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Energy sources for laparoscopic colorectal surgery: is one better than the others?

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Abstract

Background: The wide acceptance of the laparoscopic approach in both benign and malignant colorectal diseases has led to the development of several multifunctional tools aiming to overcome the limitations of conventional electrosurgery (ES). The aim of this study was to compare ES, ultrasonic coagulating shears (US), electrothermal bipolar vessel sealers (EBVS) and a relatively new energy device that combines both ultrasonic and bipolar energy (Thunderbeat, TB), in terms of safety, efficacy and cost-effectiveness in patients undergoing laparoscopic colorectal resection (LCR).

Methods: A review of the literature was performed in Medline and the Cochrane Library. Only randomized controlled trials (RCTs) and cohort studies were considered for inclusion.

Results: Four RCTs, one retrospective and two prospective cohort studies were eligible for inclusion. Bleeding control was better with US compared to ES and operative time was shorter with both US and EBVS compared to ES. These advantages were more evident in challenging colorectal resections, such as low anterior resections. US and EBVS seemed to be more cost-effective compared to ES, although supporting data are limited. US and EBVS appeared to be equivalent with regard to different outcome parameters. Preliminary data on the efficacy and safety of TB are promising.

Conclusion: Although US and EBVS have the advantages of less blood loss and/ or a shorter operative time compared to ES, the current evidence does not demonstrate which multifunctional instrument is the most effective in LCR. High-quality RCTs are required to confirm the preliminary promising results with the use of TB in LCR.

Keywords:

- Laparoscopy
- Colorectal resection
- Dissection
- Vessel sealing
- Electrocautery
- Ultrasonic
- Electrothermal bipolar vessel sealers
- Thunderbeat

INTRODUCTION

Laparoscopic colorectal resection (LCR), both for benign and malignant diseases, has gained wide acceptance since the first report of laparoscopic-assisted colectomy in 1991 [1]. This is mainly induced by the more favorable short-term outcomes of the laparoscopic approach compared to open colorectal surgery [2-5]. Additionally, results from large randomized controlled trials (RCTs) have demonstrated that the long-term oncologic outcome after LCR for colorectal cancer is not inferior to open surgery [6-11].

LCR is a technically demanding procedure and mesenteric tissue dissection and vessel ligation might be challenging, particularly in obese patients and in the presence of inflammation, such as in diverticulitis or inflammatory bowel diseases [12]. Conventional mono- and bipolar electro-surgery (ES) is widely used for dissection and vessels control in LCR. However, it has some limitations, including smoke production and the risk of collateral thermal injuries. Furthermore, it might be time-consuming. The rapid increase in popularity of LCR has led to the development of technologies and surgical tools aiming to overcome these shortcomings of ES. Therefore, ultrasonic coagulating shears (US), electro-thermal bipolar vessel sealers (EBVS) and, more recently, an energy device that combines both ultrasonic and bipolar energy (Thunderbeat, TB – Olympus Medical Systems Corp., Tokyo, Japan) have become available. However, these devices are non-reusable and are considerably more expensive compared to ES. Therefore, it is essential to prove the advantages compared to ES justifying their introduction in LCR.

The aim of this study was to review the clinical outcomes of the different energy sources used in LCR.

MATERIALS AND METHODS

Literature search

A search strategy was performed in Medline by using the Pubmed search engine and the

Cochrane Library. The following medical subject headings (MeSH) and free-text words alone or in combination were used: “laparoscopy”, “minimally invasive”, “colorectal”, “colectomy”, “dissection”, “conventional electrosurgery”, “electrothermal bipolar vessel sealer”, “ultrasonic shears”, “vessel ligation”, “Ligasure”, “Ultracision”, “harmonic scalpel”, “Thunderbeat”. The publication period was restricted to January 1999 until January 2016 as the more advanced coagulation devices were not available on the market before this period.

