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ORIGINAL ARTICLE

# Analysis of endoloops and endostaples for closing the appendiceal stump during laparoscopic appendectomy

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**Abstract**
*Purpose* An inadequate closure of the appendiceal stump can lead to intra-abdominal surgical site infections. The aim of this study was to assess the efficiency of different closure techniques by focusing on the intraoperative and postoperative complications versus cost.
*Methods* From June 2011 to June 2013, 333 patients from two different hospitals undergoing laparoscopic appendectomy were included in this study. The patients were divided into two groups based on the technique used for appendiceal stump closure: there were 104 patients in the stapler group and 229 in the loop group.
*Results* Among the 333 patients who underwent laparoscopic appendectomy, there were two (0.6 %) intraoperative complications and 22 (6.6 %) postoperative complications. There were no significant differences between the groups with respect to the intraoperative and postoperative complications. The length of the operation was 7 min shorter when the endoloop was used ($p = 0.014$). The mean costs of the operation were significantly lower when the loop was used (€ 554.93) compared to the stapler (€ 900.70) ($p = 0.000$).
*Conclusions* There is no clinical evidence supporting the routine use of endoscopic staplers. The appendiceal stump can be secured safely with the use of endoloops in the majority of patients. Surgeons have to be more selective when choosing how to perform closure, and an endostapler should be used only in cases where it is clinically indicated.

**Keywords** Appendicitis · Laparoscopic appendectomy · Appendiceal stump closure · Endoloop · Stapler

## Introduction

Acute appendicitis is the most common indication for intra-abdominal emergency surgery, and appendectomy is one of the most commonly performed procedures in abdominal surgery [1]. Although laparoscopic appendectomy (LA) has not yet achieved the status of a "Gold Standard" treatment, it is being progressively accepted as the treatment of choice for acute appendicitis. Numerous studies have shown many benefits of LA, including a faster recovery, less postoperative pain, reduced wound infections, shorter hospital stay and earlier return to work [1–3]. LA also offers surgeons a better visualization and identification of another abdominal pathology that can mimic acute appendicitis [4, 5]. Although the technique used for LA was first described more than 20 years ago, the technical details are still being modified, and improvements can be measured in terms of complications and costs. There are several technical variations that can potentially affect the

M. Rakić · R. Kliček · L. Patrlj
Department of Surgery, University Hospital Dubrava, Avenija Gojka Šuška 6, 10000 Zagreb, Croatia

M. Jukić
University of Split, School of Medicine, Šoltanska 2, 21000 Split, Croatia

Z. Pogorelić (✉)
Department of Pediatric Surgery, Split University Hospital Centre, Spinčićeva 1, 21000 Split, Croatia
e-mail: zenon@vip.hr

I. Mrklić
Department of Pathology, Split University Hospital Centre, Spinčićeva 1, 21000 Split, Croatia

N. Družijanić · Z. Perko
Department of Surgery, Split University Hospital Centre, Spinčićeva 1, 21000 Split, Croatia

outcome of LA, including the techniques used for skeletonization of the appendix, the use of single-port versus multiple-port instrumentation and the technique used for closure of the appendiceal stump.

The base of the appendix is most frequently closed using staplers or endoloop ligatures [3, 6–8]. Currently, some authors recommend the routine use of staplers to avoid leakage from the appendiceal stump, while others recommend endoloops as an economic, feasible and safe alternative [3, 6–10]. Both techniques are safe and are routinely used, but both have potential drawbacks. Complications attributable to stump closure are rare, which means that many studies will be needed to show the superiority of either method. Linear staplers are more expensive than loops, require a 12-mm port for their introduction and leave metal staples on the stump that can cause adhesion-related short bowel obstruction [11–13]. Loops are associated with more manipulation of the stump and can potentially slip, which can cause intraabdominal abscess formation. Loops are not safe for closure of the cecum when the base of the appendix is perforated, or if the inflammation of the appendix has also involved the cecum [10, 11]. The aim of this study was therefore to assess the efficiency of each technique by focusing on the intraoperative and postoperative complications versus cost.

## Materials and methods

### Patients

A total number of 333 patients (188 males and 155 females) who underwent LA because of suspected appendicitis between June 2011 and June 2013 in the Departments of Surgery and Pediatric Surgery, Split University Hospital Centre and Department of Surgery, Dubrava University Hospital, Zagreb were enrolled in the study. The study was carried out as a cross-sectional multicenter trial. Informed consent was obtained from all the patients (or their parents, in the case of pediatric patients) and the Ethics Committees of both hospitals approved the study protocol.

