), resulting in about a 30 % shrink in cell length. From 90 ªC and upper, water starts to evaporate (desiccation) and when 100 ºC is reached, water boil and form a steam, cell walls rupture due the swelling, resulting in a massive intracellular expansion and a cellular explosive vaporization with a cloud of steam, ions and organic matter. Over the 200 ºC, organic molecules are broken down leading to a Black-Brown tissue appearance called the "black coagulation". [5] Also, surgeon must remember that the edge for neural damage is 45 º C. [6]

The purpose of this review is to show and analyze the basic principles, characteristics and safety issues of the main devices used in laparoscopic surgery. We start giving an introduction on the energies in surgery. Afterward, we describe the specific characteristics and main devices of each type of energy. Finally, we discuss the findings and draw conclusions.

Energy Based Surgical Devices

Monopolar devices

Monopolar (MP) electro surgery is the most used modality in laparoscopy. It is associated with high electron flow, smoke production, higher temperature and hemostasis capacity.[7] Maximum temperature reached after activation is over 100 ºC.[10,17,18] During surgery, continuous waveform results in cutting effect, with low flow of electrons and minimal smoke production, whereas interrupted waveform is used for hemostasis. This is included by defect depending on the electrosurgical unit (ESU), allowing to select the "cutting" or "coagulating" setting .Also, using a sharp or blunt electrode tip you can modify the current density, the temperature and the final tissue effect.[5] Its is accepted that MP devices can safety divide vessels up to 2mm diameter.[8]

All radio-frequency electro surgery systems are bipolar, but the difference will be done by the location of the second (return) electrode. In this type, the current passes through the patient as it completes the circuit from the active electrode to the patient return electrode, who is located at a distance from the surgical site.[9]

According to work published by Jones in 2006, both the cutting and coagulation effect can be achieved with a power setting (PS) of 50 - 80 Watts (W).[10]

The main risks are the energy escape, direct coupling, capacitive coupling and unintended direct application. The mean incidence of electrical injuries is 1 to 5 per 1000 cases. [11, 12] Compared to other devices, this seems to have the higher smoke and vapor production.[13]

Bipolar and advanced bipolar devices (Table 3)

Table 3. ***Bipolar - Advanced Bipolar devices and main Characteristics***

Devices	***Characteristics***
ROBI ®	
Everest™	*High frequency alternated electrical current*
LigaSure - LigaSure V™ (*)	*1 to 7 mm of lateral thermal spread*
Gyrus PK™(*)	*Vessel Sealing up to 7 mm*
Kleppinger(*)	
ERBE Biclamp® (*)	
BiCision® (*)	
Enseal PTC™(**)	

Note: *: Advanced Bipolars. **: Advanced bipolar with Nanotechnology.

Bipolar (BP) born from the pursuit of a safe way of delivering the energy. Using a non modulated - low voltage current waveform allows the surgeon an effective hemostasis with less collateral damage and thermal spread (LTS).[14,15] A small circuit of active - passive electrode, generally represented by the jaws of an instrument, limit the electron flow to a restricted area of tissue.[16,17]

Broadly talking, traditional bipolar instruments are used for coagulation purposes. Due to the short separation of the electrodes, lower voltage is required to obtain the effect.[18] With PS between 30 to 50 W, an effective coagulation is obtained, with LTS in between 2 to 6 mm and maximum temperature over 100 º C.[16]

When compared to MP current, small LTS, less blood loss and better seal quality is obtain.[5]

Some disadvantages are the increased time needed for coagulation and the tissue charring - sticking, with the potential risk of adjacent tissue tearing.[16,19]

Posteriorly with the creation of the tissue response generators, the vessel sealing technology appears to stay. Combining BP and mechanical pressure, it became possible to completely fuse vessels creating a protein seal by denaturation vessels wall collagen and elastin using temperatures between 60 to 90 ºC.[16,20] Thus, by modulation of the energy needed to obtain the effect, reduces the thermal spread compared to traditional BP energy.[5]

According to main studies, these instruments can seal vessels up to 7 mm with LTS between 1 to 4 mm. [10, 21-23]

Potential disadvantages of these newer BP include the LTS, high disposable cost, variable burst pressures and the generation of smoke, vapor, and particulates which may compromise visibility, depending mostly on the type of instrument, the PS of the ESU and the duration of application.