Study selection

Two authors (MEA and EF) independently performed the literature search and subsequently the selection of studies. Studies assessing the outcome of ES, US, EBVS or TB in a group of patients undergoing LCR were eligible for inclusion in this review. Only RCTs and pro- or retrospective cohort studies were accepted as study design in this review. Animal and non-English studies as well as case-report were excluded. Reference lists from the included articles were manually checked and additional studies were included when appropriate. The following outcome parameters were extracted from each study included in this review: year of publication, study design, number of patients included, operative time, blood loss, conversion to open surgery, conversion to other laparoscopic instruments, postoperative morbidity and mortality, hospital stay and costs.

Dissecting tools

US, EBVS and TB are all multifunctional instruments that can be used as grasper, dissector, cutter or coagulator during LCR. The principle of *US* tools is based on the transformation of electrical energy into high-frequency (55,000 kHz) frictional energy. The denaturation of hydrogen bonds in tissue and blood vessel proteins by the vibrating blades results in a coagulum that seals the lumen of vessels up to 5 mm in diameter [13]. *EBVS* instrument applies high current (4 A) and low voltage (<200 V). This energy results in denaturation of collagen and elastin within the blood vessel wall that can seal vessels with a diameter up to 7 mm [14,15].

Thunderbeat integrates both ultrasonic and advanced bipolar energy in a unique instrument: it allows to cut tissue with ultrasonic energy on the one hand and reliably seal vessels up to 7 mm in diameter with bipolar energy on the other.

RESULTS

The search strategy yielded in a total of 1,694 studies, after duplication of studies from the two electronic databases. After study selection, a total of 7 studies were eligible for inclusion in this review: two RCTs [16,17] comparing ES, US and EBVS, one RCT [18] comparing ES and US, one RCT [19] and one prospective [20] and one retrospective cohort study [21] comparing US and EBVS, and one prospective cohort study [22] reporting the outcome in LCR by using TB. These studies were heterogeneous in terms of the surgical procedures performed and all except two RCTs [18,19] were small and underpowered trials.

Conventional ES versus US

In three RCTs, ES and US were compared (**Table 1**). Targarona et al. [16] randomized 38 patients with a benign or malignant disease in the left colon, sigmoid and rectum: 11 in the ES group, 12 in the US group, and 15 patients in the EBVS group. Operative time was significantly longer in patients who underwent laparoscopic colectomy with ES than US. Additionally, there was significantly more intraoperative blood loss in the ES group. Conversion to another laparoscopic instrument was only necessary in ES patients. There were no intraoperative complications related to the use of ES or US; conversion rate, postoperative morbidity, hospital stay and total costs were not significantly different between both groups.

Hubner et al. [17] randomized 61 patients undergoing laparoscopic recto-sigmoid or low anterior resection: 20 to ES, 20 to US and 21 to EBVS. They found a significantly longer operative time and more blood loss in the ES compared to the US group. Additionally, significantly more clips were needed during LCR with ES than US (median 9 vs. 3, $P < 0.001$). No patients in

both groups were converted to open surgery. Overall postoperative morbidity and hospital stay were not significantly different between both groups. Cost analysis (operating room, energy device, additional instruments) revealed that dissection by using ES was more expensive than US assuming a center volume of 200 cases per year.

The third RCT conducted by our group [18] compared ES and US in patients who underwent laparoscopic right hemicolectomy, left hemicolectomy/sigmoidectomy or low anterior resection. There was no significant difference in overall mean operative time between ES and US. However, subgroup analysis revealed that low anterior resection took longer if ES was used. Blood loss was significantly higher in the ES compared to the US group. Intraoperative complication rates were comparable in both groups (1.3% vs. 4%, $P=0.62$), as was the conversion rate to open surgery. Conversion to another energy source device was only needed in ES cases, most frequently during right hemicolectomy or low anterior resection. No differences were observed in 30-day postoperative morbidity and hospital stay.

Conventional ES versus EBVS

Both RCTs performed by Targarona et al. and Hubner et al. also included a group of patients who underwent LCR by using EBVS. The outcome parameters of this group of patients compared to the ES group are shown in **Table 2**.

