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ORIGINAL ARTICLE

Is the use of endoloops safe and efficient for the closure of the appendicular stump in complicated and uncomplicated acute appendicitis?

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Abstract

Introduction There is still controversy regarding the ideal technique to close the appendicular stump in laparoscopic appendectomy (LA). The objective of this study was to determine the safety and efficiency of the use of an endoloop (EL) and endostapler (ES) in complicated and uncomplicated acute appendicitis.

Methods Retrospective cohort study of patients undergoing LA from February 2013 to December 2019. Acute uncomplicated and complicated appendicitis were analysed separately, establishing two groups according to the stump closure technique: EL or ES. Seven hundred-nine patients were included (535 uncomplicated and 174 complicated). In uncomplicated appendicitis, an EL was used in 447 of the patients (83.55%) and an ES was used in 88 patients (16.45%). In complicated appendicitis, an EL was used in 85 patients (48.85%) and an ES was used in 89 patients (51.15%). An analysis of effectiveness and a cost analysis of each technique were performed.

Results In uncomplicated appendicitis, we found no differences with respect to global complications, although there were significant differences in the total mean hospital stay (EL group 1.55 (SD 1.48) days; ES group 2.21 (SD 1.69) days; $p = 0.046$). This meant a savings of 514.12€ per patient using the EL $p < 0.001$). In complicated appendicitis, the reoperations classified as Clavien-Dindo IIIB in the EL group (6.4%) were greater than in the ES group (0%) ($p = 0.012$), although the rate of postoperative abscesses ($p = 0.788$) and the mean volume of abscesses ($p = 0.891$) were similar.

Conclusion The systematic use of an EL could reduce costs in uncomplicated appendicitis, while in complicated cases, both options are valid. Prospective studies with a greater number of patients are needed to observe differences in postoperative complications.

Keywords Appendicitis · Appendectomy · Laparoscopy · Surgical procedures · operative · Postoperative complications · Efficiency

Introduction

Acute appendicitis is one of the most common causes of surgical emergencies in the world, with an estimated 7–8% of the world population at risk [1, 2]. The laparoscopic approach has been considered the standard procedure for acute appendicitis [1–3]. When comparing laparoscopic appendectomy (LA) with open appendectomy, decreases in surgical site infections, tolerance time and hospital stay have been observed with LA [4, 5].

With regards to the surgical technique of LA, there are controversies related to the type of closure of the stump, with some alternatives being the most widely used in our experience: endoloop (EL) and endostapler (ES). Some authors think that the type of stump closure can make a difference with respect to postoperative complications, especially infectious complications due to leakage, and this is particularly true with complicated appendicitis. Numerous studies have reported conflicting conclusions on this topic, without reaching a consensus about which technique is superior [6–8]. The use of an EL in LA can increase the surgeon's learning curve,

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although the costs of the surgical intervention may be a safe alternative to the endostapler. In contrast, use of an endostapler (ES) has been recommended to avoid leakage of the stump and intra-abdominal abscesses in complicated appendicitis [7–12], although there have already been reports refuting this recommendation [6, 10, 13].

Based on this controversy, the main objective of our study was to establish the safety and efficiency of LA in cases of complicated and uncomplicated acute appendicitis depending on the surgical technique used to close the appendicular stump (EL or ES). The secondary objective of this study was to assess the efficiency of each technique by evaluating the hospital stay and the costs derived from the surgical material.

Material and methods

Sample description

A prospective registry of patients undergoing LA was performed. Seven hundred sixty patients who initially underwent LA at the Emergency Surgery Unit from February 2013 to December 2019 were identified, and the data was entered anonymously in a prospective database. This study has been approved by the hospital ethics committee. As this is a descriptive study, it was not necessary to provide informed consent to each participant. Exclusion criteria were defined as the following: conversion to open surgery; intraoperative findings not compatible with appendicitis or performing a surgical procedure other than an appendectomy. Of the patients, 709 were included and 51 were excluded. A descriptive analysis of the sample was carried out in addition to the reference values of the results established at the national level by the Spanish Association of Surgeons (Table 1). Complicated appendicitis was defined as a gangrenous perforation of the appendix visualised intraoperatively or during macroscopic analysis, as well as localised or diffuse peritonitis; all other cases were defined as uncomplicated appendicitis.

