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SURGICAL ENDOSCOPY
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Electrothermal bipolar vessel sealing device vs. ultrasonic coagulating shears in laparoscopic colectomies: a comparative study

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Abstract
Background: Many devices are available for vascular control during laparoscopic colorectal procedures. Ultrasonic coagulating shears (UCS), vascular staplers, titanium or plastic clips, and electrothermal bipolar vessel sealing (EBVS) are currently used according to the surgeon's preference. This study aimed to compare EBVS Ligasure with UCS.
Methods: We report the outcome of 200 consecutive unselected patients who underwent laparoscopic colorectal resections of which 100 were performed with EBVS Ligasure (from September 2004 to December 2005, group 1) and 100 with UCS harmonic scalpel (from December 2002 to June 2004, group 2). Only the following three types of operation were performed: right colectomy (RC), left colectomy (LC), and low anterior resections (LAR). Emergency procedures have been excluded. The same attending surgical teams performed or supervised all procedures. Operating time, blood loss, complications, and postoperative hospital stay were investigated.
Results: Age, gender, previous surgical abdominal procedures, and ASA risk were similar between the two groups, as well as was the percentage of malignant cases (74% vs. 71%, respectively). There were 32 vs. 37 RC, 50 vs. 47 LC, and 18 vs. 16 LAR in groups 1 and 2, respectively. There was no mortality in either group. A conversion to open surgery and two major complications occurred in group 2. There were no statistically significant differences in mean operating time (111 vs. 133, 140 vs. 176, and 153 vs. 201 min) and in the mean postoperative hospital stay (5.2 vs. 6.1, 6.5 vs. 7.1, and 6.8 vs 7.3 days) for RC, LC, and LAR between group 1 and 2, respectively. We do report interesting data about statistically significant differences in the blood loss: 115 vs. 370, 150 vs. 455, and 185 vs. 495 ml for RC ($p < 0.001$), LC ($p < 0.001$), and LAR ($p = 0.002$) between group 1 and group 2, respectively.
Conclusions: In our laparoscopic colorectal experience, EBVS Ligasure has proven safe and effective in vessel sealing. Patients in whom this device was used had less blood loss and slight advantages in operating time and postoperative hospital stay.

Key words: Laparoscopic colectomy — EBVS and USC energy devices — Colonic vessels ligature

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Laparoscopic colectomy for benign and malignant diseases is an interesting surgical field in which clinical research, surgical techniques, and technology development come together. The increasing availability of new devices lets us perform procedures with reduced operating time and blood loss. However, oncologic criteria and anatomical landmarks continue to be the meaningful purposes of each series. Electrothermal bipolar vessel sealing (EBVS) and ultrasonic coagulating shears (USC) represent recent alternative systems used in vessel sealing, while metallic or reabsorbable clips and vascular staplers remain traditional mechanical vessel closure systems [7]. Clips are placed easily in 2–7-mm vessels, but they increase the overall cost of the procedure, as do vascular stapler cartridges. Vessel closure by laparoscopic suture may be very time consuming, and monopolar/bipolar energy might be used to secure 1–3-mm vessels, but there is significant potential for dangerous thermal spread [4] and extension of operating time. USC and EBVS devices have been described as effective in vessel closure in both open and laparoscopic procedures, leading to shorter operating time.

EBVS tools, suitable to seal vessels up to 7 mm in diameter, are based on a technology that fuses tissue bundles and vessels, reforming the collagen in vessel walls and connective tissue into a permanent seal. By means of high-current and low-voltage energy, collagen

Table 1. Patients' anagraphic data and risk factors

	EBVS group (n = 100)	UCS group (n = 100)	Statistical significance[a]
Males	51	59	ns
Females	49	41	ns
Mean age (years)	67.2	65.1	ns
Age range (years)	36–93	39–88	ns
Older than 70 years	31	33	ns
Mean BMI	28.4	27.8	ns
BMI range	25–38	24–37	ns
Previous abdominal surgery	48	53	ns
ASA I	47	54	ns
ASA II	37	34	ns
ASA III	16	12	ns