In the study by Targarona et al. [16], operative time was significantly longer in patients who underwent laparoscopic colectomy with ES. Additionally, there was more intraoperative blood loss in the ES group, although this difference did not reach statistical significance. A slightly higher rate of conversion to other laparoscopic instruments occurred in the EBVS group. No intraoperative complications related to the use of ES or EBVS were recorded. Conversion rate, postoperative morbidity, hospital stay and costs were comparable between ES and EBVS.

Hubner et al. [17] found no significant difference in blood loss between both groups, whilst operative time was significantly shorter in the EBVS group. An additional instrument was

more frequently used in ES patients, although the difference did not reach statistical significance. The EBVS procedures were significantly cheaper compared to the ES procedures.

US versus EBVS

Additional to the RCTs by Targarona et al. [16] and Hubner et al. [17], another RCT compared US with EBVS [19]. The outcomes of these three RCTs are shown in **Table 3**. Furthermore, one prospective [20] and one retrospective cohort study [21] was conducted comparing US or EBVS in patients undergoing LCR.

In the study by Targarona et al. [16], operative time, intraoperative blood loss, conversion to open surgery and conversion to another laparoscopic instrument were comparable between both groups. There were no differences in postoperative morbidity, hospital stay and costs.

Hubner et al. [17] found no significant differences in blood loss and operative time between US and EBVS. The use of another laparoscopic instrument was necessary in more US procedures, and postoperative morbidity rate was higher in EBVS patients; however, these differences were not significantly different.

Rimonda et al. [19] included a total of 140 patients. They found no significant differences in operative time and intraoperative blood loss between both groups. Intraoperative complications related to the electronic device occurred in one US patient (1.4%) and in three of the EBVS patients (4.2%) ($P=0.62$). In one patient of the US group (1.4%), the surgeon switched to ES due to failure of the dissecting tool. Conversion rate, postoperative complication rate and hospital stay were not significantly different between both groups.

Takada et al. [20] conducted a prospective study comparing 30 patients undergoing laparoscopic transverse colectomy or sigmoidectomy for cancer with US ($n=15$) or EBVS ($n=15$). They found a higher number of rebleeds and a longer time for mesocolon dissection in the US patients. There were no postoperative complications and hospital stay was not significantly different between both groups.

Campagnacci et al. [21] retrospectively reported the outcomes of 200 patients who underwent laparoscopic right or left colectomy or low anterior resection with US (100 patients) or EBVS (100 patients). Intra-operative bowel injuries caused by US occurred in 2 patients (2%). Mean operative time was similar in both groups, whilst intra-operative blood loss was significantly lower in the EBVS group (115 vs. 370 ml for right colectomies, 150 vs. 455 ml for left colectomies and 185 vs. 495 ml for low anterior resections). Conversion to open surgery was only required in one patient in the US group. No difference was observed in hospital stay between both groups.

Thunderbeat (TB)

To date, there are no studies comparing TB to other energy sources for dissection and vessel ligation during LCR. We have recently reviewed our initial experience with 25 consecutive patients who underwent LCR with TB between September 2015 and December 2015. The baseline characteristics and type of colorectal resections are summarized in **Table 4**. There were no intra-operative complications related to the use of TB and estimated blood loss was negligible in all cases. No malfunction of the tool was recorded.

Milsom et al. [22] reported in 2015 the results of a single institution prospective pilot study including 30 patients undergoing laparoscopic right or left hemicolectomy for cancer by using the TB (**Table 4**). Mean time \pm standard deviation for dissection with TB to remove the specimen was 80.6 ± 35 minutes. Ligation of the major vessels was successful in all cases and no intra-operative bleeding occurred. The median number of TB applications to seal the inferior mesenteric artery was 3 (range 2-8), and 2 (range 1-4) seals were required for the ileocolic vessels. No organ injuries or other complications related to TB were observed. The median number of times the TB device was taken out from the abdomen during the operation to clean up the tip was 2 (range 1-4). Malfunction of the TB occurred in 2 patients (6.7%).

