Endoloop versus endostapler: what is the best option for appendiceal stump closure in children with complicated appendicitis? Results of a multicentric international survey

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Abstract

Background There is a limited and conflicting evidence about the most appropriate method for appendiceal stump closure during laparoscopic appendectomy (LA). We aimed to compare endoloop (EL) versus endostapler (ES) for stump closure during LA for complicated perforated appendicitis in children.

Methods We retrospectively reviewed the records of 708 patients (463 boys and 245 girls with an average age of 9.8 years) who underwent LA for complicated appendicitis in 5 international centers of Pediatric Surgery over a 5-years period (January 2011–December 2016). The appendix was perforated with localized peritonitis in 470 cases and diffuse peritonitis in 238 patients. EL was used in 374 cases (G1), whereas ES was adopted in 334 cases (G2).

Results No intra-operative complication occurred in both groups but 5 conversions to open surgery were reported in G1 (1.3%) and 4 in G2 (1.1%) (OR 1.1; 95% CI 0.30–4.19). Use of EL was significantly associated with higher incidence of intra-abdominal abscess (OR 1.36; 95% CI 0.84–2.18), postoperative ileus (OR 3.61; 95% CI 0.76–17.11), and re-operations/readmissions (OR 6.46; 95% CI 1.46–28.62) compared to ES. The average cost of supplies for LA was significantly higher in G2 (€ 915.60) compared to G1 (€ 578.36) (p = 0.0001). The average cost of re-operations/readmissions was significantly higher in G1 (€ 4.091,39) compared to G2 (€ 2.127,88) (p = 0.0001) (OR 1.72; 95% CI 1.47–2.01).

Conclusions Our study is the first in the pediatric population to demonstrate that the method used for appendiceal stump closure may influence the outcome of LA in complicated appendicitis. Although ES is more expensive compared to EL, our results demonstrated that appendix stump closure should be performed using ES rather than EL in complicated perforated appendicitis since its use was associated with a lower incidence of postoperative intra-abdominal abscess and postoperative ileus and lower re-operations and readmissions rates and costs.

Keywords Complicated appendicitis · Laparoscopy · Endoloop · Endostapler · Abscess · Children

Laparoscopic appendectomy (LA) is being progressively accepted as the treatment of choice for acute appendicitis in pediatric population [1, 2]. Benefits of LA over open treatment include faster recovery, less operative pain, reduced wound infections, shorter hospitalization, and earlier return to full daily activities [3]. However, despite these benefits, LA is not without complications; in particular, a significant downside of laparoscopy is the reported higher prevalence of intra-abdominal abscesses [4].

On the other side, the incidence of postoperative complications is believed to be higher when appendicitis is complicated by perforation and/or peritonitis [5, 6]. More recent literature confirmed that the severity of appendicitis is the main risk factor for developing an infectious complication [7].
There are several technical variations that may potentially affect the outcome of LA, including the use of single-port versus multi-port techniques [8, 9] and the method used for closure of the appendiceal stump [10].

Although the surgical technique of laparoscopic appendectomy is well established, controversy still exists regarding the closure of the stump. Endostaplers and endoloop ligatures are the most frequently adopted methods to close the base of the appendix [11, 12].

Currently, some authors recommend the routine use of endostaplers to avoid the risk of leakage from the appendiceal stump, while other recommend endoloops as an economic, feasible, and safe alternative [11–15]. The incidence of postoperative complications such as intra-abdominal abscess is believed to be higher when endoloops are used for appendiceal stump closure, especially in cases of complicated appendicitis [5]. More recently, van Rossem et al. [7] stated that the type of appendix stump closure with either endoloops or an endostapler did not have an effect on the development of postoperative infectious complications. The gold standard manner of stump closure remains under debate.

For this reason, we decided to perform a multicentric, international study to compare the outcomes of LA using endoloop (EL) or endostapler (ES) for stump closure in children with complicated perforated appendicitis.

Materials and methods

We retrospectively reviewed the records of 708 patients who underwent LA for complicated appendicitis in 5 international centers of Pediatric Surgery over a 5-years period (January 2011–December 2016). Patients’ data were extrapolated from the databases of each participating center. We included in the study only cases of complicated appendicitis, with perforation of the appendix and localized or diffuse peritonitis. Exclusion criteria included phlegmonous appendicitis, appendiceal abscess or mass. The data were grouped according to the stump closure method: endoloop versus endostapler. The technique used for closure of the appendiceal stump (endoloop or endostapler) was chosen based on the operating surgeon’s personal preference.