BMI = body mass index; ASA = American Society of Anesthesiologists; ns = difference not statistically significant
[a] χ^2 and t test

Table 2. Indications for surgery and procedures

	EBVS group (n = 100)	UCS group (n = 100)	Statistical significance[a]
Benign lesions	26	29	ns
Malignant lesions	74	71	ns
TNM stage I	23	22	ns
TNM stage II	24	25	ns
TNM stage III	27	24	ns
Right colectomies	32	37	ns
Left colectomies	50	47	ns
Low anterior resection	18	16	ns

ns = difference not statistically significant
[a] χ^2 test

and elastin are denatured within the vessel wall and surrounding connective tissue [8]. UCS has a high-frequency (55,000 cycles/s) vibrating blade that denatures hydrogen bonds in tissue and vessel proteins, producing a coagulum sealing lumen of vessels up to 3–5 mm in diameter [7]. UCS and EBVS are available in 10- and 5-mm-diameter shapes and come with a hand switch or a foot switch. Despite no difference in thermal spread (0.5–2 mm) between the Ligasure vessel sealer and the UCS [7], it must be kept in mind that the high temperature of the unprotected blade of the UCS lasts seconds after use.

As is well known, not including major vessel closure, during laparoscopic colectomy there are many minor vascular structures surrounding anatomical colonic ligaments that should be transected. For instance, splenic flexure take-down, reported as a systematic step by a large number of surgeons who perform left colectomies [10], may be troublesome and time consuming and could injure the spleen if primary hemostasis failure or rebleeding episodes occur while dividing the gastrocolic or splenocolic ligament.

The aim of this retrospective study was to assess the reliability of EBVS and UCS, investigating operating data and postoperative course.

Methods

Patients

One hundred patients underwent laparoscopic colorectal resections from September 2004 to December 2005 (group 1). All operations were performed using EBVS Ligasure V 5 mm (Valleylab, Boulder, CO). There were 51 males and 49 females with a mean age of 67.2 years (range = 36–93 years) (Table 1). There were 32 right colectomies , 50 left colectomies, and 18 low anterior resections (Table 2). Until 2004, when the EBVS Ligasure was introduced into surgical practice, the greater part of our colorectal procedures had been performed using UCS (Ethicon Endosurgery, Cincinnati, OH) 10 or 5 mm. As with the EBVS series, 100 laparoscopic colorectal procedures were performed using UCS between December 2002 and June 2004 (group 2). This group comprised 59 males and 41 females with a mean age of 65.1 years (range = 39–88 years). In this group there were 37 right colectomies, 47 left colectomies, and 16 low anterior resections. The differences between the two groups in terms of body mass index (BMI), previous surgical procedures, general condition (American Society of Anesthesiologists [ASA] risk), tumor volume, and stage and benign procedure cases have been estimated to be slightly significant (Tables 1 and 2) using χ^2 and t tests and taking into account the dilution factor that occurs when using the method of consecutive unselected patient recruitment in both groups.