The **Liga Sure™** (LS) is an advanced bipolar feedback controlled vessel sealing device that leads to a complete vessel wall fusion, without any proximal thrombus generation. [24,25] Using a measurement of tissue impedance in the electrode contact site (Tissue Effect Sensing Technology), the generator has the capability to read and change the tissue impedance every 3,333 times for second by an automatic process, delivering the right energy needed to seal the vessels. The final result is a complete obliteration and fusion of the vessels up to 7 mm, with maximum temperature below 100ºC.[26,27] The LTS reported by Sartori Is less than 1,5 mm.[28]

Using a “In Vitro” animal model, Eberli found that the temperature 2mm away from the application zone can reach between 41º to 87.3 ºC, and could remain over 45 º C up to 40 seconds after de-activation. In the histopathological assessment, thermal effect was seen from 0.6 mm to 0.9 mm away from the application area.[6]

In 2006 and 2008, Diamantis found that **LS** cause less LTS than **Harmonic Scalpel®** (HS) , with mean values of 179.7 um and 205.6 um respectively.[22,29]

Lambert on compares the LTS, time to seal, burst pressure and smoke production of four devices in a 5mm bovine arteries under controlled variables of humidity and temperature. He found that the fastest sealing time was achieved by LS (10 seconds) followed by **Gyrus PK™** (11.1 seconds), significantly fastest than **HS** (14.3 seconds) and **EnSeal™** (ES)(19 seconds).The less smoke productions was seen in the **HS ACE®** (ACE) followed by the **Gyrus PK™**.

Related to temperature and cutting speed, Startori compares **LS** to **HS** in 150 patients submitted to Thyroidectomy, and found that **LS** has a lower temperature increase and a faster cutting speed.[28] Nevertheless, the meta-analisis of Upadhaya found that **HS** significantly reduces the surgical time (in 8.79 minutes) when compares to **LS.[**30]

Hrurby in the Journal of Urology of 2007 published the comparison of energy spread between 4 instruments in an animal model. He found that the **LS** was the best in vessel sealing (up to 7 mm), followed by the **ACE**® (5mm).The lower burst pressure required for seal both, arteries and veins, was see with the **HS.** Finally, the less LTS in both arteries and veins was found in the **ACE**®, with 0.6 and 1.5 mm respectively. [31]

The **EnSeal PTC™** (ES) device uses the impedance measurement to adjust their activity, similarly to **LS**. The major advance is the use of a temperature control technology or PTC (Positive Temperature Control), regulating the temperature in the tip of the instrument while used, measured in tissue 1 mm outside the jaw by an energy deposition control system at the electrode-tissue interface.[32] Therefore, automatically regulate the temperature to a maximum of 100 º C, reducing the overheat. This nanotechnology feedback mechanism called by the owner as a "smart electrode technology" allows a better adjustment of the energy required for sealing the vessels, reducing the final LTS. Hence, less energy and heat is required to effectively seal the vessel, helped by the tissue compression.[16] In laboratory can seal vessels up to to 7 mm and withstand up to seven times normal systolic pressure.

In the study of Person in the Surgical Endoscopy of 2008, **ES** show a significant higher bursting pressures when compares to **HS**, **LS** and **LSAtlas™**. Also, present one of the shortest sealing process and the less radial adventitial collagen denaturation among all.[33]

Lambert on found that **ES** have one of the major LTS when compared to **HS** and other vessel sealing devices, with temperature in tissue 2mm away from activation reaching 58.9 ºC.[34]

Plasma devices (Table 4)

Table 4. ***Plasma Energy Devices and main Characteristics***

Devices	***Characteristics***
Plasmajet™	Ionized inner gas and low electrical current flow
Argon beam plasma coagulator	*0.5 to 10 mm of lateral thermal spread*
Helica thermal coagulator	*Seal vessels up to 6 mm*
J-Plasma®	

Using partially ionized gas containing free electrons and charged ions carrying electric current, the plasma devices transmits energy through a stream of ionized inner gas, obtaining minimal electricity flow trough that stream to the surgical site. [35]