DISCUSSION

The current evidence shows that the time needed for mesenteric dissection and vessel ligation during LCR is lower with US and EBVS compared to ES. Additionally, the use of US results in less blood loss compared to ES, whilst a significant difference in blood loss between EBVS and ES could not be demonstrated. However, the conversion rate, postoperative morbidity and hospital stay is not influenced by the type of coagulation device used.

The shorter operative time by using US or EBVS in LCR might be explained by several factors, such as reduced instrumental traffic through the ports, reduced need for additional instruments for vessel control, less intra-operative blood loss avoiding repeatedly introducing a suction device and limited production of smoke. These advantages are even more important in difficult procedures like low anterior resections for rectal cancer or colon resection for diverticulitis. In addition, pooling of the data with regard to conversion to other instruments in a previous meta-analysis demonstrated that this was significantly more frequent necessary in ES compared to US or EBVS patients [23]. Therefore, the use of US or EBVS enables the operating surgeon to complete the operation with one device in most cases, thus avoiding the sequelae of changing instruments, saving time and reducing the risk of conversion to open surgery. However, the intra-operative benefits of US and EBVS are not reflected into advantages with regard to earlier resumption of gastrointestinal functions, reduced postoperative morbidity and shorter hospital stay.

Even though two small, heterogeneous non-randomized studies [20,21] showed some advantages with the use of EBVS over US, a RCT [19] that was powered to detect a 20% difference in blood loss between US and EBVS showed no significant differences. The authors of this RCT concluded that both tools are safe and that the choice between both of them should only depend on the surgeon's preference.

With regard to cost-effectiveness, there was no difference in costs between ES and US as well as between ES and EBVS in one RCT [16], whilst the other RCT [17] showed that ES was significantly more expensive compared to both US and EBVS. Even though the EBVS and US

devices are more expensive, they might be at least as cost-effective as ES since the material-related costs might be counterbalanced by a shorter operative time and a limited need for using additional instruments, mainly including clips.

Very few data on the subjective evaluation of the different energy devices by the operating surgeons are available. Hubner et al. [17] evaluated the following features of the instruments used: dissection capacity, cutting ability, bleeding control, handling, safety and overall satisfaction. They found similar high overall satisfaction with EBVS, US and ES by the operating surgeons. The scores regarding bleeding control and safety items were significantly higher for EBVS and US compared to ES. Handling was considered the main limitation to the use of US.

Since US and EBVS have different features in terms of dissection and hemostatic power, a tool combining both characteristics should be ideal. TB is a novel dissecting tool that combines both ultrasonic and bipolar energy. Some experimental studies on porcine models have shown that TB leads to faster dissection of the mesentery than EBVS. For instance, Milsom et al. [24] conducted an experimental study on 10 female Yorkshire pigs aiming to assess the versatility, bursting pressure, thermal spread, and dissection time of TB compared to other commercially available devices, including Harmonic® ACE (HA) (Ethicon Endo-Surgery, USA), LigaSure™ V (LIG) (Covidien, USA), and EnSeal® (Ethicon). In this study, 2 cm long samples of small (2-3 mm)-, medium (4-5 mm)-, and large (6-7 mm)-diameter vessels were created. Versatility, defined as the performance of the surgical instrument based on hemostasis, histologic sealing, cutting, dissection and tissue manipulation, was higher and dissection time was shorter with TB compared to the other three tools. No differences were observed in bursting pressure and thermal spread among the four instruments. Similarly, Seehofer et al. [25] found in eight German Landrace pigs a significantly higher cut speed of TB compared to HA and LIG. The tools were similar in the rate of seal failures. The safety and efficacy of TB demonstrated in these experimental studies seems to be confirmed in humans by the results of a recently published case series

of 30 patients [22] and the results of our initial experience. Further large high quality RCTs are needed to assess the real benefits of this technology in patients undergoing LCR.

CONCLUSIONS

The current evidence shows that US and EBVS significantly reduce the operative time and achieve a better bleeding control than ES in patients undergoing LCR. Large RCTs are required to confirm the promising preliminary results about safety and efficacy of TB.

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