Technique

With respect to resections for malignancy, oncologic criteria have been the main landmarks in both groups: lymph node clearance, depending on both level of vessel section and width of mesocolon dissection, and total mesorectal excision (TME) in rectal procedures. For benign cases, the only end point has been resection, making a vascularized tension-free anastomosis. However, to make the anastomosis, e.g., in diverticular disease, a limited dissection of a inflammatory shortened mesocolon may be inappropriate. Therefore, in both groups of our study, procedures for malignancy and a significant number of benign procedures were performed using the same surgical steps: vessel ligature close to their origin, Gerota–Toldt plane mesocolon medial to lateral dissection, gastrocolic and splenocolic ligament division, splenic flexure take-down, Gruber mesosigmoid fold section, and Waldeyer nerve-sparing fascia dissection in left colectomy. Equally, the same procedures were used for right colectomy cases. On ileocolic vessels, right colic vessels, and the inferior mesenteric vein, Ligasure V was applied sequentially two or three times before cutting. In the left colectomy procedure, the inferior mesenteric artery (IMA) was always dissected before its section to identify and spare the left paraortic hypogastric trunk. This runs posterior to the IMA and is located 1 cm from the artery's origin. When the IMA is divided distal to the left colic artery (LCA), as occurred in some cases of our series, one must keep in mind that the left trunk may be endangered because its distance from the LCA is about 0.4–05 cm [12]. In nearly all our cases the IMA was titanium clipped before section, avoiding electrothermal sealing. Also, in the UCS series we used titanium clips rather than remain confident in arterial vessel section by the ultrasonic device. Splenic flexure was mobilized, dividing the gastrocolic ligament starting at the midtransverse colon to the splenocolic ligament, and meeting with the Gerota–Toldt plane previously dissected by cutting the avascular connection of the distal mesocolon to the pancreas inferior border. Once dissection was completed, the specimen was retrieved through a protected minilaparotomy and the mesocolon was divided toward the visceral serosa to prepare the anastomosis stump (intra-abdominal transanal mechanical and extra-abdominal manual in left and right colectomies, respectively). Finally, after closure of the minilapatoromy, the pneumoperitoneum was re-established to check both hemostasis and reposition the small bowel correctly.

Statistical analysis

The following parameters between the two groups were assessed using the χ^2 test and the t test: conversion to open surgery, major complications, operating time, blood loss, and length of postoperative hospital stay. A level of 5% was used as the criterion for statistical significance. The Primer of Biostatistics for Windows software (McGraw-Hill, Blacklick, OH) was used for statistical analysis.

Results

A left colectomy for diverticular disease was converted to open surgery in the UCS group because of inadequate vascularization of the colonic stump after laparoscopic resection; a complete derotation of the right colon with cecorectal anastomosis was necessary. Two major complications occurred in the UCS series. A 75-year-old female patient, who underwent right colectomy for severe dysplasic polypoid lesion, had abdominal pain and bile leakage through the abdominal drain on the second postoperative day. Surgical exploration found a duodenal fistula near the origin of the right colonic vessel. Review of the videotape of the operation allowed us to see that during vessel dissection by UCS, a duodenal serosa white ischemic lesion resulted from the overheated active blade of the UCS touching the duodenal wall (Fig. 1). After reoperation, which consisted of duodenal primary wall closure and omental patch, the patient developed a right flank abscess that required percutaneous ultrasound-guided drainage. The patient needed 76 days of postoperative hospital stay.

In the second complication case of the UCS series, a 63-year-old female patient, who underwent T3N0 right colon carcinoma resection, was reoperated on on the third postoperative day because of intraoperatively undetected ileal microperforation, most likely originating from surgical manipulation by the UCS device or another instrument during right laparoscopic colectomy. The presence of biliary peritonitis suggested a temporary ileostomy be performed instead of just lesion closure. The patient was dismissed on postoperative day 13.

Mean operating time was 111 min (range = 70–195 min) for right colectomies, 140 min (range = 120–170 min) for left colectomies, and 153 min (range = 130–220 min) for low anterior resections in group 1 and 133 min (range = 95–190 min), 176 (range = 95–240 min), and 201 min (range = 145–320 min) in group 2, respectively. No statistically significant difference was observed between the mean operating times and between the mean hospital stay of the two groups (Table 3). We have observed a statistically significant difference in the mean blood loss between the two groups, as reported in Table 3. This evident benefit in the EBVS group was experienced in all the procedures performed. Both groups underwent the same procedure as determined by the mean number of lymph nodes that accompanied the malignant specimen, 14.1 and 14.6 in right colectomy, 13.5 and 13 in left colectomy, and 11.5 and 11.8 in low anterior resections in groups 1 and 2, respectively.