The two groups were compared in regard to the incidence of intra-operative and postoperative complications, length of surgery, length of hospital stay, rates of re-operations and readmissions, costs of supplies, and costs of re-operations/readmissions. The intra-operative complications included access-related complications, such as organ lesions and intraperitoneal bleeding. Postoperative complications were assessed according to the Clavien–Dindo classification system [16] and included bleeding into the abdominal wall, formation of intra-abdominal abscess, wound infection, postoperative ileus, and small bowel obstruction. Any patient with clinical features suggestive of a postoperative intra-abdominal collection had abdominal US and, if confirmed, was started on antibiotics or prepared for US-guided or CT-guided drainage and, in case of failure, for surgical drainage.

In all cases, patients were discharged when they were afebrile, pain was managed by oral analgesics and oral intake was stable.

We calculated the average cost of supplies for LA in both the groups, considering all the supplies used for the intervention. Beside the specific device used for stump closure (endoloop or endostapler), we included also the costs of all disposable materials used for surgery including disposable trocars, the sealing device used for mesoappendix skeletonization, drainages. To calculate total cost, the price of the endostapler was set at € 378.50 and the price of the endoloop was set at € 32.50 for assessment of the difference on the direct costs of the operation.

We also calculated the average cost of re-operations/readmissions, including costs of surgery and hospitalization. This study received the appropriate Institute Review Board (IRB) approval.

Statistical analysis was carried out by using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA), version 13.0. Demographic data were compared using the Student’s t test. The χ2 test or Fisher’s exact test was used for analyzing the incidence of complications. Significance was defined as p < 0.05.

Surgical technique

LA was performed using a three-trocar technique, one 5- or 10-mm trocar placed umbilically as camera port and two 5-mm trocars placed in the left iliac fossa and suprapubically. The mesoappendix was dissected, depending on the surgeon’s preference, with either a bipolar tissue sealing system (LigaSure) or using thermal fusion technology (MiSeal, Microline).

In the endoloop group, the loops were placed over the base of the appendix and the appendix was divided between the loops. The use of one or two proximal loops and one distal loop was the standard method.

In the endostapler group, a 12-mm trocar was placed in the left lower abdomen for the stapler. The endostapler was fired at the base of the appendix with blue cartridges and a 35- or 45-mm blade. In case of inflammation of the cecum, the stapler was fired taking a rim of healthy cecum. In the last four patients, a 5-mm diameter endostapler was adopted.

The appendix was then extracted using a disposable specimen retrieval bag through the largest port site. Local suction and irrigation of abdominal fluids were performed when purulent fluids were present in the abdomen. The skin
incisions were routinely closed with separate resorbable sutures.

**Results**

Seven-hundred and eight patients from all participating centers were included in the study. There were 463 boys and 245 girls with an average age of 9.8 years (range 6.9–11.8) and an average weight of 45.7 kg (range 26–60). The appendix was perforated with localized peritonitis in 470 cases (66.4%) while a diffuse peritonitis was found in 238 patients (33.6%).

The data were grouped according to the stump closure method: an EL group, called G1, included 374 patients (52.8%) and an ES group, called G2, included 334 cases (47.2%).

Preoperatively, all patients underwent a clinical examination and laboratory analysis [WBC count, C-reactive protein (CRP)] and abdominal ultrasonography (US). All patients received the same antibiotic therapy protocol (cephalosporin + metronidazole) in the postoperative period. Laboratory analysis (WBC count, CRP) was repeated on postoperative days 1, 3, 5, and 7. Intravenous antibiotics were stopped once patients were afebrile for more than 24 h with normal white cell count.

The analysis of the patients’ demographics revealed that there was no significant difference between G1 and G2 in regard to patients’ average age at surgery, preoperative average white blood cell (WBC) count, and preoperative average C-reactive protein (CRP).

No intra-operative complication was recorded but five conversions to open surgery were reported in G1 (1.3%) and 4 in G2 (1.1%) (p = 0.55; OR 1.1; 95% CI 0.30–4.19) because of technical challenges related to severe adhesions.

There was no significant difference between the two groups in regard to average operative time, average analgesic requirement, average time of resumption of oral diet, average resumption of gastrointestinal (GI) transit, average length of hospital stay, average duration of antibiotic therapy. As for postoperative complications, use of EL was significantly associated with higher incidence of intra-abdominal abscess (OR 1.36; 95% CI 0.84–2.18) and postoperative ileus (OR 3.61; 95% CI 0.76–17.11) compared to ES. Incidence of wound infections was not significantly different between the two groups (G1: n = 4 or 1.0%; G2: n = 2 or 1.1%; OR 0.89; 95% CI 0.22–3.59).

