The outcomes of laparoscopic versus open appendectomies for complicated appendicitis

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Background
The role of laparoscopic appendectomy remains controversial in the context of complicated appendicitis. This study aimed to compare the clinical outcome of laparoscopic versus open appendectomy (OA) in patients with complicated appendicitis regarding operative time, morbidity, hospital stay, postoperative pain, ileus, 1-month follow-up, and need for readmission.
Methods
A randomized controlled study was performed on 40 patients presenting with complicated appendicitis. 20 patients were subjected to laparoscopic appendectomy (LA) and 20 patients underwent traditional OA.
Results
25 (62.5%) patients were female, and 15 (37.5%) patients were male. A significant difference was noted in the domains of postoperative pain, return of peristalsis, time to start oral, hospital stay, and return to daily activities. The mean operative time was shorter in OA 91.4±11.99 min than in LA 109.1±16.71 min No statistically significant difference between both groups was calculated as regards the occurrence of intraabdominal collection.
Conclusion
Based on its clinical outcomes, laparoscopy should be considered in the setting of complicated appendicitis. The possibility of intraabdominal collection should not be a barrier against the widespread practice of this surgical procedure among laparoscopic surgeons if adequate precautions were employed.

Keywords:
complicated appendicitis, laparoscopic appendectomy, laparoscopy, open appendectomy, outcomes of laparoscopic appendectomy

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Introduction

Complicated appendicitis includes acute appendicitis accompanied by perforation, peri-appendicular abscess, or appendicular mass [1]. Obstruction of the appendicular lumen results in rapid appendicular distension due to the small capacity, resulting in a significant increase in the intraluminal pressure [2]. A pressure above 85 mmHg, results in thrombosis of the venules, further impairing the lymphatic drainage and the arteriolar inflow. This will eventually increase vascular congestion resulting in appendiceal engorgement. The Mucosa becomes hypoxic and begins to ulcerate, which decreases the mucosal defenses, allowing the intraluminal bacteria to invade the appendiceal wall [3]. the appendix will eventually perforate if left untreated with the development of a peri-appendiceal abscess [3].

In acute appendicitis, the risk of perforation ranges from 20% to 30% [4]. It was estimated that the traditional triad of pain, fever, and vomiting is present in around 76% [5]. Patients with Complicated appendicitis frequently present with systemic signs and symptoms of sepsis. Female patients have a considerably lower probability of perforation and on the contrary elderly people and children have a considerably higher probability of perforation [4]. Failure of conservative therapy and a delay in diagnosis can be considered the predominant causes of perforation in acute appendicitis [6].

Performing laparoscopic appendectomy (LA) for cases of acute appendicitis is considered one of the most prevalent procedures in surgery. LA has many benefits superior to open appendectomy (OA), as small incisions are needed and the procedure provides good visualization, better access to the abdominal organs, quick postoperative recovery, less postoperative pain, better outcomes for obese patients, shorter stay at the hospital, and better aesthetic outcomes. LA is superior to OA, according to meta-analysis of randomized controlled trials. Which additionally implied that LA had threefold higher rates of intraabdominal abscess formation than OA [7].

Additionally, in comparison with OA, LA may have the benefit of decreasing the incidence of developing postoperative intraabdominal adhesions. Few studies compared the incidence of adhesive small intestinal obstruction following LA and OA, and the findings are inconsistent [8,9].

Furthermore, the LA permits the surgeon to leave a macroscopic normal appendix in place, in cases where the surgery is aborted, in contrast to an OA, where the traditional scar in the right lower quadrant is consistent with an appendectomy [10]. It is unclear if LA has more advantages for patients with complicated acute appendicitis by an abscess, perforation or an intestinal obstruction [7].

Method

Study design

This randomized controlled trial included patients with complicated appendicitis. This study was done at Alexandria Main University hospital, Alexandria, Egypt, in the period from June 2020 to July 2022. The study protocol was approved by the ethical committee of our institute. All patients with evidence of complicated acute appendicitis (severe right iliac fossa pain, tenderness, rebound tenderness, rigidity, fever more than 38, leukocytosis more than 15 000/mm^3, duration of symptoms more than 3 days and turbid peri-appendicular collection by ultrasonography (US) or computed tomography (CT) were included. Patients with an immobile appendicular mass on examination under general anesthesia, patients who were unfit for laparoscopic surgery and those who refused to participate were excluded. Informed consent was obtained from all participants and approved by the ethics committee of our institutions.

Sampling technique and randomization

52 patients with complicated appendicitis were admitted to the Gastroenterology Surgery Unit (GIT) Surgical Unit in AUMH. A total of 12 patients were excluded, 6 for having immobile appendicular mass on examination under general anesthesia and 6 for having severe cardiopulmonary comorbidities. The remaining 40 patients constituted our study pool which were randomly allocated to group A for LA and group B for OA with 20 patients per group.