The patients were first grouped according to whether the appendicitis was complicated or uncomplicated, and were later subdivided according to the stump closure technique, EL or ES, which was chosen based on the surgeon's preferences, situation and availability of the material. In the uncomplicated appendicitis group, 535 patients were included (75.45% of the sample; 49.9% men), with a mean age of 32.32 (SD 14.46) years, while the complicated appendicitis group included 174 patients (24.55% of the sample; 60.34% men), with an average age of 32.32 (SD 14.46) years. The technique chosen for closure of the appendicular stump in 532 patients (75.03%) was the EL technique, while in 177 (24.97%) patients the ES technique was used (Fig. 1) Regarding the preoperative comorbidities of the patients, only two patients from the group with postoperative complications presented relevant concomitant pathology in the group of complicated appendicitis with von Willebrand disease (one in each subgroup). However, the rest of the patients did not present predisposing pathology, immunosuppression, anticoagulant or antiplatelet treatment.

Table 1 Description of the sample adjusted to the standard of the Spanish Association of Surgeons (SAS) for the Accreditation of Trauma and Emergency Surgery Units

Sample	Results	Standard SAS (*)
Age (years)	34.56 (SD 15.99)	
Sex		
Men	398 (52.36%)	
Women	362 (47.64%)	
Complicated appendicitis	174 (24.55%)	< 30%
Open-surgery conversion	21 (2.76%)	< 10%
Morbidity	62 (8.7%)	< 10%
Reintervention	8 (1.1%)	< 10%
Readmission	15 (2.1%)	< 10%

SD, standard deviation; *SAS*, the Spanish Association of Surgeons

Statistical analysis of safety and efficiency variables

The two subgroups (EL and ES) of each group (uncomplicated vs. complicated) were compared. The variables under study were defined as the following: the incidence of postoperative complications (postoperative complications were classified according to the Clavien-Dindo classification), hospital stay and the rate of reoperation and readmission. The safety assessment of the appendicular stump closure method was performed by comparing global postoperative complications, which were defined as postoperative bleeding, postoperative ileus, intra-abdominal abscess (rate of abscesses and volume of the abscess) or infection of the surgical wound. To identify intrahospital and out-of-hospital complications during the following 30 postoperative days, the hospital electronic system medical record database was evaluated in order to collect information on visits to the emergency department, postoperative images or interventions, as well as outpatient appointments with a prior appointment or hospital readmissions. In all cases, the patients were discharged from the hospital, with discharge criteria including afebrile patients and those with controlled pain with oral analgesia, intestinal transit and oral tolerance. The study of the technique's efficiency was carried out by comparing the costs of the material used in the intervention according to the acquisition prices by our hospital; the average stay of the first admission and the total stay (accumulated stay of the first admission and readmissions). The