In regard to management of postoperative complications, wound infections were treated with antibiotic therapy in all patients of both groups (II grade Clavien). Postoperative ileus was managed by nasojejunal tube decompression in all cases (II grade Clavien) except six cases of EL group (G1) who required surgical intervention for adhesiolysis (IIIb grade Clavien). Intra-abdominal abscesses were all managed with antibiotic therapy and/or US-guided or computed tomography (CT)-guided drainage (II grade Clavien) except ten patients (two G2 patients and eight G1 patients) who required, after failure of an attempt with imaging-guided drainage, surgical drainage under general anesthesia (IIIb grade Clavien).

Re-operations and readmissions rate was significantly higher in G1 (n = 14 or 3.7%) compared to G2 (n = 2 or 0.5%) (OR 6.46; 95% CI 1.46–28.62). The average cost of supplies for LA was significantly higher in G2 (€ 915.60) compared to G1 (€ 578.36) (p = 0.0001). The average cost of re-operations/readmissions was significantly higher in G1 (€ 4,091,39) compared to G2 (€ 2,127,88) (p = 0.0001) (OR 1.72; 95% CI 1.47–2.01).

Patients’ demographics and outcome parameters are reported in Table 1.

**Discussion**

Acute appendicitis is increasingly treated laparoscopically because of several reported advantages compared to open approach including faster recovery, less pain, and fewer wound infection rates [1–4]. Although the surgical technique of laparoscopic appendectomy is well established, the type of appendiceal stump closure is the most discussed technical aspect of a LA because it is believed that most of the postoperative complications are possibly caused by its inappropriate management [7, 17]. The most devastating complications after LA are of an infectious origin, mainly formation of intra-abdominal abscesses [4, 6]. This complication has significant clinical implications because often a re-intervention or readmission is required. Previous studies have suggested that there is an increased risk for postoperative complications, such as intra-abdominal abscess formation and small bowel obstruction, in complicated appendicitis, both in children and adults [6, 18]. More recent literature confirmed that the severity of appendicitis is the main risk factor for developing an infectious complication [7].

Although several methods for stump closure have been described until now, including endoloop, endostapler, intracorporeal suturing, titanium clips, polymeric clips, and bipolar endocoagulation, the most appropriate closure method is still under debate [9, 19–22]. Both endoloops and endostaplers are used most frequently in the current practice to close the appendix stump [10–14]. Both techniques are safe but both have potential drawbacks. Endostaplers are more expensive than endoloops, require a 12-mm port for their introduction, and leave metal staples on the stump that can cause adhesion-related small bowel obstruction [23–25]. Endoloops are associated with more manipulation of the stump and can potentially slip, causing intra-abdominal
abscess formation. Endoloops 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 [13, 23]. However, there is very few evidence about this topic in the current literature and available studies reported conflicting conclusions. Currently, some authors recommend the routine use of endostaplers to avoid the risk of leakage from the appendiceal stump, while other recommend endoloops as an economic, feasible, and safe alternative [10–13].

Complicated appendicitis is associated with more inflammation than uncomplicated appendicitis and it is generally believed that when the mesoappendix and the base of the appendix are gangrenous or fragile by perforation, use of endoloop is unsuitable [26]. Miyano et al. did not find any significant difference in the incidence of intra-abdominal abscess formation or other postoperative complications between the endostapler and endoloop groups in their study, focused only on complicated appendicitis [27]. The same results were found in the most recent paper published on this topic: the authors concluded that the severity of appendicitis was an independent risk factor for developing an infectious complication and the type of appendix stump closure with either endoloops or an endostapler did not have an effect on the development of postoperative infectious complications [7]. However, this paper was mainly based on adults’ data (76.3% of cases), whereas children represented only 23.7% of the study population.

We included in our study only cases of complicated appendicitis, with perforation of the appendix and localized or diffuse peritonitis. Both groups were homogeneous in regard to the anatomic–pathologic grade of the appendicitis and each surgeon decided to use endoloop or endostapler to close the appendix stump only on the base of the personal surgical experience. Since there was no difference in the rate of perforated appendices between the two groups, we could eliminate a potential bias and correlate the differences in the postoperative outcome between the

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two groups with the specific use of a device over another for the stump closure.