All patients with suspected appendicitis who were 5- to 80-year old were enrolled in the study. The exclusion criteria were patients younger than 5-year old, or older than 80 years of age, those who required conversion to open appendectomy (OA), those who needed application of a clip for stump closure and patients who refused LA.

The technique used for closure of the appendiceal stump (loop or stapler) was chosen based on the operating surgeon's personal preference. The data were grouped according to the stump closure technique; a stapler group (104 patients; 31.2 %) and an endoloop group (229 patients; 68.8 %). In each group, the patients were divided in three subgroups based on the intraoperative and histopathological findings (acute appendicitis, perforated appendicitis and other/no pathology). Preoperatively, all patients underwent a clinical examination and laboratory analysis. In most of the patients, abdominal ultrasonography was performed. The patient data are summarized in Table 1.

### Hypothesis and outcome measures

The primary endpoint of this study was to test the hypothesis that there would be a higher frequency of postoperative complications in patients in whom the appendiceal stump was secured using endoscopic loops compared to the patients in whom an endostapler was used for securing the appendiceal stump in laparoscopic appendectomy.

The primary outcome measure was the rate of intraabdominal surgical-site infections, defined as a postoperative intraabdominal abscess and peritonitis. The secondary outcome variables were the intraoperative and postoperative complications, duration of the operation, hospital stay, rate of reoperations and the differences in the costs of the operation.

The intraoperative complications included access-related complications, such as organ lesions and intraperitoneal bleeding. Postoperative complications included bleeding into the abdominal wall, wound infection, postoperative ileus, small bowel obstruction and formation of an intraabdominal abscess.

The price of the described stapler was set at € 378.50 (Endopath-Endocutter ATG45, Ethicon Endo-surgery, Cincinnati, OH, USA) and the price of the endoloop was set at € 32.80 (Vicryl-Endoloop 0; Ethicon Endo-surgery, Cincinnati, OH, USA) for assessment of the difference in the direct costs of the operation.

### Surgery

LA was performed using a three-trocar technique with a combination of 5- and 10-mm trocars. When loops were used, the 10-mm trocar was placed supraumbilically, and one of the two 5-mm trocars was placed in the left lower abdomen and the other was placed in the right upper abdomen. One loop was placed at the base of the appendix and one clip was placed distally, and the appendix was divided between the loop and clip with the device used for dissecting the mesoappendix.

When staples were used, a 12-mm trocar was placed in the left lower abdomen for the stapler and a disposable specimen retrieval bag; one 5-mm trocar was placed supraumbilically and another 5-mm trocar was placed in the

**Table 1** The demographic, laboratory and clinical data, and the treatment outcomes of the patients who underwent laparoscopic appendectomy

| | Group I Stapler ($n = 104$) | Group II Loop ($n = 229$) | $p$ |
|---|---|---|---|
| Demographic data | | | |
| Age (years) | 38 (9–80) | 26 (6–74) | 0.000* |
| Gender (M/F) $n$, (%) | 60/44 (57 %/43 %) | 118/111 (52 %/48 %) | 0.367** |
| BMI (kg/m$^2$) | 25.5 (17–34) | 22.1 (18–30) | 0.093* |
| Preoperative laboratory values | | | |
| Leukocytes ($\times 10^9$/L) | 13.5 (7.0–22.0) | 14.1 (5.5–34.6) | 0.200* |
| CRP (mg/dL) | 53.24 (0.30–244.0) | 49.22 (0.1–379.0) | 0.641* |
| Neutrophils (%) | 79.5 (65.4–92.0) | 81.4 (70.5–93.1) | 0.354* |
| Clinical data | | | |
| Duration of symptoms (h) | 39 (4–360) | 32 (3–240) | 0.078* |
| Body temperature (°C) | 37.6 (36.5–39.0) | 37.4 (36.8–39.5) | 0.754* |
| Migration of pain in the right lower quadrant of the abdomen | 80 (77 %) | 174 (76 %) | 0.851** |
| Localized pain (Blumberg +, Rovsing +) | 89 (86 %) | 205 (89 %) | 0.100** |
| Treatment outcomes | | | |
| Duration of surgery (min) | 55 (20–130) | 48 (18–170) | 0.014* |
| Hospital stay (days) | 3.6 (2–10) | 4 (1–17) | 0.060* |
| Reoperation ($n$, %) | 2 (1.9 %) | 1 (0.4 %) | 0.183** |

* $t$ test

** Chi-square test

right lower abdomen. One stapler load was used to divide the appendix. In all cases, a 5-mm scope was used through the supraumbilical trocar. The mesoappendix was dissected, depending on the surgeons' preferences, with either a harmonic scalpel (Ultracision™, Ethicon Endo-surgery, Cincinnati, OH, USA), a bipolar tissue sealing system (Ligasure™, Valleylab, Boulder, CO, USA) or using thermal fusion technology (MiSeal™, Microline). Each specimen was retrieved inside a disposable specimen retrieval bag (Ecosac EMP 70, Espiner Medical Ltd.) through the largest trocar.