Discussion

There are several studies that evaluated the use of UCS and EBVS devices in laparoscopic colorectal resections retrospectively or in a nonrandomized way. In one study [14], the authors evaluated the effectiveness of both 10-mm UCS and 10-mm EBVS by reviewing videotaped procedures and comparing the rebleeding episodes of each case. The study assessed 30 cases of transverse

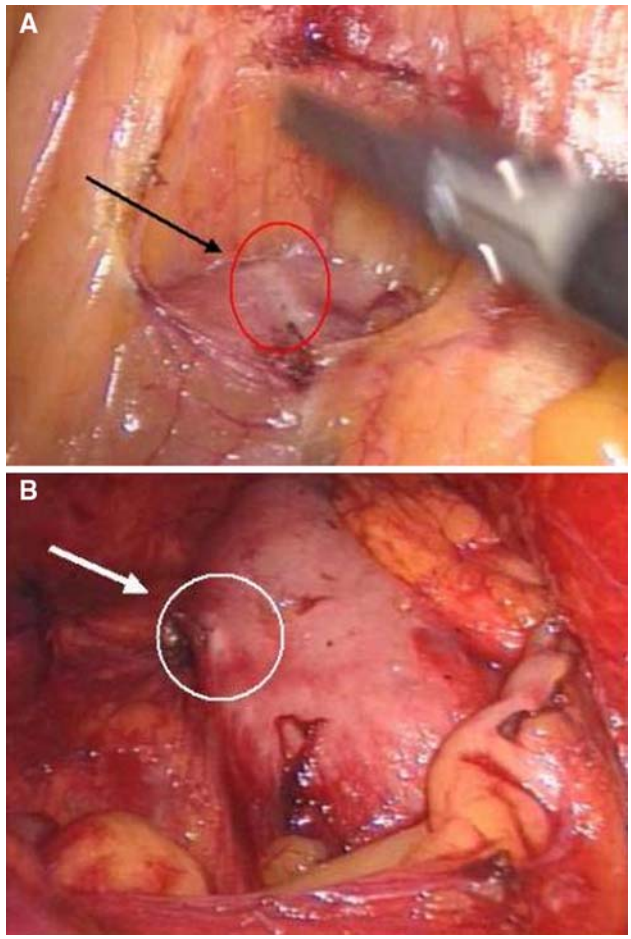

Fig. 1. **A** Right colectomy. Arrow points to the red circle which indicates a duodenum white serosa lesion after the UCS overheated blade made contact. **B** After the procedure was over.

colectomy and sigmoidectomy and reported significantly lower rebleeding episodes in the EBVS cases than in the UCS cases (0.3 vs. 1.2 and 0.3 vs. 2.0 in 16 transverse colectomies and 14 sigmoidectomies, respectively) and shorter operating time throughout mesocolon dissection (11.4 vs. 23 min). Focusing attention on procedures that are quite uncommon, i.e., transverse resection and sigmodectomy for colon cancer, neither right mesocolon nor right colonic vessels were dissected or divided. Moreover, the authors used both 10-mm EBVS and 10-mm UCS in all but the main mesocolic artery division.

In 2001 Heniford et al. [8] published their initial results from using EBVS, followed in 2003 [7] by publishing a comparison study among a number of hemostasis tools, including UCS and EBVS. They reported that use of EBVS allowed an overall reduction of operating time in open procedures but not as much in laparoscopic procedures, and they proved that its use was significantly faster and more efficient than any alternative ligation technique (e.g., suture, hemoclips, UCS) for intestinal resection. In an experimental study on pigs in which hemostasis was performed on small, medium, and large arteries by titanium or plastic clips, EBVS, and UCS, Harold et al. [7] concluded that EBVS can be used with confidence in vessels up to 7 mm of diameter. EBVS has been approved by the United States

Table 3. Results

	EBVS group ($n = 100$)	UCS group ($n = 100$)	Statistical significance[a]
Conversions to open surgery	0	1	ns
Major complications			
Right colectomies	0	2	ns
Left colectomies	0	0	
Low anterior resection	0	0	
Mean operating time (min)			
Right colectomies	111 (70–195)	133 (95–190)	ns
Left colectomies	140 (120–170)	176 (95–240)	ns
Low anterior resection	153 (130–220)	201 (145–320)	ns
Mean blood loss (ml)			
Right colectomies	115 (30–160)	370 (150–680)	$p < 0.001$
Left colectomies	150 (70–220)	455 (270–845)	$p < 0.001$
Low anterior resection	185 (100–285)	495 (280–900)	$p = 0.002$
Mean postoperative hospital stay (days) (uncomplicated cases)			
Right colectomies	5.2 (4–6)	6.1 (5–7)	ns
Left colectomies	6.5 (5–7)	7.1 (5–8)	ns
Low anterior resection	6.8 (5–8)	7.3 (6–8)	ns

