Can ultrasonic surgical devices be used to close the appendicular stump?

Ann. Ital. Chir., 2017 88, 6: 562-566
pii: S0003469X17027452

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Laparoscopic appendectomy is increasingly being performed because of its quick recovery time, low instance of wound infection, and early return of patients to home and work. Operating time should be short yet safe. Therefore, in this study, we compared the effects of various sealing systems on the length of surgery and examined whether these systems could be used to separate the appendix from its stump successfully. This prospective and randomized ex vivo study was conducted on 20 consecutive patients diagnosed with acute appendicitis. All patients underwent classical open appendectomy. The patients were classified into two groups according to the type of sealing system used. The LigaSure® system was used for coagulation in Group L and the Harmonic® system in Group H. After coagulation, a pressure system was used to evaluate the closure of the appendix. Results showed that the use of ultrasonic instruments alone to close the appendiceal stump caused an incomplete closure.

KEY WORDS: Appendicular stump, Laparoscopic appendectomy

Introduction

Laparoscopic appendectomy is increasingly being performed because of its quick recovery time. The method was first described in 1983 by Semm and was first performed in 1987 by Shreiber[1]. It presents a lower instance of wound infection, a faster recovery time, and an earlier return home for the patient compared with open appendectomy [2,3]. Laparoscopic appendectomy has become the standard appendectomy method in some clinics. When performed successfully using a single-port laparoscopic device, it is called single-incision laparoscopic appendectomy [4].

The various methods (e.g., use of Endoloops, Endo GIA, and polymeric clips) to close the appendiceal stump in laparoscopic surgery have been compared in the literature. In experimental and clinical studies, electrothermal bipolar vessel sealing (EBVS) systems have been shown to safely seal blood vessels up to 7 mm in diameter and to safely close the appendiceal stump [5-7].
The Harmonic® instrument is an ultrasonic surgical device that simultaneously cuts and denatures tissue. Its scalpel vibrates at a frequency of approximately 55,500 Hz/s. These high-frequency vibrations cause stress and friction in the tissue molecules, thus leading to protein denaturation. The device causes minimal energy transfer to the surrounding tissue [8]. It has four actions on tissue: cutting, coaptation, coagulation, and cavitation [9].
We performed this study to clinically compare the performance of the Harmonic® Ace laparoscopic instrument(Ethicon Endo-Surgery, Cincinnati, OH, USA) with that of the LigaSure® 5 mm laparoscopic instrument (Tyco Healthcare Valleylab, Boulder, CO, USA), a feedback-controlled EBVS system.

Pervenuto in Redazione Giugno 2017. Accettato per la pubblicazione Luglio 2017
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Methodology

This prospective and randomized ex vivo study was conducted on 20 consecutive patients who had been clinically and/or radiologically diagnosed with acute appendicitis at the General Surgery Clinic of Harran University School of Medicine. All patients underwent open appendectomy for acute appendicitis. Surgery was performed by a single surgical team. Ethical approval for the study was obtained from the ethics committee of our university, and a written consent was obtained from all patients prior to the commencement of the study.

Procedure

The study had two components. First, we investigated the relationship between the appendix size and diameter and the level of explosive pressure. Second, we considered the effects of the instruments used, namely, the instruments' resistive power in terms of the amount (in mm/Hg) of explosive pressure needed to generate an adhesive force and the effectiveness of the relationship with the appendiceal length-to-diameter ratio.

Patients with abdominal pain who had been diagnosed with acute appendicitis and had undergone appendectomy were included in the study. Demographic data were collected from the enrolled patients.

The patients underwent appendectomy with a McBurney's incision under general anesthesia. The mesoappendix and appendicular artery were ligated using a 3/0 polyglactin 910 suture (Vicryl®; Ethicon). After separating the appendix from its stump, the stump was buried in the cecum with purse-string-style sutures with a Vicryl® round pin. During surgery, another surgeon recorded the diameter and the length of the removed appendix.

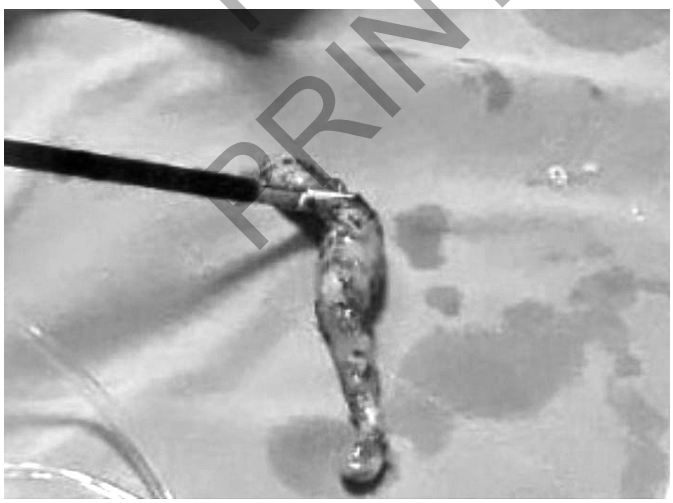

Fig. 1: Closing the appendicular stump again.

Fig. 2: Pressurizing the appendix with a sphygmomanometer.

In the first group of patients (group H), the Harmonic® device was used to close the proximal portion of the appendix. This closure was performed with the device set to level 5 (reduced cutting and increased coagulation) and was discontinued when the tissue had been separated completely. In the second group of patients (group L), the LigaSure® device was used to close the appendix. The device was set to level 3, and its scissors were used to cut the tissue when a warning from the feedback control was received (Fig. 1).