Operative data that were assessed intraoperatively included

Appendicular position, type of complication (perforation, gangrene, or appendicular mass) and any other pathologies or collections were recorded. Operative time, Operative difficulties (difficulty in dissection, or bleeding), and the occurrence of Conversion were all recorded. (Figs 1 and 2).

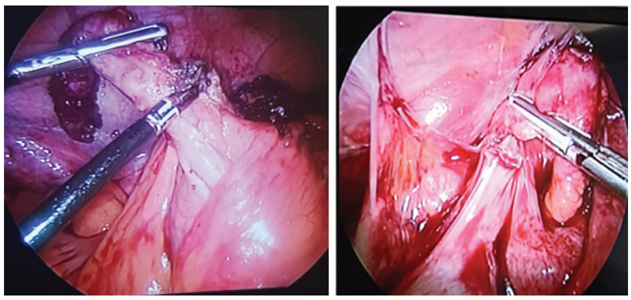
Postoperative care and follow-up

Pain severity and temperature were assessed every 12 h. The time of resumption of oral intake was determined by monitoring peristalsis. Observation of drains output, if present, was done also every 12 h. Length of hospital stay, time or restoration of physical activity, the presence or absence of wound-related complications, postoperative complications, postoperative intraabdominal fluid collection, and need of readmission were noted.

Statistical analysis

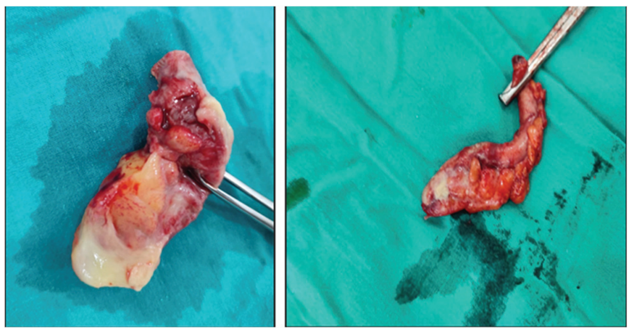
Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. Qualitative data were described using the number and percent. Quantitative data were described using minimum and maximum, mean, and standard deviation and median. A comparison between different groups

Figure 1



Operative image of complicated Laparoscopic appendectomy.

Figure 2



Operative image of complicated open appendectomy.

regarding categorical variables was tested using the χ^2test. When more than 20% of the cells have expected count less than 5, correction for $\chi^2$was conducted using Fisher's exact test or Monte Carlo correction. For normally distributed data, a comparison between the two groups using independent *t*-test was done. For abnormally distributed data, Mann-Whitney Test (for data distribution that was significantly deviated from normal) was used to analyze two groups. Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

Results

In group A the age ranged from 18-55 years with a mean (29.35±10.70). In group B, the range of age was from 18–53 years and the mean were (28.10±9.35).

In group A, 7 (35%) patients were men and 13 (65%) patients were women. In group B, 8 (40%) patients were men, and 12 (60%) patients were women. In group A, 8 (40%) patients were married and 12 (60%) patients were single. In group B 7 (35%) patients were married and 13 (65%) patients were single.

In group A, 6 (30%) patients were underweight, 8 (40%) patients were normal, 4 (20%) patients were overweight and 2 (10%) patients were obese. In group B, 5 (25%) patients were underweight, 9 (45%) patients were normal, 4 (20%) patients were overweight, and 2 (10%) patients were obese.

Both groups were comparable as regard demographic data, marital status and body mass index (BMI).

According to medical history

In group A, nine (45%) patients had medical comorbidities three were diabetes mellitus, four patients had hypertension, one patient had hypertension and DM and one patient had bronchial asthma. In group B, six (30%) patients had medical comorbidities, two of them were diabetic, three patients had hypertension and one patient had bronchial asthma. There is no significant difference among the groups related to the medical comorbidities ($P=0.327$).

According to previous surgical history

In group A, two (10%) patients had previous operations, both of them had a cesarean delivery. In group B, four (20%) patients had previous surgeries, one patient underwent open cholecystectomy and the other three patients had cesarean delivery. There is no significant difference among the two groups ($P=0.667$).

According to Alvarado score

The patients in group A got scores ranging from 9 to 10, with a mean of (9.80±0.41). The patients in group B got scores which were within the same range with a mean of (9.75±0.44) as shown in Table 4. Regarding the Alvarado score, there is no significant difference between the two groups ($P=0.799$). (Table 1).

