Review article

“Energy devices in gynecological laparoscopy – Archaic to modern era”

Amruta Jaiswal, Kuan-Gen Huang*

Department of Obstetrics and Gynecology, Chang Gung Memorial Hospital, Linkou Medical Center and Chang Gung University College of Medicine, Kweishan, Taoyuan, Taiwan

ARTICLE INFO

Article history:
Received 21 December 2016
Received in revised form 21 July 2017
Accepted 1 August 2017
Available online 1 September 2017

Keywords:
Electrosurgery
Energy devices
Gynecology
Laparoscopy

ABSTRACT

The introduction of newer vessel sealing systems has revolutionized techniques of hemostasis during laparoscopic surgery. These devices allow for rapid sequential tissue and vessel sealing, coagulation, and transection. Despite of widespread use of newer advanced bipolar and ultrasonic devices, monopolar and conventional bipolar electro-surgery still carry weightage due to wider range of tissue effect, dissection capabilities, cost effectiveness, and ease of availability. Here in we discussed different types of commonly available energy sources in terms of mechanism, efficacy and safety as thorough knowledge is utmost important for surgeon to choose appropriate instrument for surgical procedure.

Hemostasis is basic in all surgical procedures. Traditional methods of staples and clips have gradually been abandoned due to cost, difficulty with repeated applications, and problems of displacement. Standard energy devices monopolar and bipolar coagulation are currently widely used due to their inexpensive nature and reusability. Also the new vessel sealing technologies are so successful that they have largely made the need for laparoscopic suturing of vascular pedicles redundant. However, this involves high instrument cost, thermal spread, and sticking and charring of tissues.

Monopolar electro-surgery is most commonly used modality in laparoscopic surgeries because of its low cost, general availability, and diverse range of available tissue effects. However, potential shortcomings of monopolar electro-surgery, including the need for a dispersive electrode, the relatively high power settings, the possibility of stray current injuries, and the inability to seal vessels larger than 1–2 mm diameter, led to the development of conventional bipolar electro-surgery.

Commonly used electrosurgical devices in minimally invasive gynecology surgery (Table 1)

Monopolar

Monopolar energy is the most commonly used electrosurgical modality because of its versatility and clinical effectiveness. Electrosurgical generator has “cut” and “coag” settings, cut refers to
unmodulated continuous waveform and coagulation refers to modulated interrupted waveform. During laparoscopic surgeries continuous waveform results in flow of low energy electron thus minimal smoke production with tissue cutting whereas interrupted waveform is associated with high energy electron flow and more smoke production with high temperature but better hemostasis.\textsuperscript{11} Monopolar energy is based on the use of active and passive electrodes. In monopolar electrosurgery, the active electrode is located on the surgical site. The return electrode is located on the patient, at site away from surgical site to complete electrical circuit (cautery plate). The current passes through the patient as it completes the circuit from the active electrode to the patient return electrode.\textsuperscript{7,10} It has the ability to use continuous and “mix/blend” current to dissect tissue while providing some hemostasis, fulguration in the interrupted mode which results in adequate hemostasis by carbonizing tissues with high capillary or small vessel density, and coagulation of grasped tissue can be achieved where desiccation occurs and proteins denature resulting in a coagulum formation. Maximum temperature reached after activation is \textgreater{} 100 °C.\textsuperscript{11–13} The tissue effects possible with monopolar electrosurgery include tissue vaporization and transection, fulguration, desiccation, and small vessel coaptation.

### Bipolar

In bipolar energy sources current passes between two active electrodes which are in close proximity to each other unlike the monopolar in which it travels through patient body. As current passes between tips of instrument, it only affects tissue grasped between electrodes. These are relatively safe and more useful as compared to monopolar as it causes minimum collateral spread, reduce risk of interference with other devices and better coagulation.\textsuperscript{7} The disadvantage of using conventional electrosurgery are it cannot cut tissue and requires more time to coagulate causing more tissue charring and adherence of tissue which may lead tearing of adjacent vessel causing more bleed.\textsuperscript{7} These shortcomings were overcome by advanced new generation bipolar and ultrasonic devices. Conventional electrosurgical devices (monopolar and bipolar) use are associated with strat current injuries like capacitive coupling, insulation coupling, and direct coupling.\textsuperscript{13}

