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Necessity of Invaginating the Appendiceal Stump in Laparoscopic Appendectomy for Acute Nonperforated Appendicitis

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Objective: This study aimed to assess the necessity of invaginating the appendiceal stump in laparoscopic appendectomy for patients with acute nonperforated appendicitis.

Summary of background data: Laparoscopic appendectomy has become the preferred method over open appendectomy for acute appendicitis, offering benefits such as shorter intraoperative times and reduced wound sepsis. However, the necessity of invaginating the appendiceal stump, aimed at preventing stump leakage and intrabdominal infection, remains unclear.

Methods: This retrospective observational study was conducted at Nippon Medical School Musashikosugi Hospital from 2009 to 2018 and involved patients aged ≥15 years diagnosed with acute nonperforated appendicitis who underwent emergency surgery without preoperative intra-abdominal abscess. Patients were divided into 2 groups: open appendectomy with stump invagination (Group O) and laparoscopic appendectomy without stump invagination (Group L). The primary outcomes were incidences of appendiceal stump leakage and postoperative intra-abdominal abscess.

Results: The study involved 119 patients in Group O and 175 in Group L. Both groups were comparable in age, sex, body mass index, blood examination results, operating time, and drain insertion rate. Group L presented more cases of gangrenous appendicitis with severe inflammation but had shorter postoperative stays compared with Group O. The incidence of postoperative intra-abdominal abscess was 2% (2 cases) in Group O and 2%

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(4 cases) in Group L with no significant difference. No cases of stump leakage were observed in either group.

Conclusions: Invaginating the appendiceal stump in laparoscopic appendectomy for nonperforated appendicitis may be unnecessary as its omission does not increase short-term postoperative complications.

Key words: Appendicitis – invaginating stump – laparoscopic surgery

Laparoscopic appendectomy (LA), first described by Semm in 1983,[1] has become a common alternative to open appendectomy (OA) for treating acute appendicitis. Studies show that LA offers several clinical benefits over OA, including shorter intraoperative duration, reduced rates of wound sepsis, fewer reoperations, shorter postoperative hospital stays, and lower rates of readmission.[2,3] Moreover, various techniques for ligating appendiceal root in LA have been reported, such as intracorporeal knotting, clip application, Endoloop, and linear stapling.[4] However, there is no consensus on whether the appendiceal stump should be invaginated during LA.

The rationale behind invaginating the appendiceal stump is to prevent stump leakage and subsequent intrabdominal infection. In traditional OA, several reports show that not invaginating the appendiceal stump does not increase short-term postoperative complications.[5–7] However, this practice has not been widely adopted given the ease of stump invagination in open surgery. In contrast, invaginating the appendiceal stump in laparoscopic surgery is more challenging. If invagination is deemed essential and cannot be achieved laparoscopically, it may necessitate moving the ileocecal region to the umbilicus or converting to open surgery. To date, the necessity of invaginating the appendiceal stump in LA has not been fully investigated. However, given the evidence suggesting that omitting invagination does not affect postoperative complications in OA, it could be feasible to omit this step in LA as well.

In 2010, we introduced a technique for LA in which the appendiceal root is ligated without invagination of the stump, contrasting with our OA method in which the stump is invaginated (Fig. 1). This study aimed to examine the necessity of invaginating the appendiceal stump in LA by comparing the short-term surgical outcomes between LA with simple ligation and OA with stump invagination.

Methods

Study design

This retrospective observational study involved consecutive patients who underwent emergency appendectomy for acute nonperforated appendicitis between January 1, 2009, and December 31, 2018. The study took place at the department of digestive surgery of Nippon Medical School Musashikosugi Hospital.

Patient selection

The study included patients who met the following criteria: (1) diagnosed with acute nonperforated appendicitis without preoperative intra-abdominal abscess and treated with emergency surgery, (2) aged 15 years or older, and (3) underwent OA with invagination of the appendiceal stump or LA without invagination of the appendiceal stump. The determination of nonperforated appendicitis was based on intraoperative or pathological findings. Computed tomography was used to identify preoperative intra-abdominal abscesses. The age restriction to 15 years and above was implemented because patients younger than 15 years were treated in the department of pediatric surgery.

The exclusion criteria were as follows: (1) OA without invagination of the appendiceal stump or LA with invagination of the appendiceal stump, (2)

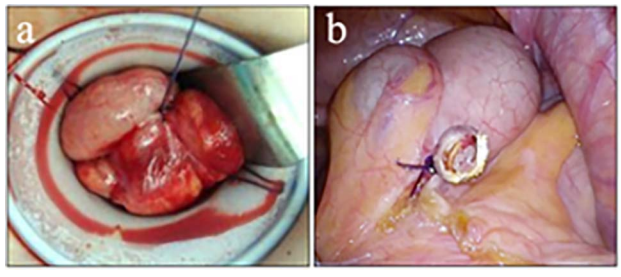

Fig. 1 Intraoperative photographs showing (a) open appendectomy with invagination of the appendiceal stump and (b) laparoscopic appendectomy without invagination of the appendiceal stump.