ns = difference not statistically significant
[a] χ^2 and t test

Food and Drug Administration to seal vessels up to 7 mm in diameter. In addition, EBVS and UCS did not differ in thermal tissue spread [7]. Recently developed EBVS devices are designed to reduce the risk of heat conduction toward adjacent structures by an active feedback control to limit the power output. Complications from thermal injuries caused by the UCS laparosonic blade overheating the viscera or organs have been described [2].

In 2003 Dubuq–Lissoir [4] presented a series of eight laparoscopic radical hysterectomies, six pelvic lymph node dissections, and one oophorectomy performed using a bipolar radio frequency generator and a 5-mm grasper dissector. In that series, EBVS was able to laparoscopically seal uterine arteries at their origin and major vessels in every procedure. One minor rebleeding episode occurred while sealing the uterosacral ligament and required regrasp and hemostasis. Comparing his experience with EBVS with that using standard laparoscopic tools, the author found that operating time was about two hours less with EBVS. The author had success with using the 5-mm EBVS as a dissector because of its smooth and atraumatic tip (Fig. 2).

Akari et al. [1] conducted a retrospective study to compare 15 hand-assisted total colectomies using UCS to 18 using the EBVS Atlas 10 mm. The operating time was 55 min longer with the UCS, but a major rebleeding episode requiring reoperation occurred in the EBVS group.

Marcello et al. [11] summarized their prospective randomized study of Ligasure Atlas 10 mm compared with titanium clips/vascular stapler. They enrolled about 50 patients in each group in which formal right and left colectomies were performed, among other procedures. The main purpose of the study was to assess costs, technical versatility, and operating time, testing the effectiveness or failure of the Ligasure and the titanium clips/vascular stapler on vascular pedicle ligation. Although not statistically significant, a slight difference was observed in operating time and costs in favor of the Atlas.

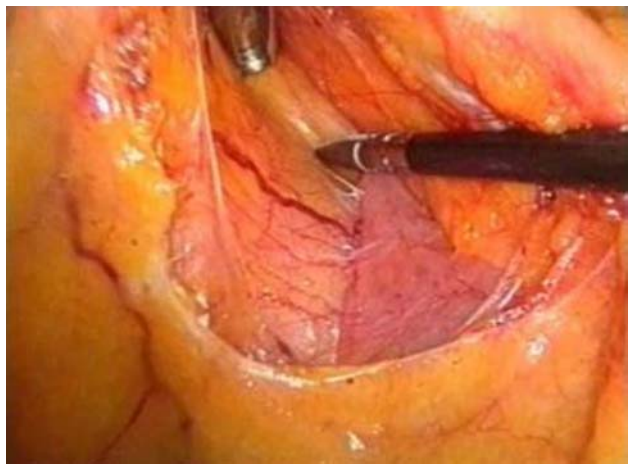

Fig. 2. Ligasure V used as dissector close to duodenum wall in right colectomy

We have been using 5- and 10-mm UCS devices in our laparoscopic colorectal resections for several years, with significant improvements in bleeding control and operating time. We achieved better hemostasis with UCS than with the mono-bipolar coagulator, but rebleedings did not go to zero. In operating time reduction, hemostasis played a role as well as expertise; practice with the UCS increased its use as dissector, grasper, or coagulator. On the one hand, that reduced the number of instruments in operating field. On the other hand, there was a serious negative aftermath consisting of a late perforation of the duodenum after the overheated blade of the UCS made contact. This complication required a second surgical procedure and percutaneous drainage of a large paraduodenal abscess. The patient complained of right flank pain and fever after many days with significant discomfort and delay of discharge from the hospital.