### Ligasure

The Ligasure™ (Valleylab Inc., Boulder, CO, USA) (LS) vessel sealing instruments use a high-current, low-voltage continuous bipolar radiofrequency energy in combination with a feedback controlled response system that automatically delivers and disrupts the power according to the composition and impedance of the tissue between the jaws of the instruments. It fuses collagen and elastin within the vessel walls, resulting in a permanent seal that can withstand three times the normal systolic pressure, and seals vessels up to 7 mm. Maximum temperature during activation is below 100 °C,\textsuperscript{14–17} thus reduces thermal spread to 1 mm with LS Precise and to 1.5 mm with LS V.

### Plasma kinetic gyrus

The Plasma Kinetic Gyrus™ (PK) (Gyrus ACMI, Southborough, MA) is a bipolar electrosurgical device that uses plasma kinetic technology to deliver a high current at a very low voltage to the tissue. It has two tier jaw design with serrated surfaces for secure grasping. A series of rapid pulses allows a cooling phase during coagulation, thereby decreasing lateral thermal spread. It can seal vessel up to 7 mm by denaturing the protein within the vessel walls, forming a coagulum that occludes the lumen. It yields maximum temperature which is below 100 °C.\textsuperscript{16} This technology does not have a feedback mechanism like LS and Enseal; however, it allows the physician to choose how long energy is applied with the aid of audible tone change, indicating tissue desiccation to the user. This system has two different modes (vapor pulse coagulation and plasma kinetic tissue cutting) delivering predetermined levels of energy matched to special surgical instruments.\textsuperscript{10}

### Enseal

ENSEAL™ (Ethicon Endo-surgery, US, LLC) this tissue-sealing and hemostasis system is a bipolar instrument that combines a high-compression jaw with a tissue dynamic energy delivery mechanism. Because of the configuration and the temperature sensitive matrix (Nanopolar thermostats) embedded within the jaws of the instrument, each tissue type within the jaws receives a different energy dose that is constantly changing as the tissue is being sealed and its impedance changes.\textsuperscript{10,18} It is the first and only system that controls energy deposition at the electrode-tissue interface.\textsuperscript{15} The instrument has a blade that simultaneously cuts the sealed tissue. It can seal vessels ranging in diameter from 1 mm to 7 mm, also sealed vessel walls are capable of withstanding greater than seven times normal systolic pressure.\textsuperscript{1}

### Ultrasonic devices

In 1993, Amaral first described the ultrasonic scalpel for laparoscopy as having the ability to provide both vessel sealing and tissue transection. However, it gained practical popularity only from 2010 onwards. It produces tissue effects by converting electrical energy into vibrations at more than 20,000 cycles per second which is above the audible range.\textsuperscript{15,26} Instrument consist of transducer, hand grip, long shaft and blades. The upper blade, called tissue pad is an inactive one which helps in grasping the tissues and also prevents the vibrational energy from spreading further while lower active jaw vibrates and denatures protein in the tissue to

---

**Table 1**

Different types of available energy sources and tissue effect produce by them.\textsuperscript{21,43}

| Type                        | Tissue effect                          |
|-----------------------------|----------------------------------------|
| Monopolar                   | Vaporization, fulguration, desiccation, coaptation |
| Conventional bipolar        | Desiccation, coaptation                |
| Advanced bipolar            | Desiccation, coaptation, tissue transection |
| Ultrasonic technology       | Desiccation, coaptation, mechanical tissue transection |
| Hybrid device               |                                        |
| Laser energy                |                                        |
| Radiofrequency (RF) energy  |                                        |
| Ligasure, pk gyrus, ENSEAL  |                                        |
| Ultrascision harmonic scalpel, Harmonic ACE, Harmonic focus, SonoSurg, AutoSonoix | |
| Thunderbeat                 |                                        |
| Nd: YAG laser, Argon laser, CO₂ laser | |
| System 7550TM ABC, Cardioblate |                                        |
| RF 3000, starburst, cardioblate |                                        |