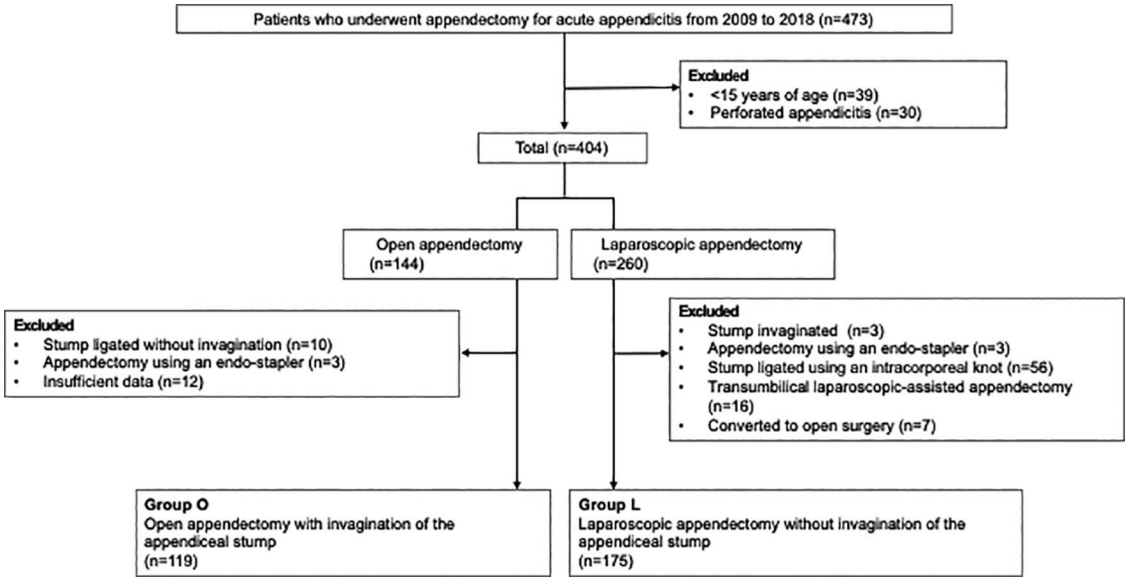

Fig. 2 Study flowchart.

use of an endostapler for appendectomy, (3) ligation of the appendiceal stump using an intracorporeal knot, (4) transumbilical laparoscopic-assisted appendectomy, and (5) conversion from laparoscopic to open surgery.

The patients were classified into two groups: Group O (OA with invagination of the appendiceal stump) and Group L (LA without invagination of the appendiceal stump). In Group L, the appendiceal stump was secured using an Endoloop (Ethicon Inc, Somerville, New Jersey) with a PDS II suture (Ethicon).

Primary outcomes

This study compared the groups based on the patients' demographic characteristics, surgical outcomes, and incidence of postoperative complications. The primary outcomes focused on the occurrence of appendiceal stump leakage and postoperative intra-abdominal abscesses. To evaluate for appendiceal stump leakage and intra-abdominal abscesses, abdominal computed tomography scans were conducted in cases of fever, elevated white blood cell count or C-reactive protein levels, or abdominal symptoms within 30 days following surgery. Additionally, we examined the number of ligatures used at the appendiceal root.

Statistical analysis

For categorical variables, the χ^2 test was employed. Continuous variables were analyzed using the Mann–Whitney *U* test. All tests were two-sided, and *p*-values below 0.05 were considered statistically significant. Statistical analyses were performed using SPSS software, version 26.0 (IBM Japan Ltd, Tokyo, Japan).

Results

The flowchart of the study is depicted in Fig. 2. During the study period, a total of 473 patients were diagnosed with acute appendicitis and underwent emergency surgery. Of these, 69 patients were excluded: 39 patients were under 15 years of age, and 32 patients, including 2 under 15 years, had perforated appendicitis. Further exclusions were made in the OA group (n = 144), in which 25 patients were excluded for various reasons: 10 underwent OA without invagination of the appendiceal stump, 3 underwent appendectomy using an endostapler, and 12 presented with insufficient data. In the LA group (n = 260), 85 patients were excluded: 3 underwent LA with invagination of the appendiceal stump, 3 underwent appendectomy using an endostapler, 56 had the appendiceal stump ligated using an intracorporeal knot, 16 underwent transumbilical laparoscopic-assisted appendectomy, and 7 required conversion to open surgery. Consequently, 294 patients were included in this study with 119 in Group O and 175 in Group L. Group O accounted for 86% of the patients from 2009 to 2011, whereas Group L, following the introduction of LA, comprised 96% of the patients from 2012 to 2018 (Fig. 3).