The Argon Beam Coagulator, using a rigid sectored and a non contact application, deliver high frequency-low voltage current thorough ionized argon gas in a rate between 0.5 to 7 Lt/min. The LTS reported range between 4 to 10 mm, depending on the current density, gas flow rate, time spend on activation and distance between the tip and the target.(35,36) Meanwhile, Plasma Jet™ is other surgical tool that generates and delivers a neutral argon plasma stream in a non contact application using bipolar electrodes, obtaining effective coagulation and fulguration. Characteristically uses lower electrical energy (30 - 60 W) and argon plasma stream rate (less than 0.4 Lt/min), with LTS ranging between 0.5 to 2 mm.[35,36]

Helica Thermal Coagulator is another device that uses electrical charged helium plasma with lower power levels (2 - 35 W), and reaching up to 800 º C. [35]

The **J-Plasma Device**® is an FDA approved multimodal electrosurgical instrument. Using a cold helium plasma stream, allows cutting, coagulation, fulguration and dissection in a single device. Standard power settings (10 5 power with 4 L/min) generates a tip heating which quickly fall after suspended activation. Pedroso in 2014, studying the effect in porcine liver, kidney and muscle, found that the depth thermal spreads (DTS) was less than 2mm regardless the PS and gas flow used.[35]

The **Gyrus PK™** is a bipolar device that uses plasma kinetic technology to delivery low-voltage electrical current, sealing vessels up to 7 mm by producing an intra-luminal coagulum due protein denaturation. Maximum temperature reach is under 100 ºC. Set up can be made in two modes (by defect) : Vapor Pulse Coagulation and Plasma Kinetic Tissue Cutting.[31] The main difference between this and other advanced bipolar instruments are the way of applying energy (using a series of rapid pulses) and the absence of a feedback mechanism system.[37]

Even when Gyrus theoretically decreases the LTS due his pulse-off periods during application, this has not been found in the recent studies.[34] Piet row, studying the vessel sealing action in pigs arteries, found it is effective in seal vessels up to 6 mm with LTS ranging between 2.7 to 4.7 mm.[38]

Ultrasound devices (Table 5)

Table 5. ***Ultrasound devices and main Characteristics***

Devices	***Characteristics***

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Harmonic ACE® - ACE +® - H1000®	
Sonicision™	*High speed mobilization and cavitation*
SonoSurg™	*1 to 4 mm of Lateral thermal Spread*
Autosonix™	*Vessel Sealing up to 5 mm*
Lotus®	
Sonicbeat™	

Since the first description of the ultrasonic scalpel by Amaral in 1993, the technology became widely used, mostly from 2010.[32]

Three generations of US devices have been introduced: The **Ultracision Ultrasonic Scalpel®** (First Generation, 1989); the **Harmonic ACE®**(Second generation: **Ultracision™** and **SonoSurg™**, 1998 - 2004) and the **Sonicision™** (Third generation: 2011). The main difference between the 2 devices of the second generation is that the **SonoSurg™** uses slower US frequencies (47 kHz vs 55.5 kHz) aiming better hemostatic control.

Sonicision™is the first cordless laparoscopic instrument. In 2012, the **Harmonic ACE** +®was launched by Johnson and Johnson (JJ), including a tissue conditions response, similarly to the last generation devices. Finally in 2017 the **Harmonic HD1000i**®appeared, the newest US device launched by Ethicon Endosurgical.

Using a piezoelectric element that converts electrical to mechanical energy by polarity changes, and provided by two blades (one of these active), a vibration rate between 23.500 to 55.500 HZ (with 50 - 100 microns amplitude) is generated due to the dilatation - contraction sequence of the piezoelectric system.[39] The active movement of the titanium blade induces longitudinal / linear oscillation waves leading to a final mechanical effect on the tissue where applied.[40] Thus, section and hemostasis is obtain based in two basic principles: The high speed mobilization (over 18 Khz) and the cavitation. The last one, defined as a creation and explosion of cavities in a liquid state, will generate "cavitional bubbles" at the tip of the instrument due the vibration, which concentrates in the surface and finally implodes, collapsing and breaking the cell. Therefore, a cut effect is obtained by increasing of the temperature in the blade surface, protein denaturation, hydrogen bonds breaking and friction between the blade and tissue due to the vibrations.No contraction of the vessels sealed and significantly less heat from tissue friction is obtain.[41,42] This is quite different to bipolar energy, which reduces the vessel caliber and creates a proximal thrombus within it.