---

A. Jaiswal, K.-G. Huang / Gynecology and Minimally Invasive Therapy 6 (2017) 147–151
form a sticky coagulum. One of the ultrasonic device, Harmonic ACE™ (Ethicon Endo-Surgery, Cincinnati, OH, USA) oscillates at frequency of 55,000 cycles per second. It has approval of United States food and drug administration to seal vessel up to 5 mm in diameter. Whereas ultrasonic devices operating at various other frequencies also exist. The mechanical vibrations are produced by the piezoelectric transducers embedded in the tools which convert the applied electrical energy to mechanical vibrations which are then transferred to the active blades for cutting or coagulation. It operates at a frequency of 55.5 kHz and has five power levels. Increasing the power level increases cutting speed and decreases coagulation. In contrast, less power decreases cutting speed and increases coagulation. However, the study had stated the ultrasonic devices reaching temperatures of up to 200°C which can cause lateral thermal damage to adjacent tissue. A new Harmonic ACE™ is approved by the FDA to seal vessels up to 7-mm diameter. General disadvantages of ultrasonic devices include slower coagulation compared with electrosurgery, altering of the frequency or impedance of the surgical system itself due to blade fatigue, temperature elevation, excessive applied pressure, or improper use.

Thunderbeat

Thunderbeat™ (Olympus Medical Systems Corp., Tokyo, Japan) (TB) is the first device to integrate both ultrasonically generated frictional heat energy and advanced bipolar energy in one instrument. The ultrasonic technology rapidly cuts and precisely dissects tissue while the advanced bipolar technology provides reliable vessel sealing. It is multifunctional, as can seal and cut vessels up to 7 mm in size with minimal thermal spread. The generator has level 1 for cutting and sealing while level 3 for sealing mode. The jaw is designed to provide precise, controlled dissection and continuous bipolar support with grasping capability.

Comparison of efficiency and efficacy of different electrosurgical devices

Preference for choosing any energy source differs between surgeons. It is difficult for one to have informed decision about relative merits of any energy sources. Efficiency of any energy source depends on seal time, lateral thermal spread, burst pressure, smoke production. There are animal studies comparing Ligasure V, Gyrus PK, an ultrasonic device, and ENSEAL. Newcomb et al showed a trend toward lower burst pressures and higher failure rates as vessel diameter increased for all 5 mm laparoscopic instruments tested. Gyrus PKS™ cutting forceps (PK), Gyrus Plasma Trissector™ (GP), Harmonic Scalpel™ (HS), EnSeal™ (RX), LigaSure™ V™ with LigaSure™ Vessel Sealing generator (LS), LigaSure™ V™ with Force Triad™ generator (FT), and Ligamax™ 5 endoscopic multiple clip applicator (LM) were tested to compare burst pressure, sealing time, and failure rate. Overall highest burst pressures and lowest failure rates were seen with the RX, LS, and FT. Burst pressures for the RX, LS, and FT were not significantly different from surgical clips for any vessel size tested. However, according to them seal time was significantly faster for FT compared to LS for all vessel sizes (P < 0.05) and faster than RX for both 4–5 mm and 6–7 mm vessels (P < 0.05), making seal time a differentiating factor between devices with the highest burst pressures and lowest failure rates.

In another animal study to compare TB vs. HS, Enseal and LS. Versatility score (depending on hemostasis, histologic sealing, cutting, dissection, and tissue manipulation) was higher (P < 0.01) and dissection time was shorter (P < 0.01) using TB compared with the other three devices. Bursting pressure was similar among TB and the other three instruments. Thermal spread was similar between TB and HA (P = 0.4167), TB and EnSeal (P = 0.6817), and TB and LIG (P = 0.8254). Difference in thermal spread was noted between EnSeal and HA (P = 0.0087) and HA and LIG (P = 0.0167). Thus author concluded, TB has a higher versatility compared with the other instruments tested with faster dissection speed, similar bursting pressure, and acceptable thermal spread.