Our multicentric international (Europe and USA) survey is the first study focused only on a pediatric population to demonstrate that the method used for appendiceal stump closure may influence the outcome of LA in complicated perforated appendicitis. In our series, closure of the appendix stump using endoloops was associated with higher incidences of intra-abdominal abscess formation and postoperative ileus compared to use of endostapler. In addition, a higher re-operation rate was reported in the endoloop group compared to the endostapler group.

The only disadvantages in the use of endostapler, already reported in the previous studies [17, 27, 28], are the need of a 12-mm trocar to introduce the stapler and the high cost of the device. Use of endostapler also requires additional costs, including the disposable 12-mm trocar needed for its introduction. It should also be considered that the bigger port might be associated with more incisional hernia and worse cosmetics. However, new endostaplers of 5-mm diameter are now available on the market and we have started to adopt them in the last few operated cases. The diffusion of this instrumentation, as effective as the 12-mm device but with the enormous advantage of the 5-mm diameter, will allow to overcome the limit of 12 mm diameter of the most commonly adopted endostaplers.

As for technical point of view, when the stump closure is performed with endostapler, we have to place the trocar for the stapler in the left lower abdomen so as to reach easily the appendix with the stapler and to have a better ergonomics position to perform the appendix stump closure. In addition, several types of endostaplers are currently available; beside the traditional linear staplers with straight tips, there are some devices with roticulated or curved extremities with the aim to facilitate the placement of the anvil exactly where needed. However, in regard to the type of stapler, we did not find any difference among the different devices.

In our series we recorded a higher incidence of postoperative ileus in the endoloop group and only patients of endoloop group needed re-operation for adhesiolysis. These results are in contrast with the previously reported evidence that endostaplers leave metal staples on the stump that can cause adhesions-related small bowel obstruction [23–25]. We believe that the higher incidence of postoperative ileus that occurred after use of endoloop in our series was probably due to a more frequent occurrence of postoperative leakage from the stump in perforated appendicitis. The secondary inflammatory reaction would justify the higher rate of postoperative formation of parietal–epiploic adhesions requiring surgery.

Actually, the most important factor in deciding which technique to use in routine clinical practice is the cost–benefit analysis. As suggested by Chu et al. [29], surgeons should review the cost implications of their practice to provide the most cost-effective care without jeopardizing the clinical outcome.

We believe that the main indications to use the endostapler for appendix stump closure are cases with perforation or necrosis of the appendiceal base or cecum and a broad-based appendix and we suggest a selective use of the endostapler for appendiceal stump closure in such cases. The reason for this is the higher chance of cutting through an inflamed appendix base when using endoloops. The lower incidence of intra-abdominal abscesses and other postoperative complications reported in our series with use of endostapler was associated with lower re-operations and readmissions rates. In our series, the average cost of re-operations/readmissions was significantly higher in the endoloop group (€ 4.091,39) compared to endostapler group (€ 2.127,88) (OR 1.72; 95% CI 1.47–2.01). These data further confirmed that the lower re-operations and readmissions rates reported in our series with use of endostapler provided an effective economic advantage, despite the higher cost of the device.

As recently reported [17, 30], the most cost-effective disease-adapted strategy in laparoscopic appendectomy could be routine use of endoloops and use of an endostapler only when indicated. As reported in our study, the use of endostapler, despite its higher cost compared to endoloop, would be justified in cases with perforation or necrosis of the base of the appendix, also in hospitals that normally use endoloop for stump closure.

The limitations of our paper include its retrospective nature, the heterogeneous patients’ collection, and the multicenter aspect of the study, that made the data hardly comparable. Each center extrapolated the records of the patients from its own databases. Since the procedures were performed by different surgeons, also potential performance bias should be taken into consideration.

In conclusion, although endostapler is more expensive compared to endoloop, our results demonstrated that appendiceal stump closure should be performed using endostapler rather than endoloop in complicated appendicitis with perforation or necrosis of the appendiceal base since use of endostapler in such cases was associated with a better outcome of LA, with a lower incidence of postoperative intra-abdominal abscess formation and postoperative ileus and lower re-operations and readmissions rates and costs.

Compliance with ethical standards

Disclosure Drs Maria Escolino, Francois Becmeur, Amulya Saxena, Holger Till, George W. Holcomb 3rd, and Ciro Esposito declare that they have no conflicts of interest or financial ties to disclose.
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