All these process are made using a high frequency ultrasonic transducer with a microprocessor-controller generator detecting changes in the feedback acoustic patterns.[34]

Many advantages of this US energy has been described, as minimal LTS, cut and coagulate at the same time, less surgical time and heat production, minimal smoke, great precision near vital structures, few tissue charring/sticking and better wound healing.[41,42,44-47]

It is accepted as a safe and useful instrument in endoscopic surgery, sealing vessels between 2 to 5 mm [28, 41, 42, 45, 46]

Some disadvantages are the formation of aerosolized fatty droplet (harming the laparoscopic visualization), slower coagulation (compared to electrical energy), higher temperatures and excessive applied pressure.[16,23,48]

Cutting and coagulation effects are influenced by the power level, tension of the tissue, blade surface and the grip force - pressure. Combining these, a better cut or coagulate effect are obtained. Broadly speaking, more power level and grip pressure determines more cut rather coagulation. Usually, there are two settings for the device: the MIN and MAX set, where MIN results in better hemostasis and high thermal spread, and MAX in quickly cutting with less LTS.

HS has lower subjective and objective smoke production when compared to other devices, except the **Thunderbeat™**, which shows an even lower rate of smoke generation.[34,43]

The heat of the device will vary according to the frequency and amplitude of the blade movements. Those parameters are similar in the **Ultracision™** and **SonoSurg™** (explaining the similar temperature and velocity profiles), but the **Sonicision™** trends to reach higher temperatures due more displacement of the active blade. The temperature in tissues 1 cm away from the active blade range between 60ºC to 140ºC, and will depend predominantly on the output power effect (OP) selected and the time spent on activation. Hence, for a safe application it is recommended to maintain in the setting MAX, apply shorter activations (less than 5 seconds and ideally alternated with 5 seconds of pause) and always see and control the active blade.[41,42,47]. Bubenik demonstrated in an animal model that using the OP 3, you cannot seal vessels higher than 4.5 mm.[49] Also , surgeons must never forget that the tip of the instrument increases heating after de-activation, reaching until 54ºC and 58ºC at 2.5 and 5 seconds post de-activation, respectively.

In 2012, Druzijanic analyze the LTS of **MP**, **LS** and HS in peritoneum of patients who underwent laparotomy, using light microscopy and morphometric imaging analysis. The results confirm that **HS** is safe, with mean LTS of 90.4 um and 127.4 um. Meanwhile for **LS** and **MP**, the values were 144.1 um and 215.7 um, respectively. [47]

Another factor to analyze is the device energy emissivity that will depend primarily on the material it was constructed with. An equilibrium value (0.5) is the ideal, and represent equal absorbing - dissipation of the heath. Lower values are associated with faster heating and tip cooling, but more heat dissipation, and therefore the risk of damaging surrounding tissues. [50]

An evaluation of three US devices (**ACE®**, **Sonicision™** and **SonoSurg™**) was presented by Kim in 2014. Applying cutting and coagulating setting to a bovine mesentery and lamb renal veins, found no significant differences in emissivity and maximum coagulation temperatures among them, ranging from 0.39 - 0.49 and 187 - 193 ºC respectively. **Soncision™** show the maximum cutting temperature (227.1ºC) followed by the **ACE®** (191.1ªC) and **SonoSurg™** (184.4ºC). The cooling time (to reach 60º C after de-activation) was significantly lower for the **SonoSurg™**(27.4 sec.) compared to **ACE®**(35.7sec.) and **Sonicision™** (38.7 sec).[50] Similar results were found by Seehofer in 2012, comparing **Thunder beat™** (TB), **ACE®** and **LS** in a pig model found that that **TB** and **ACE®**reach temperatures significantly higher than LS (192 - 209 ªC), with longer cooling time after de-activation.[51] A summary of these and other results are shown in **Table 6.**

Table 6. ***Comparison between main devices used in laparoscopic surgery*** (Combined data from Lamberton et al., Kim et al; Hefermehl et al; Alkatout et al., Newcomb et al., Milsom et al,, Seehofer et al.and Obona et al.)