An ex vivo study comparing LS vs. PK vs. Harmonic ace vs. Enseal in simulator with bovine arteries of 5 mm size found out burst pressure as LS > ES > HS, Smoke production as HS < LS < PK, Sealing time shorter for LS (10 s) < PK (11.1 s) < HS (14.3 s) < Ensell (19.2 s). Lateral thermal spread less with HS (49.9 °C) < PK (64.5 °C) but same for LS (55.5 °C) and Ensell (58.9 °C). LS has the highest burst pressure and fastest sealing time and was the highest rated overall. The HS produced the lowest thermal spread and smoke but had the lowest mean burst pressure. The GP had the highest smoke production, and variable burst pressures. The burst pressure of the TB in the larger-artery category (5–7 mm) was superior to that of the HA. The highest mean burst pressure was measured in the TB group (734 ± 64 mmHg); this was slightly higher than in the LS (615 ± 40 mmHg) group and significantly higher than in the HA group (454 ± 50 mmHg). The dissection speed of the TB was significantly faster than that of the LS and slightly faster than HA. The temperature profile of the HA and the TB was similar with respect to the maximum heat production and the kinetics of cooling down to 60 °C. The maximum temperature during activation and shortly thereafter was around 200 °C in the HA and TB groups. In contrast, the temperature in the LS group during and after activation was constantly below 100 °C.

Safety and efficacy of these newer instrument comparing with conventional bipolar in laparoscopy gynecology surgeries are studied by many authors comparing different factors like total operative time, blood loss, need for blood transfusion, mean hospital stay, postoperative pain, and postoperative complication (Table 2). The results states that Thunderbeat, Ligasure, Gyrus PK, Harmonic and Enseal are better than or as reliable as conventional electrocoagulation.

Shortcomings of energy devices

Few limitations or complications related to energy devices are an inevitable reality of laparoscopy, it is important to have a systematic awareness of the types of complications, know how to respond appropriately, and know how to communicate and deal with complications. All laparoscopic energy sources, to a lesser or greater extent cause lateral thermal spread, irrespective of vaporization, fulguration, desiccation, or coaptation effect; a temperature beyond the “cell kill” threshold may occur causing inadvertent tissue damage increasing morbidity and mortality. Smoke or vapor plumes hampering visibility is mostly observed with monopolar, whereas least seen with ultrasonic devices. Second most common complication associated with laparoscopy surgery after veres or trocar placement (41.8%) are related to use of electrosurgical devices (25.6%). Possible mechanisms behind injuries are mistaken target application, stay current injury due to defective insulation, direct coupling (when active electrode touches another metal instrument), capacitive coupling, alternative site burns (due to defective dispersive pad). Though rare, injury to ureter, bladder and bowel have been reported with insidious use of energy devices. To prevent possible complications it is very important to understand mechanism, biophysics, functions and possible injuries of each instrument.