When this process had been completed, the tissue was allowed to cool for approximately 10 min. A 21-G injector needle (Bicakcilar, Istanbul, Turkey) was then inserted into the appendix and connected to a serum pressure system. After air had been removed from the serum system, 1000 cc of 0.9% NaCl solution (Kansuk, Istanbul, Turkey) packaged in polyvinyl chloride was inserted into the other end. The serum package was then pressurized using a sphygmomanometer cuff until it exploded (Fig. 2). The type of closing device, explosive pressure, and appendix size were recorded for each patient.

Statistical Analysis

The Kolmogorov–Smirnov test was used for the initial data analysis. The independent-samples *t*-test was used to analyze the parametric variables, and Fisher's exact test was used for the categorical variables. P values < 0.05 were considered statistically significant. Data were analyzed using the SPSS statistical software package (v. 18.0 for Windows; SPSS Inc., Chicago, IL, USA).

Results

We observed no relationship between explosive pressure and diameter or length of the appendix. Explosive pressure did not differ according to patient age or sex, but it differed significantly between groups (Tables I, II).
Appendiceal closure procedures provided significantly greater resistive pressure in group L than in group H (p = 0.016). Explosive pressure was <80 mmHg in six patients in group H. If cecum pressure exceeded 80 mmHg in these patients, the use of the Harmonic® device would not achieve successful closure of the appendiceal stump.

Discussion

The superiority of laparoscopic appendectomy for infection can not be ruled out. In a study done in terms of wound infection, comparison of laparoscopic with open appendectomy was found to be zero compared to 5.7% in cases of minimal or non-inflame cases. In case of suppurative, gangrenous or perforated cases, this ratio was 9.1% to 17.6%, respectively [10].
Stump closure is one of the most important stages in laparoscopic appendectomy. If a problem occurs at this stage, severe complications can develop from an operation that is otherwise considered relatively simple.
Endo GIA, Endoloops, and clips can be used for stump closure, but the determination of the safest and least expensive method remains controversial. It is safe to use endoloop and titanium clips in relatively low grade appendicitis, but different methods should be used in cases of phlegmonous, gangrenous or perityphlitic abscess [11-12].
The degree of expansion into the walls of an organ is calculated by Laplace's law and is related directly to the luminal diameter and inner organ pressure (expansion = pressure diameter). The cecum is the part of the colon that swells the most underpressure because of its large diameter. In colonoscopy, colonic injury (barotrauma) can occur when pressure exceeds 80 mmHg [13]. After appendectomy, the appendiceal stump may also be exposed to this pressure. We suggest that explosive pressure < 80 mmHg should not be considered safe and that this value should be the minimum pressure for the intraluminal side of the appendix. The LigaSure® and Harmonic® devices can both be used to close the lumen, but the introduction of appropriate pressure is required. A review of the literature identified only experimental studies, which were not conducted on humans. In patients undergoing right hemicolectomy, the maximum pressure that the cecum can tolerate can be measured using the method described above. We included this study in terms of evaluating evidence-based medicine.
Ultrasonic devices can be used safely in organs with lumen-free microvascular structures [14-16]. EBVS systems are not ultrasonic, and their effects are derived from radiofrequency energy originating from an electric current. These systems have feedback control systems with a working range of 2-4 s, and they cause the dissipa-

TABLE I - *Statistical analysis of Groups L and H*

	Group L	Group H	*P*
Age (Mean±SD)	30.30±11.17	31.2±7.94	0.838
Gender (M/F)	8/2	7/3	1
Appendix Length (Mean±SD) (cm)	8.4±1.64	9.6±2.63	0.237
Appendix Diameter (Mean±SD) (mm)	10.3±1.33	10.1±1.44	0.752
Explosion Pressure (Mean±SD) (mm/Hg)	230±50.77	129±109.38	**0.016**
(*P*<0.05 is significant)			

TABLE II - *Correlation analysis of Groups L and H*

Group L:	A	AL	AD	EP	Group H:	A	AL	AD	EP
A (r)		0.077	0.12	-0.027			0.142	0.481	-0.053
(p)	0.832	0.742	0.94				0.695	0.16	0.883
AL(r)		-0.061	0.452					-0.309	0.377
(p)		0.868	0.19					0.386	0.284
AD(r)			0.033						0.295
(p)			0.928						0.408

A: Age; AL: Apendix Length (cm); AD: Apendix Diameter (mm); EP: Explosion Pressure (mm/Hg); (*P*<0.05 is significant)

tion of more heat into the surrounding tissue [17]. This large amount of heat causes collagen denaturation on the tissue wall. An experimental study demonstrated that EBVS systems completely close the lumen of the appendix microscopically [5], but the edematous nature of tissue in true appendicitis, which changes the cell morphology, should be borne in mind. Studies also showed that these systems could be used for gastrointestinal anastomosis [18]. In an experimental study of 15 rabbits, LigaSure® was shown to be safe with applying to 7 caecum and 8 intestinal resections [19].

Postoperative leaks secondary to coagulation and inflammation increase the rate of abscess formation. The use of a stapler is the most reliable way to prevent this complication, but it is more expensive than using the Endoloop [20]. A meta-analysis showed that the use of endoclips prolongs the operation time but renders the operation more effective, safe, and cost effective. The authors of this meta-analysis did not recommend the use of a coagulation instrument alone because they found it inadequate [21].

Conclusion

Laparoscopic appendectomy is now being performed with increasing frequency. The preference for this method is based on its reduced rate of wound infection, reduced hospital stay, accelerated return to work, and ability to minimize the development of postoperative herniation. Operation time must be short to ensure patient comfort, but the operating cost should also not be forgotten. In this study, we demonstrated that the complete closure of the appendiceal stump might not be achieved with the use of an ultrasonic instrument alone. We found that the use of ultrasonic devices for stump closure in appendectomies was not safe.

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