Devices	*LTS.*	*MAXIUM TEMPERATURE*	*SMOKE PRODUCTION*	*MEAN BURST PRESSURE*	*TIME TO SEAL.*	*TISSUE STICKING*
Harmonic Scalpel™	*49(1.5mm)*	*200*	*Low*	*454*	*14*	*Low*
LigaSure™	*55(1.7mm)*	*Below 100*	*Low*	*615*	*10*	*Middle*
EnSeal™	*58(1.8mm)*	*100*	*Medium*	*678*	*19*	*Low*
Thunderbeat™	No Data (1.6 mm)	200	Low	734	10.7.	Lowest

* Note: LTS: Lateral thermal spread (Celsius grade at 2 millimeters lateral - lateral histologic damage); MEAN BURST PRESSURE: MmHg; TIME TO SEAL: Seconds; TISSUE STICKING: Low: No or minor sticking, Middle: Requiring activation of instrument to release tissue.

Other devices

The **Altrus® Thermal Tissue Fusion System** achieves protein denaturalization through the direct application of thermal energy (heat) and mechanical pressure, without passing any electrical or US energy through the patient. A closed feedback loop between energy source and hand-piece is used to control the temperature delivered to tissue.[35] Harold in the Surgical Endoscopy of 2003 found that the burst pressure needed to seal was significantly lower when compared to **HS** and **LS**.[23]

The **FM wand®** (**Table 7**) is a newer instrument that generates ferromagnetic heat energy from radio-frequency current. The device has a tip with an active blade and thermally inner surface, and heat is conduct perpendicularly in tissue grasped by the jaws.[52] The device can be set up in three modes: FM, for high power seal and divide(vessels less than 2mm diameter); FM2, for seal and divide(vessels upper than 2 mm) and FM1, for seal only. No grounded pad is needed since there is no spark , arcing or current stray, because the energy return to ground through the generator and does not pass through patient.

Studies by Chen in 2015 and 2017 are shown (in vitro and in vivo) that this device can seal vessels up to 7 mm with burst pressures consistent with bipolar sealers (mean of 1098 mmHg) , less LTS than **HS** (mean of 1.68 mm), and transection speeds 8 and 18 seconds faster than HS and **LS**, respectively.[52]

Table 7. ***Ferromagnetic heat devices and main Characteristics***

Devices	***Characteristics***
	Pure heat from radio frequency current
FM wand®	*Less than 2 mm of lateral thermal spread*
Seal vessels up to 7 mm	

Hybrid devices

The **Thunder beat™** (Table 8) is an ultrasonic - bipolar coupled instrument of Olympus born to combine the cutting efficiency of the ultrasound with the coagulation advantages of the bipolar energy.

Table 8. ***Hybrid devices and main Characteristics***

Devices	***Characteristics***

Thunderbeat ™	*Ultrasound and electrical current* *Less than 5 mm of lateral thermal spread* *Seal vessels up to 7 mm*
Fastest surgery and higher versatility among all	

It allows delivery of electrical bipolar and ultrasonic frictional heat energy, giving it a wide versatility based in five variables: hemostasis, cutting, desiccation, histologic sealing and tissue manipulation. All those determine a faster surgery and higher versatile score when compares with any other device, with higher bursting pressure and lower LTS.[43] The generator has three levels starting from 1 (cut and seal mode) to 3 (seal mode).[32]

Milsom in 2012 comparing **TB, ACE®**, **LS** and **ES** found the **TB** has the shorter dissection time and the higher versatility score among all, with no significant differences in LTS and burst pressure.[43,53]

In laboratory, can seal vessels up to 7 mm diameter.[51,53] Among all devices gives better field visibility and faster average cutting time(10.7 sec).[43]

Devices Comparation in Gynecological Surgery

The main studies comparing operative time, blood loss, post operative pain score, complications and hospital stay of these newer instruments in humans, was analyzed and presented by Amruta Jaiswal and his group on the Gynecology and Minimally Invasive Therapy in 2017.[32]Main findings of four randomized controlled, one cohort and three retrospective studies reveal:

1. All these new energy devices decrease surgical time and increase versatility during surgery compared to conventional electro coagulation.