| Author                     | Type of study                      | Device          | Sample size (N) | Procedure                                          | Operative time (Min.) | Blood loss (mL) | Postoperative pain score | Complication | Hospital stay (days) | Inference                                                                 |
|---------------------------|-----------------------------------|-----------------|-----------------|----------------------------------------------------|-----------------------|-----------------|-------------------------|----------------|---------------------|---------------------------------------------------------------------------|
| Anna Fagoti et al. 2014   | Randomized, controlled trial      | TB vs. standard | N = 71 (excluded 21 due to intraoperative criteria). TB = 25, SES = 25 | Laparoscopic radical hysterectomy with bilateral pelvic lymphadenectomy | TB-85 (P = 0.001)     | TB-50 (P = 0.52)  | At 24h TB-1.96 SES-3.35 | TB-0 (P = 0.31) | TB-3 (P = 0.82) | TB associated with short operative time and less postoperative pain |
| Hakan Ayatan et al. 2014  | Randomized prospective study      | LS vs. Enseal vs. PK | N = 45 | Total laparoscopic hysterectomy | LS-138 (P = 0.004) | No significant difference | No significant difference | No significant difference | LS-1.1 (P = 0.22) | Enseal device is at least as reliable as the conventional electrosurgical technique in laparoscopic supracervical hysterectomy (LASH). |
| Ralf Rothmund et al. 2013 | Prospective, randomized, controlled trial | Enseal vs. standard bipolar | N = 160, Enseal-80 bipolar = 80 | Laparoscopic Supracervical hysterectomy | Enseal-78.18 (P = 0.02) | No significant difference | No significant difference | No significant difference | PK-6.9 (P = 0.1) | PK has advantage of less blood loss compared to HS |
| Janssen et al. 2011       | Randomized controlled trial       | LS vs. CB       | N = 140 | Laparoscopic hysterectomy | LS-148.1 (P = 0.46) | LS-234.1 mL (P = 0.46) | -- | -- | LS-2.9 (P = 0.94) | No significant differences in operating time and blood loss for PK vs. CB |
| Hsuan Su et al. 2011      | Retrospective study               | PK vs. CES      | N = 194 | Laparoscopic myomectomy | PK-190.4 (P = 0.025) | PK-397 mL (P < 0.01) | -- | Less for PK (P < 0.01) | PK-6.9 (P = 0.1) | PK has advantage of less blood loss compared to HS |
| Demirturk et al. 2007     | Retrospective study               | HS vs. LS       | N = 40, HS-19 LS-21 | Total laparoscopic hysterectomy with salpingo-oophorectomy | LS-95.95 (P < 0.001) | HS-152.63 (P < 0.001) | -- | -- | HS-3.24 (P = 0.436) | HS has advantage of less operative time and less blood loss compared to HS |
| Lee et al. 2007           | Retrospective case—control study  | PK vs. CB       | N = 76 | Laparoscopic radical hysterectomy with pelvic lymphadenectomy | PK-172 (P = 0.03) | PK-397 mL (P < 0.01) | -- | -- | PK-6.9 (P = 0.1) | PK has advantage of less blood loss compared to HS |
| Wang et al. 2005          | Prospective, non randomized trial | PK vs. CB       | N = 62 PK-31 CB-31 | LAVH | PK-87.6 (P = 0.368) | PK-196.8 (P = 0.105) | -- | -- | PK-3.2 (P = 0.499) | Operation time, blood loss, transfusion rate, length of hospital stay: no significant difference |