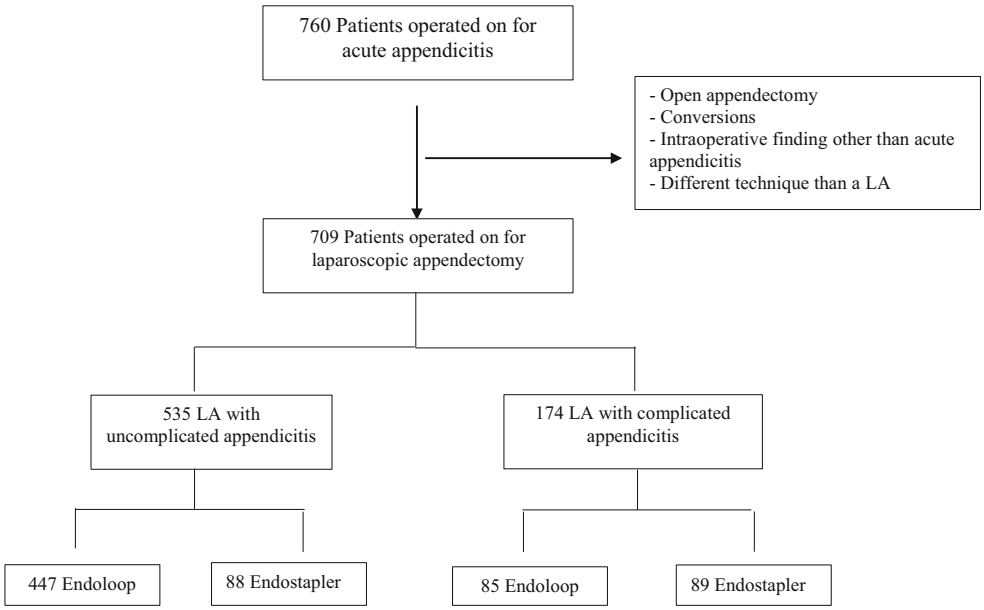

Fig. 1 Flow chart for patient selection and allocation to groups. LA, laparoscopic appendectomy

LA: Laparoscopic Appendectomy.

expenses derived from the hospital stay included the cost of the personnel that took care of the patient, cost of the material used during the stay and the cost of the drugs administered to the patient, average cost of the total stay and the total cost (total stay cost plus material cost). Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA), version 24.0. The qualitative variables were expressed in terms of absolute frequencies and percentages, while the average and standard deviation were used to express the quantitative variables. Data analysis was carried out using contingency tables in which Fisher's exact test, the chi square test and Spearman's test were applied for qualitative variables, and analysis of variance and the Student's *t* test were applied for quantitative variables. Values with $p < 0.05$ were considered statistically significant.

Surgical technique

LA was performed with the same surgical technique: pneumoperitoneum with Veress in the left hypochondrium (12–15 mmHg depending on the surgeon's preferences), 3 trocars were placed: 11 mm paraumbilical for optics, in the left iliac fossa (5 mm if an EL was used and 12 mm if an ES was used) and in the 5-mm hypogastrium. In the EL group, 3 loops were placed on the base of the appendix and the appendix was sectioned, leaving 2 proximal in the stump, with extraction of the distal with the piece. In this technique, the mesoappendix was dissected with monopolar energy. In the patients where the ES (Covidien® Multifire Endo GIA Auto Suture) was used, it was shot at the base of the appendix with a blue charge with a length of 35–30 mm. In these patients, the meso-appendix was dissected according to the surgeon's preferences, either with monopolar energy or with a 35–30 mm white-load stapler. The appendix was endobolically removed by the broader trocar. Aspiration drainage was left in highly selected cases of perforated appendicitis, depending on the preference of the surgeon. Eleven or 12-mm trocar closure was performed with absorbable suture, and skin closure was performed with apices.

Standard postoperative care procedure

Following the WSES Jerusalem guidelines [8], patients with uncomplicated appendicitis only had a preoperative dose of antibiotic, without prolonging the antibiotic therapy afterwards. In complicated appendicitis, antibiotic therapy was maintained in the postoperative period for 3–5 days. The antibiotic used was according to our hospital protocol based on local resistance: amoxicillin-clavulanate 875–125 mg/8 h or Ceftriaxone 1 g/24 h + Metronidazole 575 mg/8 h. In cases of suspicion of ESBL-producing germs, treatment with carbapenems was established, and in cases of risk factors for infection by pseudomonas, piperacillin-tazobactam 4–0'5 mg/8 h was used. The patients started oral tolerance 6–8 h after the intervention as long as it was not contra-indicated. Postsurgical analgesia was generally performed alternately, with paracetamol 1 g/8 h and metamizole 575 mg/8 h. Early ambulation of patients is encouraged. In the case of uncomplicated appendicitis, the patient was discharged approximately 24 h after the intervention. In complicated appendicitis, admission was prolonged until the patient presented clinical and analytical improvement.