### Statistical analysis

The data were analyzed using the Microsoft Excel for Windows Version 11.0 (Microsoft Corporation, USA) and Statistica for Windows Release 12.0 (Statsoft Inc., Tulsa, OK, USA) software programs. Student's $t$ test was used to analyze the continuous data and the Chi-square test was used for the statistical analysis of the categorical data. All values of $p < 0.05$ were considered to indicate statistical significance.

## Results

A total of 333 patients were included in the study; 104 in the stapler group and 229 in the loop group. An analysis of the patient data showed that there was a significant difference between the endoloop group and the stapler group only with respect to age. The mean age of patients in the stapler group was 38 (9–80) years, and that in the loop group was 26 (4–74) years ($p = 0.000$) (Table 1). There were no significant differences between the two groups regarding the gender, BMI, preoperative laboratory values (white blood cell count, C-reactive protein level, neutrophil count) or clinical data (duration of symptoms, body temperature, local clinical findings) (Table 1).

The mean duration of surgery was 55 (20–130) min when a stapler was used compared with 48 (18–170) min when endoloops were used ($p = 0.014$). The mean hospital stay was 3.6 (2–10) days for the stapler group and 4.0 (1–17) days for the endoloop group ($p = 0.060$). Only two patients required reoperation in the stapler group, and one patient required reoperation in the loop group ($p = 0.183$) (Table 1).

A histopathological analysis revealed a positive diagnosis of appendicitis in 280 patients (84.1 %). There were 33 patients (9.9 %) with an innocent appendix and 20 patients (6.0 %) with other pathology (Table 2).

Among the 333 patients who underwent LA, there were two (0.6 %) cases with intraoperative complications (one thermal organ injury and one case of bleeding from the mesoappendix) and there were 22 (6.6 %) postoperative complications. There were seven (2.1 %) wound infections (four in the stapler group, three in the loop group), seven (2.1 %) intraabdominal abscesses (three in the stapler group, four in the loop group), five (1.5 %) small bowel obstructions (two in the stapler group, three in the loop group), two (0.6 %) cases of trocar site bleeding (one in the stapler group and one in the loop group) and one (0.3 %)

**Table 2** The histopathological findings in patients who underwent laparoscopic appendectomy

| Histopathological findings of the appendix | Group I STAPLER ($n = 104$) | Group II LOOP ($n = 229$) | TOTAL ($n = 333$) |
|---|---|---|---|
| Phlegmonous ($n$) | 45 | 71 | 116 |
| Gangrenous ($n$) | 31 | 82 | 113 |
| Perforated ($n$) | 16 | 26 | 42 |
| Chronic ($n$) | 4 | 5 | 9 |
| No pathological findings ($n$) | 7 | 26 | 33 |
| Other pathology ($n$) | | | |
| Tuboovarian abscess | 1 | 2 | 20 |
| Acute inflammation of the fallopian tubes | 0 | 4 | |
| Torsion of ovarian/fallopian tube cysts | 0 | 7 | |
| Meckel's diverticulum | 0 | 2 | |
| Enterobiasis | 0 | 3 | |
| Torsion of the epiploic appendage | 0 | 1 | |

appendix stump insufficiency in the loop group. There were no significant differences between the endoloop group and the stapler group regarding the intraoperative and postoperative complications (Table 3).

We performed a reoperation in only three patients. The procedures used for treating the complications are shown in Table 4. The mean cost of supplies for LA using a stapler was € 900.70, and was € 554.93 using the loops ($p = 0.000$). The different prices of LA with regard to the device used for mesoappendix skeletonization are shown in Table 5.