Conventional bipolar- CB, Conventional Electrosurgery-CES, Harmonic scalpel- HS, Ligasure- LS, Plasma kinetic gyrus-PK, standard electrosurgery- SES, Thunderbeat-TB.
Conclusion

All these new energy devices are an appealing, safe alternative for cutting, coagulation, and tissue dissection during surgery and should decrease time and increase versatility during surgical procedures. Preference depends upon nature of surgical task, surgeon's own experience with instrument, availability, and cost. All the available advanced bipolar devices are different although approved to seal vessels of 1–7 mm in diameter. It is every surgeon's desire to incorporate multiple functions into one device so as to reduce surgical time and instrument traffic. However, monopolar and conventional bipolar electro-surgery are still used due to wider range of tissue effect, dissection capabilities, cost effectiveness, and ease of availability. In conclusion, there is insufficient evidence for one vessel sealing technology to be considered superior to the other. In future thermal imaging techniques with histological comparisons should be designed to determine the relationship between failure rates, thermal spread, coagulation necrosis, and presence or absence of apposed nucleated cells.

References

1. Winer WK, Stepanion AA. Trends in laparoscopic electrosurgery. Perioper Nurs Clin. 2007;2(2):145–154.
2. Cushing H. Electro-surgery as an aid to the removal of intracranial tumors. Surg Gynecol Obstet. 1928;47:751–784.
3. Sutton C, Abbott J. History of power sources in endoscopic surgery. J Minim Invasive Gynecol. 2013;20(3):271–278.
4. Frangenheim H. Tubal sterilization under visualization with the laparoscope. Geburtshilfe Frauenheilk. 1964;24:470.
5. Rioz J-E, Cloutier D. A new bipolar instrument for laparoscopic tubal sterilization. Am J Obstet Gynecol. 1974;119(6):737–739.
6. RK K. Female outpatient sterilization using bipolar coagulation. Bull Post-Graduate Comm Med Univ Syd. 1977;33(8):144–154.
7. Pandey D, Yen C-F, Lee C-L, Wu M-P. Electrosurgical technology: quintessence of the laparoscopic armamentarium. Gynecol Minim Invasive Ther. 2014;3(3):63–66.
8. Lin HZ, Ng YW, Agarwal A, Fong YF. Application of a new integrated bipolar and ultrasonic energy device in laparoscopic hysterectomies. ISRN Minim Invasive Surg. 2013;2013:1–4.
9. Mauro MC. Economics and energy sources. J Minim Invasive Gynecol. 2013;20(3):319–327.
10. Lyons SD, Law KS. Laparoscopic vessel sealing technologies. J Minim Invasive Gynecol. 2013;20(3):301–307.
11. Vilea GA, Rajakumar C. Electrosurgical generators and monopolar and bipolar electrosurgery. J Minim Invasive Gynecol. 2013;20(3):279–287.
12. Voyles C, Tucker RD. Safe use of electrosurgical devices during minimally invasive surgery. Laparoscopy Today. 2005;4(2):16–20.
13. Advincula AP, Wang K. The evolutionary state of electrosurgery: where are we now? Curr Opin Obstet Gynecol. 2008;20(4):333–338.
14. Campbell PA, Cresswell AB, Frank TG, Cuschieri A. Real-time thermography during energized vessel sealing and dissection. Surg Endosc. 2003;17(10):1640–1645.
15. Person B, Vivas DA, Ruiz D, Talcott M, Coad JE, Wexner SD. Comparison of four energy-based vascular sealing and cutting instruments: a porcine model. Surg Endosc. 2007;21(2):534–538.
16. Kim FJ, Channins Jr MF, Gewehr E, et al. Temperature safety profile of laparoscopic devices: harmonic ACE, Ligasure V (LV), and plasma trisector (PT). Surg Endosc. 2008;22(6):1464–1469.
17. Carbonell AM, Joels CS, Kercher KW, Matthews BD, Sing RF, Heniford BT. A comparison of laparoscopic bipolar vessel sealing devices in the hemostasis of small-, medium-, and large-sized arteries. J Laparoendosc Adv Surg Tech. 2003;13(6):377–380.
18. Cho HY, Choi KJ, Lee YL, Chang KH, Kim HB, Park SH. Comparison of two bipolar systems in laparoscopic hysterecomy. JLS. 2012;16(3):456–460.
19. Brill AL. Bipolar electrosurgery: convention and innovation. Clin Obstet Gynecol. 2008;51(1):153–158.
20. Newcomb WL, Hope WW, Schmelzer TM, et al. Comparison of blood vessel sealing among new electrosurgical and ultrasonic devices. Surg Endosc. 2006;20(3):90–96.
21. Enam TA. How safe is high-power ultrasonic dissection? Ann Surg. 2003;237(2):186.