2. Insufficient evidence to consider a specific device/vessel sealing technology superior to the other.

3. Thunder beat™ appears to be associated with short operative time and less post operative pain.

4. Gyrus PK™ appears to have less blood loss when compares to conventional electro surgery.

5. LS appear to have less operative time and blood loss when compares to HS.

CONCLUSION

All newer energy devices will cause variable grades of collateral undesired effects like LTS, temperature rise over 45ºC and smoke plumes. Until today, no one of the new devices or vessel sealing technologies seems to be superior, but some tendencies arise. The **ultrasonic devices** show low thermal spread, burst pressure and smoke production. In advanced bipolar systems, while **ES** and **Gyrus PK™** seems to be slower in sealing time, variable in burst pressures and higher in smoke production, **LS** appears to have the highest burst pressure, the fastest vessel sealing time and the lesser blood loss. Despite all the specific characteristics, all devices produce rises of temperatures over 40 degrees 2 mm away for activation zone, thus, such devices must be used carefully near the vital structures. **FM wand®** is a newer ferromagnetic heat device that appears to have at least similar safety patterns when compared to US and advanced bipolar systems. **Thunder beat™** is a unique instrument that combines two types of energy and allows faster surgery, higher versatility, better field visibility and less postoperative pain

An adequate set of the power source must be followed up by the surgeon, and basic rules of laparoscopy must be performed at all time to ensure safety.

Declarations

Not applicable

Competing Interests

Not competing interest to declare

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To our family and friends that will always support us.

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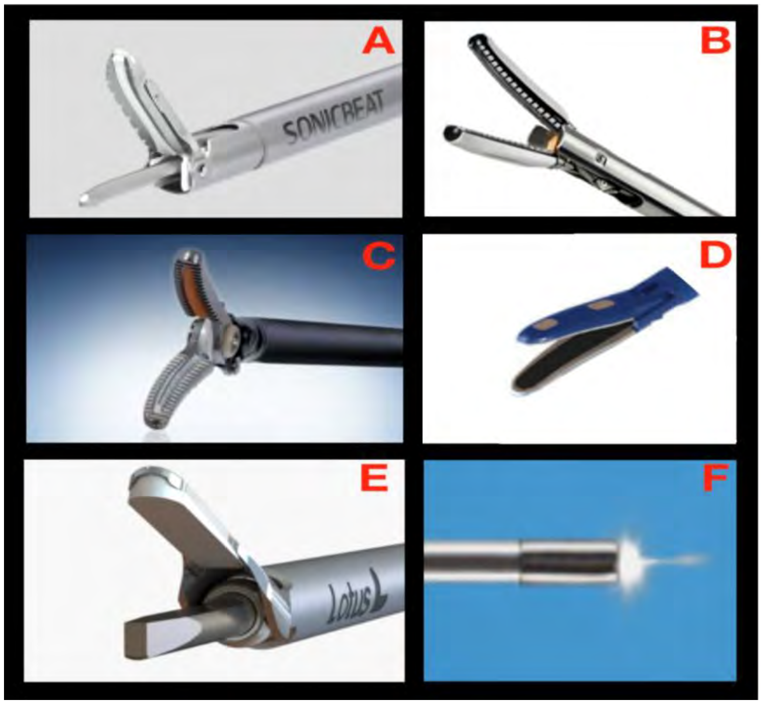

Tables and Figures

Image 1: Main Laparoscopic Devices (Pt1)

A: Sonicbeat. © (Copyright OLYMPUS CORPORATION All Rights Reserved) Produced by Olympus, is a 5 mm diameter / 20 to 45 cm length instrument, with a straight jaw.

B: Altrus-Thermal Tissue Fusion System. © (Copyright CONMED Corporation. All Rights Reserved) Produced by Conmed, is a 5 to 10 mm diameter / 16 to 36 cm length instrument, with a straight jaw.