According to Intraoperative assessment

According to intraoperative appendicular gross pathology

In group A, the appendix was perforated in 18 (90%) patients, gangrenous in one (5%) patient, and appendicular mass in one patient (5%). In group B it was perforated in 17 (85%) patients, gangrenous in one (5%) patient and appendicular mass in two (10%) patients as shown in Table 2. There is no significant

Table 1 Comparison among the two studied groups according to Alvarado score

	Laparoscopic (*n*=20)	Open (*n*=20)	*t*	*P*
Alvarado score				
Min. – Max.	9.0–10.0	9.0–10.0		
Mean±SD.	9.80±0.41	9.75±0.44	190.0	0.799
Median (IQR)	10.0 (10.0–10.0)	10.0 (9.50–10.0)		

IQR, Inter quartile range; SD, Standard deviation, t, Student *t*-test. *P*: *P* value for comparing among the two studied groups.

Table 2 Comparison among the two studied groups according to IO Gross of appendix

IO Gross of appendix	Laparoscopic (*n*=20) No. (%)	Open (*n*=20) No. (%)	χ^2	^{MC}P
Perforated	18 (90.0)	17 (85.0)		
Mass	1 (5.0)	2 (10.0)	1.317	0.667
Gangrenous	1 (5.0)	1 (5.0)		

χ^2, Chi square test; MC, Monte Carlo. *P*: *P* value for comparing among the two studied groups.

difference among the two groups ($P = 0.667$) regarding the intraoperative gross pathology of the appendix.

CIntraoperative Detection of abscess or collection

In group A, purulent collection could be detected in 18 (90%) patients. In group B, the purulent collection was found in 17 (85%) patients as shown in Table 6 and Fig. 5. There is no significant difference among the two groups as regards the detection of collection ($P = 1.000$).

Intraoperative bleeding needed to control

In group A, intraoperative bleeding happened in three (15%) patients. In group B, intraoperative bleeding happened in two (10%) patients as shown in Table 6 and Fig. 5. There is no significant difference among the two groups regarding bleeding incidence ($P = 1.000$).

Incidence of conversion

In group A, only one (5%) patient needed to convert from laparoscopic to OA as appendicular mass with tough adhesion which could not be dissected was found as shown in Table 3.

According to operative time

In group A, operative time had ranged from 85 min to 135 min with a mean (109.1±16.71). In group B, it ranged from 70 min to 110 min with a mean (91.40 ±11.99). (Fig. 3 & Table 4) There is a significant difference among the two groups with a lesser time in group B ($P = 0.001$).

Table 3 Comparison among the two studied groups according to IO bleeding, IO Collection or abscess and conversion

	Laparoscopic (n=20) No. (%)	Open (n=20) No. (%)	χ^2	^{FE}P
IO Bleeding	3 (15.0)	2 (10.0)	0.229	1.000
IO Collection or abscess	18 (90.0)	17 (85.0)	0.229	1.000
Conversion	1 (5.0)	0	1.026	1.000

FE, Fisher Exacts; χ^2, Chi square test. *P*: *P* value for comparing among the two studied groups.

According to postoperative assessment

Postoperative pain was assessed by a visual analogue pain scale: (Table 5 & Fig. 4)

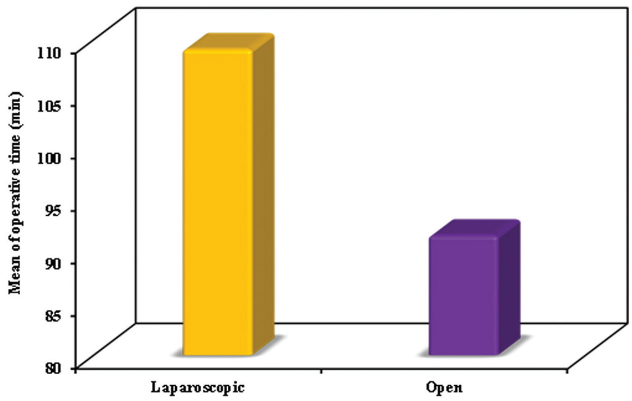
There was a significant difference among the two groups ($P < 0.001$) with higher scores in group B.

Return of peristalsis and time to start oral: (Table 6 & Figs. 5 and 6)

In group A, return of peristalsis ranged from one to 5 days with a mean (2.80±1.28). In group B, it ranged from 3 to 8 days with a mean (5.10±1.74). There was a significant difference among the two groups with a lesser time in group A ($P < 0.001$).

In group A, regarding the time which was needed to start oral intake, it had ranged from 1 to 5 days with a

Figure 3



Comparison among the two studied groups according to operative time.

Table 4 Comparison among the two studied groups according to operative time

Operative time (min)	Laparoscopic (n=20)	Open (n=20)	t	P
Min. – Max.	85.0–135.0	70.0–110.0		
Mean±SD.	109.1±16.71	91.40±11.99	3.838*	0.001*
Median (IQR)	111.0 (92.50–123.0)	93.0 (81.0–101.0)		

IQR, Inter quartile range; SD, Standard deviation; *t*, Student *t*-test. *P*: *P* value for comparing among the two studied groups. *: Statistically significant at *P* less than or equal to 0.05.