Results

Uncomplicated appendicitis

In the uncomplicated appendicitis group, 535 patients were included, and they were divided according to the chosen technique of closure of the stump. In 447 patients, an EL was used (83.55%), and in 88 patients an ES was used (16.45%). In the comparative data analysis of the variables studied between the EL and ES, we found that the overall rate of postoperative complications between the two groups did not offer differences (OR 1.01 [0.28–3.58]), with $p = 0.98$. If we focus on the IIIB group, one of the patients required reoperation in the immediate postoperative period due to an obstruction secondary to adhesions, and one patient required percutaneous drainage of an intra-abdominal abscess. There were no significant differences in the postoperative bleeding rate, with p = 0.072 (all of them were managed conservatively) or postoperative ileus (OR 0.845 [0.1–7.1]) with $p = 0.877$. Regarding infectious complications, there were no surgical wound infections in patients who underwent surgery for uncomplicated appendicitis, and no statistically significant differences were found in postoperative abscess ($p = 0.237$). The mean volume of abscesses formed in the EL group was 57 cm^3 (SD 31.25) with a median volume of 66.1 cm^3. There were 5 readmissions in the 30 postoperative days, without differences between the 2 groups studied ($p = 0.405$) (Table 2).

In the efficiency study, the common costs of the two techniques involve an 11-mm optical trocar (€27.22), a 5-mm hypogastric trocar (€20.57), an endoclinch and an endodissector (€ 3.5) and an endobag (€34.48). Regarding the difference in the technique, when we performed the EL technique, an additional 5-mm trocar, 3 endoloops (€39.75) and endoscissors (€3.5) were used, while in the ES technique, an additional 12-mm trocar (€24.02) and 1 endoGIA with 2 loads of the stapler (€211.75) were used. On the other hand, we must take into account the length of hospital stay as a variable cost. The mean hospital stay in the EL group was 1.55 (SD+ 1.48) days and 2.21 (SD 1.69) days in the ES group, with $p = 0.046$. In our environment for third-level hospitals and taking into account that our hospital is part of the Andalusian Health Service, which offers a public service that depends directly on the government, it has been established that the cost of a patient's day stay amounts to €603.70 [14]. Therefore, in uncomplicated appendicitis, the cost of the total stay when counting readmissions due to the complications of the EL group amounts to €892.71, while in the ES group, the cost of stay was 1236.84€, indicating statistically significant differences $p = 0.001$. If we count the expenses derived from the cost of the material plus the cost of the stay in the total cost, the average cost for patients operated on by the EL technique was €932.46 compared to €1,446.59 for those operated on by the ES technique (Table 3).

Complicated appendicitis

In the statistical analysis comparing the two subgroups, no differences were found in the number of general postoperative complications ($p = 0.863$), with an OR of 1.062 (0.536–2.1). There were 3 postoperative haemorrhages in the EL group and 0 in ES group (no significant differences). There were no differences regarding postoperative ileus (OR 1.28; CI 0.53–3.1) ($p = 0.58$). Regarding surgical wound infections, the results were also not significant, with only two cases in the ES group. Concerning Clavien-Dindo III complications, we did not find significant differences, with $p = 0.386$. The mean volume of postoperative abscesses was 256.77 cm^3 (SD 283.85), with a median volume of 175 cm^3, and there were no differences in the volumes produced by the two techniques ($p = 0.788$). In terms of the management of these abscesses, 16 of the 19 abscesses required interventional procedures (Clavien-Dindo IIIA vs. Clavien-Dindo IIIB), although there were statistical differences ($p = 0.012$) regarding reoperation between the EL group (6.4%) and the ES group (0%), of the 6 reoperated patients. Five patients were reoperated because the presence of the abscess not accessible for percutaneous puncture, while the other patients were reoperated due to an ileal perforation unrelated to the technique of closure of the appendicular stump. There were no differences regarding readmissions in the 30 postoperative days (8.2% in the EL group vs. 3.4% in the ES group; $p = 0.168$). Two of the patients had Von Willembrand disease: one of them in the EL group was readmitted with a surgical site haematoma that later became infected, being one of the patients requiring reoperation to wash the cavity. The other patient in the ES group had a surgical site infection with an abscess that was treated conservatively with antibiotics.