22. Kuo HH, Li Y, Wang CJ, Juang HT, Lee CY. A case-controlled study comparing harmonic versus electrosurgery in laparoscopic myomectomy. Taiwan J Obstet Gynecol. 2017;56(1):73–76.
23. Sankaranarayanan G, Resapu RR, Jones DB, Schwitzberg S, De S. Common uses and cited complications of energy in surgery. Surg Endosc. 2013;27(9):3065–3072.
24. Obonna G, Mishra R. Differences between Thunderbeat, LigaseSure and Harmonic scalpel energy system in minimally invasive surgery. World J Lap Surg. 2014;7:41–44.
25. Milsom J, Trencecha K, Monette S, et al. Evaluation of the safety, efficacy, and versatility of a new surgical energy device (THUNDERBEAT) in comparison with Harmonic ACE, Ligasure V, and EnSeal devices in a porcine model. J Laparoendosc Adv Surg Tech A. 2012;22(4):371–378.
26. Lambertson CR, Hsi RS, Jin DH, Lindler TU, Jellison FC, Baldwin DD. Prospective comparison of four laparoscopic vessel ligation devices. J Endourol. 2008;22(10):2307–2312.
27. Seehofer D, Mogli M, Boos-Knoop S, et al. Safety and efficacy of new integrated bipolar and ultrasonic scissors compared to conventional laparoscopic 5-mm sealing and cutting instruments. Surg Endosc. 2012;26(9):2541–2549.
28. Fagotti A, Vizzigalli G, Fanfani F, et al. Randomized study comparing use of THUNDERBEAT technology vs standard electrosurgery during laparoscopic radical hysterectomy and pelvic lymphadenectomy for gynecologic cancer. J Minim Invasive Gynecol. 2014;21(3):447–453.
29. Rothmund R, Kraemer B, Brucker S, et al. Laparoscopic supravacuclar hysterectomy using EnSeal vs standard bipolar coagulation technique: randomized controlled trial. J Minim Invasive Gynecol. 2013;20(5):661–666.
30. Su H, Han CM, Wang CJ, Lee CL, Soong YK. Comparison of the efficacy of the pulsed bipolar system and conventional electrosurgery in laparoscopic myomectomy – a retrospective matched control study. Taiwan J Obstet Gynecol. 2011;50(1):25–28.
31. Janssen PF, Brolmann HA, van Kesteren PJ, et al. Perioperative outcomes using LigaseSure compared with conventional bipolar instruments in laparoscopic hysterecomy, a randomised controlled trial. BJOG. 2011;118(13):1568–1575.
32. Lee CL, Huang KG, Wang CJ, Lee PS, Hwang LL. Laparoscopic radical hysterectomy using pulsed bipolar system: comparison with conventional bipolar electrosurgery. Gynecol Oncol. 2007;105(3):620–624.
33. Ayhan H, Nazik H, Narin R, Api M, Tok EC. Comparison of the use of LigaSure, HALO PKS cutting forceps, and ENSEAL tissue sealer in total laparoscopic hysterectomy: a randomized trial. J Minim Invasive Gynecol. 2014;21(4):650–655.
34. Demirtürk F, Ayhan H, Çalışkan AC. Comparison of the use of electrotether bipolar vessel sealer with harmonic scalpel in total laparoscopic hysterectomy. J Minim Invasive Gynecol Res. 2007;33(3):341–345.
35. Wang CW, Euc J-L, Yen C-F, Lee C-L, Soong Y-K. Comparison of the efficacy of the pulsed bipolar system and conventional bipolar electrosurgery in laparoscopically assisted vaginal hysterectomy. J Laparoendosc Adv Surg Tech. 2005;15(4):361–364.
36. Ou C-S, Joki J, Wells K, et al. Total laparoscopic hysterectomy using multifunction grasping, coagulating, and cutting forceps. J Laparoendosc Adv Surg Tech. 2004;14(2):67–71.
37. Ou C-S, Harper A, Liu YH, Rowbotham R. Laparoscopic myomectomy technique. Use of colotomy and the harmonic scalpel. J Reproductive Med. 2002;47(10):849–853.
38. Holub Z, Jabor A, Sproingt L, Kliment L, FischlOvá D, Urbanek S. Inflammatory response and tissue trauma in laparoscopic hysterectomy: comparison of electrosurgery and harmonic scalpel. Clin Exp Obstet Gynecol. 2001;29(2):105–109.
39. Huang H-Y, Yen C-F, Wu M-P. Complications of electrosurgery in laparoscopy. Gynecol Minim Invasive Ther. 2014;3(2):39–42.
40. Shinhoara S, Kasai T, Kasai M, Hiraiz S. Delayed detection of ureteral thermal injury in laparoscopic surgery. Gynecol Minim Invasive Ther. 2017;6(1):45.
41. Wijaya T, Lo T-S, Jaili SB, Wu P-Y. The diagnosis and management of ureteric injury after laparoscopy. Gynecol Minim Invasive Ther. 2015;4(2):29–32.
42. Sicham BVC, Huang K-G, Mangn ADI, Ueng S-H. Laparoscopic and microscopic images of thermal injury to the ureter. Gynecol Minim Invasive Ther. 2016;5(1):45–46.
43. Law KS, Lyons SD. Comparative studies of energy sources in gynecologic laparoscopy. J Minim Invasive Gynecol. 2013;20(3):308–318.