The remaining major complication of the UCS group, ileal microperforation, might have originated from both manipulation and UCS primary injury, underscoring the importance of maneuvers and reducing the number of instruments in the operating field. In fact, since late 2004 the 5-mm stem Ligasure V device has been used in almost all our procedures. The Ligasure V 5 mm sealer/divider is a multifunctional instrument that enables us to dissect, grasp, seal, and divide minor vessels without having to isolate them. Hand-switch use, also available in the new UCS Ace (Ethicon Endo-Surgery, Cincinnati, OH), resulted in excellent ergonomics and made it easier than searching for a foot switch, as occurs when using EBVS Atlas 10 mm. Moreover, its small jaws and fine tips allowed access to tissue structures in confined spaces and fine dissection.

As detailed in our present series, left colectomy and anterior resection have always been performed with 5-mm EBVS, while in some right resections, the Atlas 10 mm was used. The Atlas EBVS was used in all Miles abdominoperineal resections and proved impressive beyond the abdominal phase with respect to saving time and bleeding during perineal dissection. In our EBVS series we found statistically significant less bleeding compared with UCS cases in all procedures. This may have contributed to the shorter postoperative hospital stay. Hemostasis failure or rebleeding not only lengthens the operating time but also requires additional maneuvers to control it. In fact, often the bleeding or rebleeding source may be found by grasping and lifting the viscera or mesenteric sheet. Repeated manipulation is potentially dangerous for iatrogenic visceral and mesenteric lesions. Moreover, there are well-defined inflammatory and neurogenic adverse effects related to mesenteric and visceral traction, namely, mesenteric traction syndrome (MTS). Mesenteric traction of the small intestine may cause histamine release from mesenteric mast cells with intraoperative tachycardia and hypotension. Nonetheless, in addition to this immediate effect, intestinal manipulation during surgery is known to cause an enteric molecular inflammatory response involving leucocytes, interleukin, and other inflammatory factors [13]. This leads to neurogenic inhibitory pathways, with neuromuscular function impairment inhibiting the gastrointestinal tract motility [3, 5]. Therefore, despite this empirical deduction, the shorter postoperative hospital stay, as result of earlier bowel movement and oral intake, in our EBVS group might be related in part to surgical cutting throughout the procedure.

In this study we compared 200 unselected consecutive cases in which UCS and EBVS devices were used. This was not a randomized prospective study, so some biases are unavoidable. However, it is our impression that peculiar biases related to this retrospective nonrandomized study are partly diluted by the number of procedures included, i.e., 100 in each group. According to comments about selection criteria for patients by Franklin et al. [6], we believe the present study's end point, and the aim of our parallel study on long-term followup of about 235 patients who underwent laparoscopic colorectal resection for cancer [9], were equally representative despite the nonrandomization. Furthermore, ethical questions may result in using randomization while the advantages of EBVS were quite obvious, leaving oncologic criteria unchanged by the study. In all events, reducing operating time and postoperative stay on the basis of potential biases does not make the results in the EBVS series negligible. In addition, in this series both UCS and EBVS colorectal resections were outside the learning curve because of our overall experience with over 700 laparoscopic procedures in over a decade. Moreover, all procedures were performed or supervised by the same surgical team thus strengthening the reliability of not only the oncologic results but of data on operating time or bleeding. Despite the above-mentioned considerations, we believe that the design of this study intrinsically exposed it to founded criticisms. For instance, the experience gained with UCS before the EBVS probably resulted in some advantages in terms of dexterity and operating time saving in the EBVS series. There also was a different technical step between the two groups, likely favoring the EBVS. In fact, the titanium clips used over all vessels in the UCS but only for inferior mesenteric artery in the EBVS patients might have had an effect on operating time. Even if these aspects seemed to have slight effect on the definitive results, they remain factors that are not quite negligible.

Conclusions

In this study the use of EBVS Ligasure V seems to offer some advantages in laparoscopic colorectal resection by means of technology and ergonomics, with respect to blood loss, operating time, and postoperative course/hospital stay. We await more studies confirming our results.

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