In the efficiency study, the average hospital stay in the EL group was 4.9 (SD 3.77) days, and in the ES group, the average hospital stay was 5.01 (SD 4.02) days, with $p = 0.89$. If we take into account the total stay (with readmissions), the average hospital total stay in the EL group was 5.43 (SD 5.9) days and in the ES group, the average hospital total stay was 5.15 (SD 4.29) with $p = 0.712$. However, the cost of the total stay was higher in EL group (175 euros more) than in ES group without finding differences in the statistical analysis $p = 0.996$ (Table 4).

Discussion

Acute appendicitis is one of the most frequent surgical emergencies, with an incidence of 7–8%. The laparoscopic approach is the standard surgical treatment [1–3]. Despite the fact that LA is a widely described technique, there is still great controversy regarding the closure of the stump, since it is believed to be one of the causes of postoperative

Table 2 Results of the safety analysis in uncomplicated appendicitis

Uncomplicated appendicitis safety	Total (n = 535)	Endoloops (n = 447)	Endostapler (n = 88)	p*	OR (95% CI)
Global postoperative complications	18 (3.4%)	15 (3.4%)	3 (3.4%)	0.98	1.01 (0.28–3.58)
Clavien-Dindo				NA	
0	516 (96.4%)	431 (96.4%)	85 (96.6%)		
I	11 (2.1%)	8 (1.8%)	3 (3.4%)		
II	6 (1.1%)	6 (1.3%)	0		
III	12	2(0.4%)	10 (11.8%)		
IIIA	0	0	0		
IIIB	2	2 (0.4%)	0	0	
IV	0	0	0		
V	0	0	0	99	
Haemorrhage	3 (0.2%)	1 (0.2%)	2 (2.3%)	0.072	10.37 (0.93–115.66)
Postoperative ileum	7 (1.3%)	6 (1.3%)	1 (1.1%)	0.877	0.845 (0.1–7.1)
Surgical wound infection	0	0	0		
Intraabdominal abscess	7 (1.3%)	7 (1.6%)	0	0.237	0.833 (0.802–0.866)
Abscess volume (cm^3)	57 (SD 31.25)	57 (SD 31.25)	0	NA	
Readmission	5 (0.9%)	5 (1.1%)	0	0.405	

Results of the safety analysis in uncomplicated appendicitis in the endoloop and endostapler groups. *SD*, standard deviation; *p*, probability that the null hypothesis is true; *OR*, odds ratio; *CI*, confidence interval

complications, such as the formation of intra-abdominal abscesses or obstruction of the small intestine [6, 9, 10]. In particular, in complicated appendicitis, there is more controversy regarding the method used to close the stump because it is associated with greater inflammation, and the base of the appendix is fragile due to perforation or gangrene [8, 15]. Therefore, the most feared complications are infectious complications related to the existence of intra-abdominal abscesses in relation to total or partial dehiscence of the appendicular stump since they determine a higher percentage of readmissions and reoperations [7, 16]. Numerous stump closure mechanisms have been used, with EL and ES being the most frequent [6–13, 15–17], and other less generalised methods, such as polymeric clips, have been described [18, 19]. The debate continues today about which of these methods is the safest and most efficient [8, 20, 21], particularly in cases of complicated appendicitis [22].

Regarding global postoperative complications in complicated appendicitis (25.4%) and uncomplicated appendicitis (3.4%), no differences were found between the EL and ES groups, with results similar to other published prospective studies in both adults and children [6, 15]. In a systematic review of the Cochrane Library [22], no differences in overall postoperative morbidity were seen. In our series, there were 2 cases (2.3%) of haemorrhages in the uncomplicated appendicitis group in the ES group. In the postoperative period, these cases were managed conservatively without the need for satisfactory reoperation. It should be noted that, in our work, in the group operated on by the EL technique, vascular control of the appendicular artery was performed by means of the