## Discussion

Abdominal pain is one of the most common symptoms of patients seeking medical attention. Acute appendicitis is the most common cause of acute abdominal pain, and distinguishing appendicitis from other disorders is sometimes difficult, particularly in young, preverbal children [1, 3–8, 10, 14]. The acceptance of LA among surgeons is increasing [15, 16]. LA has been shown to be advantageous compared to OA in regard to early postoperative parameters such as postoperative pain and recovery of the bowel function, and is also associated with a lower wound infection rate [1–3]. Despite the lack of a clear outcome benefit of LA, most cost studies have confirmed a substantially higher cost of LA compared with AO, due to expensive disposable equipment used during the procedure [8, 17]. There are various reports regarding the risk of an intraabdominal abscess after LA, and the results varied from no difference in the rate of postoperative intraabdominal abscesses between LA and OA, to an increased incidence of intra-abdominal abscess formation after LA [1, 2, 15, 18, 19]. The focus of the technical aspects in LA has been the appendiceal stump closure.

The closure of the appendiceal stump is an important step during a LA, because most of the postoperative complications are caused by its inappropriate management. The development of life-threatening events such as stercoral fistulas, postoperative peritonitis and sepsis is included in these complications. Among the alternatives, studies advocate the use of an endostapler, endoloop, intracorporeal suturing, Gea extracorporeal sliding knot (GESK), titanium clips, polymeric clips and bipolar endocoagulation. All alternatives have advantages and disadvantages for the different clinical stages of acute appendicitis, but endoloops and endostaplers are used most frequently [3, 6–12, 15, 16, 20, 21]. An alternative to the expensive linear stapler or to the less expensive endoloop would be suture ligation of the appendiceal base. This could be safely achieved by intracorporeal suturing, or even faster using an extracorporeal sliding knot, such as the GESK. An experienced laparoscopic surgeon might consider this to be both the simplest and cheapest method. Arcovedo et al. [16] demonstrated in their study that the GESK is as secure as the stapler for closure of the appendiceal stump. The GESK could be passed through a 5-mm trocar, potentially avoiding the complications associated with a larger trocar site. The rate of complications using this method was similar to that of the other reported techniques used for appendiceal stump closure. They concluded that the GESK seems to be an economic and safe alternative to the stapler. Recently, the application of clips as an alternative option to close the appendix base in laparoscopic appendectomy has been described. Several papers have described the use of polymeric non-absorbable clips (Hem-o-lok) as a safe, feasible and cost-effective method [20–22]. In these studies, one or two clips were placed on the appendix stump. The largest recommended diameter of the appendicular stump that can be safely closed with this clip is 10 mm [20, 22]. However, the base of the appendix may often exceed this diameter in cases with acute inflammation.

Rickert et al. [20] used a titanium double-shanked clip (DS-Clip) in their study. They concluded that the titanium DS-Clip is a safe and cost-effective technique for securing the appendix base in laparoscopic appendectomy. The application is easy, and can be learned quickly, making it a good option for teaching hospitals. With this type of clip, appendix stumps with a diameter of up to 20 mm could be safely closed. The disadvantage of this method is the need for a 12.5-mm trocar for introducing the clip applicator. The price for a set of four clips is predicted to be around 80 €, depending on the region.

**Table 3** A comparison of the intraoperative and postoperative complications in relation to the intraoperative findings in patients who underwent laparoscopic appendectomy

| | Acute appendicitis | | | Perforated appendicitis (Peritonitis) | | | Other or no pathological substrate | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stapler ($n = 75$) | Loop ($n = 163$) | $p$** | Stapler ($n = 16$) | Loop ($n = 26$) | $p$** | Stapler ($n = 8$) | Loop ($n = 45$) | $p$** |
| Intraoperative complications | | | | | | | | | |
| Thermal injury of the cecum | 0 | 1 | 0.496 | 0 | 0 | – | 0 | 0 | – |
| Bleeding from the mesoappendix | 1 | 0 | 0.139 | 0 | 0 | – | 0 | 0 | – |
| Postoperative complications | | | | | | | | | |
| Wound infections | 3 | 3 | 0.344 | 0 | 0 | – | 1 | 0 | 0.07 |
| Intraabdominal abscess | 3 | 3 | 0.344 | 0 | 0 | – | 0 | 1 | 0.569 |
| Stump dehiscence | 0 | 0 | – | 0 | 0 | – | 0 | 1 | 0.569 |
| Ileus | 1 | 1 | 0.588 | 1 | 2 | 0.860 | 0 | 0 | – |
| Bleeding from a trocar site | 0 | 1 | 0.496 | 1 | 0 | 0.196 | 0 | 0 | – |