C: Gyrus PK. © (Copyright OLYMPUS CORPORATION. All Rights Reserved) Produced by Olympus, is a 5 to 10 mm diameter / 15 to 45 cm length instrument, with a curved jaw.

D: FM Wand. © (Copyright Omni Guide Holdings, Inc. All Rights Reserved) Produced by Domain Surgical, is a 5 mm diameter / 15 to 45 cm length instrument, with a curved jaw.

E: Lotus-Qual. © (Copyright Bowa-Medical. All Rights Reserved) Produced by Bowa Einfach Sicher, is a 5 mm diameter / 18 to 44 cm length instrument, with a straight jaw.

F: PlasmaJet. © (Copyright Plasma Surgical. All Rights Reserved) Produced by Plasma Surgical, is a 5 mm diameter / 28 cm length instrument.

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Image 2: Main Laparoscopic Devices (Pt2)

A: LigaSure. © (Copyright Johnson & Johnson Services. All Rights Reserved) Produced by Ethicon, is a 5 mm diameter / 20 to 44 cm length instrument with curved or straight 18 to 21 mm jaw, and an effective cut length of 16 to 18 mm. The jaw aperture range between 12 to 15 mm.

B: EnSeal PTC.©(Copyright Johnson & Johnson Services. All Rights Reserved) Produced by Ethicon, is a 5 mm diameter / 14 to 45 cm length instrument with curved, straight and articulating 19 to 20 mm jaw, and an effective cut length of 16 to 17 mm. The jaw aperture range between 15 to 18 mm.

C: Thunderbeat. © (Copyright OLYMPUS CORPORATION. All Rights Reserved) Produced by Olympus, is a 5 mm diameter / 10 to 45 cm length instrument, with straight 17 mm jaw, and an effective cut length of 16 mm. The jaw aperture reaches 13 mm.

D: Ultracision.©(Copyright Johnson & Johnson Services. All Rights Reserved) Produced by Ethicon is a 5 mm diameter / 13 to 48 cm length instrument, with a curved, straight and articulating jaw.

E: Sonicision. ©(Copyright Covidien. All Rights Reserved) Produced by Covidien , is a 5 mm diameter / 13 to 48 cm length instrument, with a straight 14.5 mm jaw, and an effective cut length of 14.5 mm.

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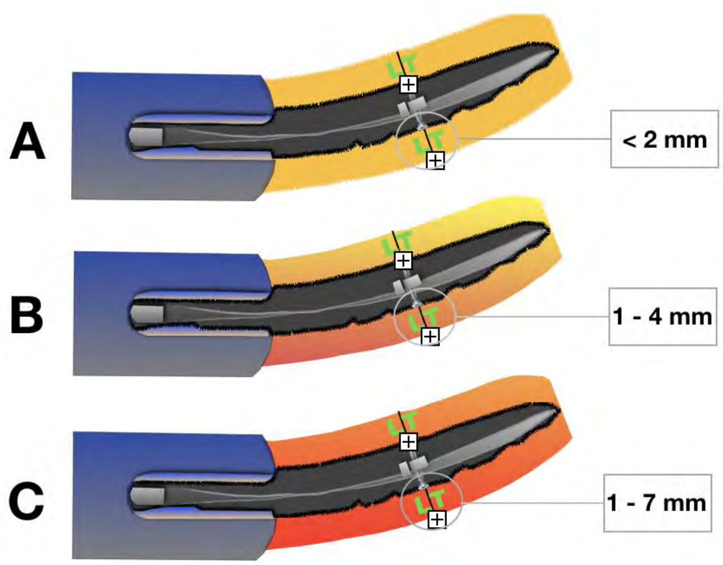
F: Sonosurg X. © (Copyright OLYMPUS CORPORATION. All Rights Reserved) Produced by Olympus, is a 5 mm diameter / 34 to 45 cm length instrument with a curved jaw.

Figure 1: Lateral thermal spread of main surgical energies. A: FM Wand ©.**B:** Harmonic Scalpel Devices. **C** Advanced Bipolar devices...



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