Table 3 Results of the efficiency analysis in uncomplicated appendicitis

Uncomplicated appendicitis efficiency	Total (n = 535)	Endoloops (n = 447)	Endostapler (n = 88)	p	EL savings per patient
Material (euros)	–	39.75	211.75	–	172
Hospital stay (days)	1.68 (SD 1.55)	1.55 (SD 1.48)	2.2 (SD 1.7)	0.046	
Total stay (days)	1.57 (SD 1.47)	1.47 (SD 1.42)	2.04 (SD 1.61)	0.001	
Total stay cost (euros)	948.99 (SD 888.03)	892.71 (SD 860.45)	1236.84 (SD 972.62)	0.001	244.13
Total cost (euros)	1017.03 (SD 899.38)	932.46 (SD 860.45)	1446.59 (SD 972.61)	0.001	514.12

Results of the efficiency analysis in uncomplicated appendicitis in the endoloop and endograpadora groups. *EL*, endoloop; *SD*, standard deviation; *p*, probability that the null hypothesis is true; Stay, hospital stay in days during the first admission; Total stay, hospital stay accumulated in days of admission plus readmissions; Total cost, cost of the material plus the average cost of the total stay

Table 4 Results of the safety analysis in complicated appendicitis

Complicated appendicitis safety	Total (n = 174)	Endoloop (n = 85)	Endostapler (n = 89)	P*	OR (95% CI)
Global postoperative complications	44 (25.3%)	21 (24.7%)	23 (25.8%)	0.863	1.062 (0.536–2.1)
Clavien-Dindo				NA	
0	131 (75.3%)	65 (76.5%)	66 (74.5%)		
I	22 (12.6%)	10 (11.8%)	12 (13.5%)		
II	4 (2.3%)	0	4 (4.5%)		
III	17	10 (11.8%)	7 (7.8%)	(0.386)	
IIIA	11 (6.3%)	4 (4.7%)	7 (7.9%)	(0.392)	
IIIB	6 (3.4%)	6 (6.4%)	0	(0.012)	(0.0–0.78)
IV	0	0	0		
V	0	0	0		
Haemorrhage	3 (1.72%)	3 (3.5%)	0	0.114	0.48 (0.41–0.56)
Postoperative ileum	23 (13.2%)	10 (11.8%)	13 (14.6%)	0.58	1.283 (0.53–3.1)
Surgical wound infections	2 (1.1%)	0	2 (2.2%)		NA
Intraabdominal abscess	19 (10.9%)	9 (10.6%)	10 (11.2%)		1.069 (0.412–2.77)
Abscess volume (cm^3)	256.77 (SD 283.84)	237.56 (SD 168.21)	274.06 (SD 367.81)	0.788	
Readmission	10 (5.7%)	7 (8.2%)	3 (3.4%)		

Results of the safety analysis in complicated appendicitis in the endoloop and endostapler groups. *SD*, standard deviation; *p*, probability that the null hypothesis is true; *OR*, odds ratio; *CI*, confidence interval

electrocautery of the mesoappendix with monopolar energy skeletonising the cecal appendix, and in the case of patients operated on by the ES technique, the vascular control was performed using either an ES or electrocautery. The technique used for vascular control of the mesoappendix is also controversial and will be the subject of further analysis in another study. Comparative studies have been performed between meso-appendix dissection and appendicular artery coagulation methods, comparing endoclip, Harmonico (®) (Ethicon Endo-Surgery, Cincinnati, OH), electrocoagulation and LigaSure™ (Covidien, Mansfield, MA) [23], as well as by endostapler [24], without having found postoperative bleeding rates above the standard rates.

The overall postoperative ileus rate was 1.3% in the uncomplicated appendicitis and 13.22% in complicated appendicitis, with no differences between the study subgroups (EL and ES). A series of appendectomies have been described, with a high incidence of postoperative ileus related to the use of the stapler due to the creation of adhesions due to the metal [25, 26]. On the other hand, the postoperative ileus has also been associated with the use of an EL in paediatric patients due to possible leakage of the stump, with secondary peritonitis in complicated appendicitis, which could justify the high rate of formation of parietal-epiploic adhesions that require surgery [7]. These findings have not been replicated in other studies. Infectious complications have been extensively studied since they are usually associated with a higher rate of reoperation and/or readmission [7]. Van Rossem [6] stated that the type of closure of the appendicular stump with EL or ES has no effect on the development of both superficial and deep infectious complications, with the severity of appendicitis (complicated vs. uncomplicated) being the main risk factor for development. In our work, we divided acute appendicitis into complicated and uncomplicated appendicitis, and the two groups were homogeneous regarding the intraoperative situation. The surgeon was the one who chose the closure method according to their clinical preference, without finding differences between both groups. Miyano et al. did not observe an increased risk of infectious complications in uncomplicated appendicitis in the paediatric population [15], although in their international multicentre study of complicated acute appendicitis in the paediatric population, Escolino et al. observed a higher rate of intra-abdominal abscess associated with EL [7]. However, these data are not comparable to our population since our patients are older than 16 years. In the Cochrane Library review, the authors did not observe differences in intra-abdominal complications, although there was an increase in trocar infection in the EL group [20], with similar results in the meta-analyses of the paediatric population, but not in adults [17]. However, in our study, there were only 2 cases of wound infection in the ES group of complicated appendicitis, with no justified clinical cause.