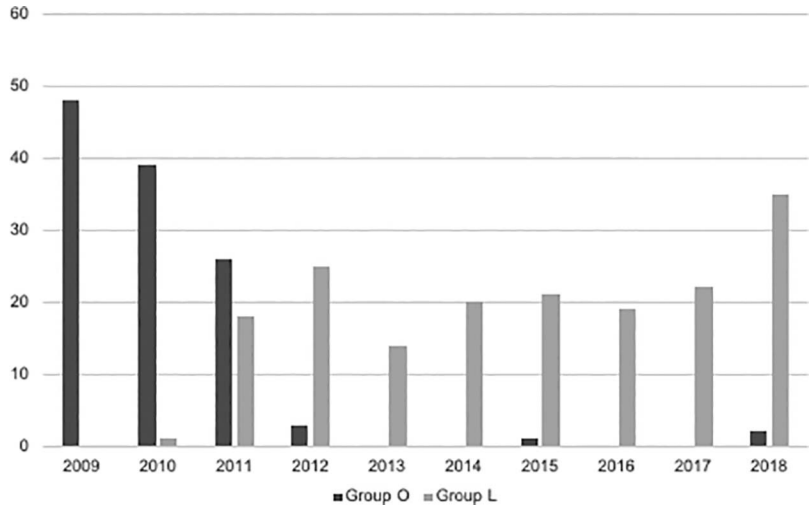

Fig. 3 Number of surgeries performed in each group during the study period.

Demographic data of the patients are presented in Table 1. There were no significant differences in patient characteristics, white blood cell counts, or C-reactive protein levels between the groups.

The surgical results are shown in Table 2. Histopathological examination revealed catarrhal in 23 patients (19.3%), phlegmonous in 69 patients (58.0%), and gangrenous appendicitis in 27 patients (22.7%) in Group O. For Group L, the findings were catarrhal in 13 patients (7.4%), phlegmonous in 90 patients (51.4%), and gangrenous appendicitis in 72 patients (41.1%). Group L had a significantly higher incidence of gangrenous appendicitis with severe inflammation compared with Group O ($P < 0.001$). The median postoperative hospital stay was significantly longer in Group O than in Group L (7 versus 5 days, respectively; $P < 0.001$). There were no cases of appendiceal stump leakage in either group. The incidence of postoperative intra-abdominal abscess was 1.7% (n = 2) in Group O and 2.3% (n = 4) in Group L ($P = 0.71$).

Table 3 presents the number of ligatures at the appendiceal root and the incidence of complications in Group L. The distribution was 61 cases (35%) with a single ligation, 111 cases (63%) with double ligations, and 3 cases (2%) with triple ligations. There was no significant difference in the incidence of postoperative complications relative to the number of ligatures.

Table 1 Patient characteristics and laboratory test results

	Group O (n = 119)	Group L (n = 175)	*P*-value
Age	35 (16–96)	39 (16–87)	0.148
Gender			
Male	63 (53%)	107 (61%)	0.162
Female	56 (47%)	68 (39%)	
BMI, kg/m^2	21.2 (17.3–30.8)	21.5 (16–36.3)	0.327
WBC, /mm^3	12,400 (3,900–26,390)	13,350 (3,300–23,710)	0.066
CRP, mg/dL	2.4 (0.1–27.97)	1.9 (0.1–26.78)	0.593

Data are presented as number (percentage) or median (range).

Group O, open surgery group; Group L, laparoscopic appendectomy group; BMI, body mass index; WBC, white blood cell count; CRP, C-reactive protein.

Table 2 Surgical outcomes

	Group O (n = 119)	Group L (n = 175)	*P*-value
Pathological findings (type of appendicitis)			
Catarrhal	23 (19.3%)	13 (7.4%)	<0.001
Phlegmonous	69 (58.0%)	90 (51.4%)	
Gangrenous	27 (22.7%)	72 (41.1%)	
Operation time, min (median range)	70 (22–138)	65 (15–159)	0.668
Drain placement	16 (13.4%)	12 (6.9%)	0.059
Length of stay, days (median range)	7 (3–35)	5 (2–16)	<0.001
Complications			
SSI	5 (4.2%)	1 (0.6%)	0.031
Leakage from the stump	0 (0%)	0 (0%)	—
Abdominal abscess	2 (1.7%)	4 (2.3%)	0.719
Ileus	1 (0.8%)	4 (2.3%)	0.347
Readmission	1 (0.8%)	1 (0.5%)	0.783
Reoperation	1 (0.8%)	0 (0%)	0.224

Data are presented as number (percentage) unless otherwise indicated.