** Chi-square test

**Table 4** The procedures used to resolve complications

| | *N* | Intraoperative | Reoperation |
|---|---|---|---|
| Intraoperative complications | 2 | | |
| Thermal injury of the cecum | 1 | 1 | 0 |
| Bleeding from the mesoappendix | 1 | 1 | 0 |
| | *N* | Conservative | Reoperation |
| Postoperative complications | 22 | | |
| Wound infections | 7 | 7 | 0 |
| Intraabdominal abscess | 7 | 6 | 1 |
| Stump dehiscence | 1 | 0 | 1 |
| Ileus | 5 | 4 | 1 |
| Bleeding from a trocar site | 2 | 2 | 0 |

**Table 5** The average cost of laparoscopic appendectomy (disposable materials) between the two groups, depending on the device used for mesoappendix skeletonization

| | Group I Stapler | Group II Loop | $p$ |
|---|---|---|---|
| Harmonic scalpel (Ultracision) (€) | 1,027.50 | 681.70 | 0.000* |
| Bipolar coagulation (Ligasure) (€) | 797.70 | 451.90 | 0.000* |
| Thermal ligation (MiSeal) (€) | 876.90 | 531.10 | 0.000* |
| Mean value (€) | 970.70 | 554.90 | 0.000* |

* $t$ test

In this study, outcomes between two established laparoscopic techniques used for appendiceal stump closure have been compared: stapler and endoloop. The authors of a few prospective randomized studies recommended the use of the endostapler, although the results did not show a significant difference between the stapler and endoloop techniques with respect to intraabdominal abscess formation [3, 10, 11]. Myano et al. [10] did not find any significant differences in the incidence of intraabdominal abscess formation or other postoperative complications between the endostapler and endoloop groups in their study. The same results were found in a few similar studies [8, 15]. In our study, there was no tendency toward a higher rate of stump insufficiency and intraabdominal abscess formation due to inefficient closure of the base of the appendix among the loop cases; in fact, our data showed that staples and loops were both safe for stump closure.

In our study, the patients were divided in subgroups according to the intraoperative and histopathological findings: acute appendicitis, perforated appendicitis, other intra-abdominal pathology or no appendiceal inflammation. There were no significant differences in the intraoperative or postoperative complications between the subgroups. After performing a systematic review, Sajid et al. [23] concluded that endoloops may be used safely and preferably to secure the appendicular stump. Compared with using a stapler, it was found that endoloops were associated with an equivalent hospital stay, perioperative complication rate, and incidence of intraabdominal abscess. The techniques used for the loop placement play an important role in the final performance of this closure technique. The placement of two loops on the appendiceal stump has been suggested to provide more secure closure, but additional benefits of second loop placement were not reported. Beldi et al. [3] found that, in cases of acute appendicitis, the appendiceal base can be safely divided using one endoloop.

There are also different reports in the literature regarding the length of the operation between endostapler and

endoloop groups. Kazemier et al. [11] reported that the length of the operation was 9 min shorter if an endostapler was used. In contrast to their findings, Sahm et al. [15] reported that the length of the operation was 19 min longer if an endostapler was used. Similar to the findings reported by Sahm et al., in our study, the length of the operation was 7 min shorter for the loop group.

The selection of a stapler or endoloop and the method used for the extraction of the appendix are usually based on the preference of the surgeon and institution. Disposable costs frequently exceed hospital reimbursements. Currently, there is no scientific literature that clearly illustrates a superior surgical method for performing these portions of LA in routine cases. Chu et al. [24] suggested that surgeons should review the cost implications of their practice to provide the most cost-effective care without jeopardizing the clinical outcome. They also reported that the cost of the stapler and the staple loads accounted for approximately 70 % of the total disposable costs [24]. An endoscopic stapler with one cartridge can be readily replaced using more manual, less expensive methods, such as clips, reusable bipolar cautery, endoloops or hand-tied sutures.

The most important factor in deciding which technique to use in routine clinical practice is the cost-benefit analysis. The mean cost of supplies in Croatia for LA using a stapler is € 900.70 and is € 554.93 using a loop. We believe that surgeons have to be more selective, and this selectively should include appendiceal stump closure using cost-effective endoloops, with the selective use of a stapler in specific cases where it is indicated.

## Conclusion

Our study showed that there is no evidence for routine stapling to secure the appendiceal stump. The appendiceal stump can be secured safely with the use of endoloops in the majority of patients, and a selective use of a stapler should be considered in a small minority of patients. Using an endoloop is a safe and cost-effective method for securing the appendiceal stump. Based on our findings, we believe that the use of staplers significantly increases the cost and duration of an operation.

**Conflict of interest** Mislav Rakić and co-authors have no conflict of interest.

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