Among the cases of uncomplicated appendicitis, 2 patients were reoperated on, while in the complicated appendicitis group, 6 patients were reoperated on. All were included in the EL group. Six of the reoperations were motivated by intra-abdominal abscess formation, 1 was motivated by adhesion formation in the context of uncomplicated appendicitis,

and 1 was motivated by issues unrelated to the appendicular stump closure technique. There were no significant differences between groups. However, in the group of complicated patients, there were differences in the rate of reoperation in EL group in relation with intra-abdominal abscesses (5 of the 6 reoperated for intra-abdominal abscesses), one of them justified by previous comorbidity due to von Willembrand disease because of surgical site infection.

It could be argued that although there were no differences in the rate of abscesses with the two techniques for closure of the stump, the possible leak after use of EL is of greater quantity and severity than that of ES [7], and the only alternative for the resolution of the condition is surgical washing. In our study, we collected the volume of abscesses produced in the two groups, with a mean volume of 237 cm^3 (SD 168.21) in the EL subgroup versus 274.06 cm^3 (DS 367.81) in the ES subgroup ($p = 0.788$). The need for an interventional procedure of the abscesses (percutaneous drainage in grade IIIA Clavien-Dindo complications and surgical drainage in grade IIIB Clavien-Dindo complications) in the two groups was similar in our study (grade III Clavien-Dindo), with no differences. The highest rate of reoperation in the EL group is more associated with locations that are not accessible by percutaneous drainage, and is not associated with greater severity in our series. There were no differences in readmission rates. These findings partially correlate with those published by Escolino et al., who found that the highest rate of postoperative abscesses in the EL group entailed a higher rate of reoperations and readmissions. Therefore, they recommended the use of ES systematically in complicated appendicitis [7]. Although we cannot reach the same conclusions clinically, our results are more similar to those of Van Rossem et al. [6], where there was not a greater number of abscesses due to EL compared to ES.

Concerning the efficiency of the technique, the difference in the average length of stay of the first admission and the total length of stay (with readmissions) of complicated acute appendicitis was similar between groups (5.43 days in the EL groups and 5.15 days in the ES group). However, for uncomplicated appendicitis, there were differences in the hospital stay that entailed 1 more day of the patient's stay in the ES group. This implies an increase in costs in the ES group. The causes of this increase in hospital stay in the ES group are not clear but have been described by other authors [14]. There is no clinical justification in this study in terms of postoperative complications for which the patient needs more days of medical attention. However, other variables should be studied, such as time to ambulation or postoperative pain that determine a longer stay.

Regarding the efficiency analysis, as no notable differences were found between the patients operated on by EL and ES techniques, we can establish that the only cost difference was found at the time of the intervention for the material used, with higher cost for the ES technique. At this point, we must bear in mind that EL and ES in complicated appendicitis are equally cost-effective, with €171.38 savings per patient that was operated on using the EL technique. These findings are similar to those published by Hildsen et al., where they compared two homogeneous groups of patients operated on for acute appendicitis, where the average cost of EL was $1988 (SD 143) compared to EG, with an average cost of $2253 (SD 99) ($p < 0.001$). These results are similar to those reported in other studies that propose the EL technique as the most cost-effective technique [27]. Other studies suggest that in different subgroups of patients, different surgical techniques may be more cost-effective, even opting for open appendectomy in certain subgroups of patients [28]. In our series, in uncomplicated appendicitis, the patients that were operated on via ES technique represent an average increase in cost per person of €514.12 compared to patients operated on with EL technique (Table 5).