Group O, open surgery group; Group L, laparoscopic appendectomy group; SSI, surgical site infection.

Table 3 Number of ligatures in the appendiceal stump using an Endoloop and the postoperative complications in Group L

	Number of ligatures			
	1 (n = 61)	2 (n = 111)	3 (n = 3)	*P*-value
SSI	0 (0%)	1 (1%)	0 (0%)	0.748
Leakage from the stump	0 (0%)	0 (0%)	0 (0%)	—
Abdominal abscess	0 (0%)	4 (4%)	0 (0%)	0.307
Ileus	2 (3%)	2 (2%)	0 (0%)	0.796

Data are presented as number (percentage).

Group L, laparoscopic appendectomy group; SSI, surgical site infection.

Discussion

In this study, two important clinical observations were made. First, it was observed that the incidence of appendiceal stump leakage and intra-abdominal abscess formation in patients of Group L, who did not undergo invagination of the appendiceal stump, was comparable to that in Group O, in which patients underwent this procedure. Second, the study found no correlation between the number of ligatures applied at the appendiceal root using the Endoloop and the incidence of postoperative complications.

The incidence of appendiceal stump leakage and intra-abdominal abscess in Group L was comparable to that of Group O. Both groups exhibited a 2% incidence of postoperative intra-abdominal abscess, aligning with prior studies reporting rates between 1.7% and 5%.[8,9] Several studies report no association between the invagination of the appendiceal stump and the incidence of postoperative complications in LA. However, these studies had potential selection bias due to reliance on surgeon discretion for stump invagination.[8–10] This discretion was largely based on the difficulty and skill required for invagination using a laparoscope. In contrast, this study predefined the invagination based on the surgical approach, such as OA or LA, reducing potential bias. We introduced an LA technique in 2010, leading to Group O constituting 86% of patients between 2009 and 2011, and Group L accounting for 96% from 2012 to 2018. The surgical approach was determined based on the timing of when we introduced LA. Therefore, the selection bias in this study related to stump invagination was likely less than in previous studies. Our results suggest that invagination of the appendiceal stump in LA may not be crucial for preventing postoperative complications, such as appendiceal stump leakage and intra-abdominal abscess.

The association between the number of ligatures at the appendiceal root using the Endoloop and the incidence of postoperative complications was found to be insignificant. To date, there has been no report addressing the optimal number of ligations of the appendix root using the Endoloop. In this study, a single ligation of the appendiceal root was performed in 61 patients (35%) in Group L, and no cases of appendiceal stump leakage or intra-abdominal abscess were observed. These results suggest that a single ligation may be sufficient for cases with nonperforated appendicitis. However, further studies are needed to determine the ideal number of ligatures at the appendiceal root.

Avoiding unnecessary stump invagination is recommended as there have been reports of adult intussusception involving an invaginated appendiceal stump as well as a case indicating the need to rule out a cecal tumor as a potential complication of invagination.[11–13] However, this study did not include cases of appendicitis with perforation. In patients with a fragile appendiceal root due to severe inflammation, simple ligation of the appendix may lead to stump collapse. Therefore, the decision to not invaginate the appendiceal stump should be made with careful consideration of the condition of the appendiceal root or stump.

This study included cases of LA in which the appendiceal root was ligated using an Endoloop. Various methods exist in LA for ligating the appendiceal root, including the use of clips, staplers, and intracorporeal knotting. Previous studies indicate that these methods have comparable postoperative complication rates.[14,15] Nonabsorbable polymer clips or titanium clips, although cost-effective and convenient for ligating the appendiceal root, are not recommended for cases with severe inflammation or large appendix diameters given their associated risks.[16–19] Staplers can reduce the operative time as they simultaneously address the appendiceal root and mesentery; however, their high cost warrants limiting their use to cases with severe inflammation.[19] Intracorporeal knotting, though less expensive, typically extends the operative duration and requires significant surgical skill.[20] The Endoloop, although costlier than clips but less so than staplers, provides a reliable means to ligate the appendiceal root regardless of appendix diameter.[19] Therefore, the use of an Endoloop is considered the most reasonable method for ligating the appendiceal stump.

This study has certain limitations. First, it included only 6 cases of postoperative abscess, which may result in inadequate statistical power. Future multicenter

studies incorporating a larger number of cases are needed to enhance statistical robustness. Second, the surgical approaches varied; patients with invaginated appendiceal stumps underwent open surgery, whereas those without invaginating stumps underwent laparoscopic surgery. This variation in surgical techniques could potentially influence the outcomes.

In conclusion, our study demonstrated that invagination of the appendiceal stump may be unnecessary following the ligation and transection of the appendiceal root using an Endoloop in laparoscopic procedures for nonperforated appendicitis, particularly in cases without a fragile appendiceal root.

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