In cases of complicated appendicitis, the use of EL and ES techniques does not lead to differences in the average cost per stay or the total cost, although there are still differences in the fixed costs of the material used per patient (€171.38). The economic impact of reoperation on the EL subgroup in cases of complicated appendicitis was argued by Escolino et al. [7]. This was corroborated in our series, although since there were no differences in invasive procedures to resolve the abscess, we can conclude that the rate of reoperation is an incidental finding

Table 5 Results of the efficiency analysis in complicated appendicitis

Complicated appendicitis efficiency	Total ($n = 174$)	Endoloop ($n = 85$)	Endostapler ($n = 89$)	p	EL savings per patient
Material (euros)	–	39.75	211.75	–	172
Hospital stay (days)	4.97 (SD 3.9)	4.9 (SD 3.77)	5.01 (SD 4.02)	0.89	
Total stay (days)	5.28 (5.13)	5.43 (SD 5.9)	5.15 (SD 4.29)	0.712	
Cost of total stay	3191 (SD 3101)	3281.29 (SD 3575)	3106 (SD 2587.5)	0.712	– 175
Total cost	3319 (DS 3100.6)	3321.04 (DS 3575.72)	3318.43 (SD 2587.50)	0.996	– 3

Results of the efficiency analysis in complicated appendicitis in the endoloop and endostapler groups. *EL*, endoloop; *SD*, standard deviation; *p*, probability that the null hypothesis is true; Stay, hospital stay in days during the first admission; Total stay, hospital stay accumulated in days of admission plus readmissions; Total cost, cost of the material plus the average cost of the total stay

rather than a fact associated with EL. Therefore, the added cost of the EL in the reoperation loses value. Due to the retrospective nature of the study, we found that although the data collection was carried out by the same researchers in a homogeneous and prospective way, some interesting data about the pathology was not analysed (classification of complicated appendicitis into gangrenous, localised or generalised peritonitis; in the case of perforation, location, the position of the perforation in the appendix etc.). The operating time and the stapler shots required for each patient are variables of interest that were not included. However, there are similar published studies [14] in which there are no statistically significant differences in surgical time with the use of both techniques, so this parameter should not influence the final results of this study.

One of the limitations of the study is that due to the low rate of postoperative complications, larger numbers would contribute significant changes to the results, so they must be considered with caution, despite being a significant cohort of a third-level hospital with a specific Emergency Surgery and Trauma unit.

In terms of the cost, we have made a weighted estimate regarding the stay and the associated costs according to reference prices, although they are not individualised data-specific to each patient. All these limitations derived from the study design make randomised studies with a prospective design necessary to establish more emphatic conclusions regarding the most suitable type of appendicular stump closure in the surgical treatment of complicated and uncomplicated acute appendicitis.

Conclusion

The use of an EL and ES in LA does not offer differences in terms of postoperative complications in uncomplicated appendicitis, and the systematic use of EL can reduce costs. For complicated appendicitis, both techniques, EL and ES, may be a cost-effective alternative, although higher quality studies are necessary.

Authors' contributions Study conception and design: Felipe Pareja Ciuró and Virginia Durán Muñoz-Cruzado. Acquisition of data: Gregorio Anguiano Díaz and Daniel Aparicio Sánchez. Analysis and interpretation of data: Alejandro Sánchez Arteaga and José Tinoco González. Drafting of manuscript: Gregorio Anguiano Díaz and Virginia Durán Muñoz-Cruzado. Critical revisión of manuscript: Luis Tallón Aguilar, Felipe Pareja Ciuró and Javier Padillo Ruiz.

Data Availability Available.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval Approval for this prospective review was obtained from Hospital Universitario Virgen del Rocío. The procedures in this study adhere to the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to participate Not applicable.

Consent for publication Not applicable.

Code availability Not applicable.

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