Table 5 Comparison among the two studied groups according to postoperative pain score

	Laparoscopic (n=20)	Open (n=20)	t	P
Pain				
Min. – Max.	1.0–5.0	3.0–8.0		
Mean±SD.	2.75±1.29	5.45±1.61	5.859*	<0.001*
Median (IQR)	3.0 (2.0–4.0)	5.50 (4.0–7.0)		

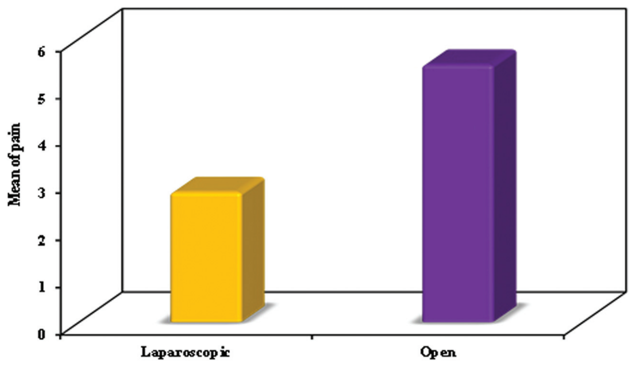
IQR, Inter quartile range; SD, Standard deviation, *t*, Student *t*-test. *P*: *P* value for comparing among the two studied groups. *: Statistically significant at *P* less than or equal to 0.05.

Table 6 Comparison among the two studied groups according to return of peristalsis and time to start oral

	Laparoscopic (*n*=20)	Open (*n*=20)	*U*	*P*
Return of peristalsis (days)				
Min. – Max.	1.0–5.0	3.0–8.0		
Mean±SD.	2.80±1.28	5.10±1.74	62.500*	<0.001*
Median (IQR)	2.50 (2.0–4.0)	5.0 (3.50–6.50)		
Time to start oral (days)				
Min. – Max.	1.0–5.0	3.0–8.0		
Mean±SD.	2.75±1.21	4.95±1.67	60.500*	<0.001*
Median (IQR)	2.50 (2.0–4.0)	5.0 (3.50–6.0)		

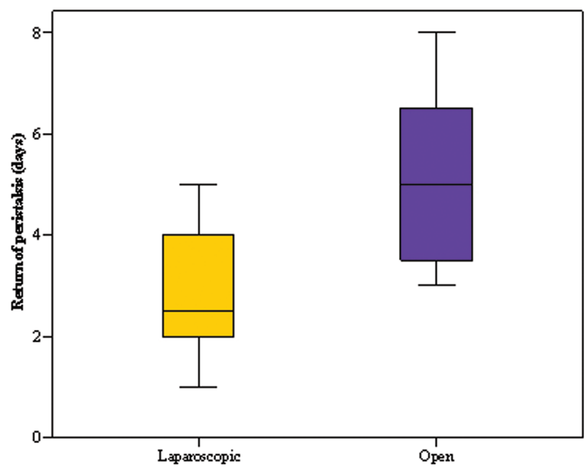
IQR, Inter quartile range; SD, Standard deviation; *U*, Mann Whitney test. *P*: *P* value for comparing among the two studied groups. *: Statistically significant at *P* less than or equal to 0.05.

Figure 4



Comparison among the two studied groups according to pain.

Figure 5



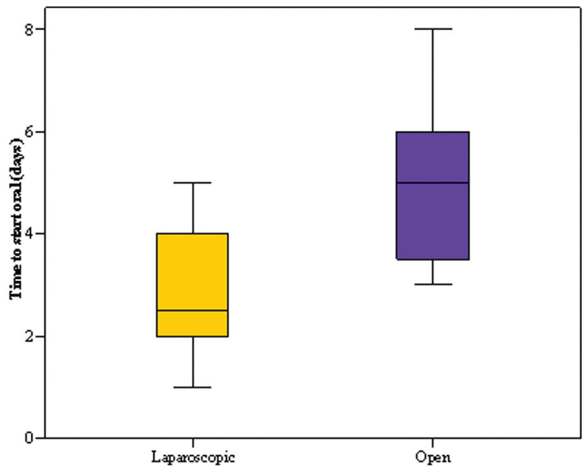
Comparison among the two studied groups according to return of peristalsis (days)

mean (2.75±1.21). In group B, it ranged from 3 to 8 days with a mean (4.95±1.67). There was a significant difference among the two groups with a lesser time in group A ($P < 0.001$).

Postoperative hospital stay and return to normal activity

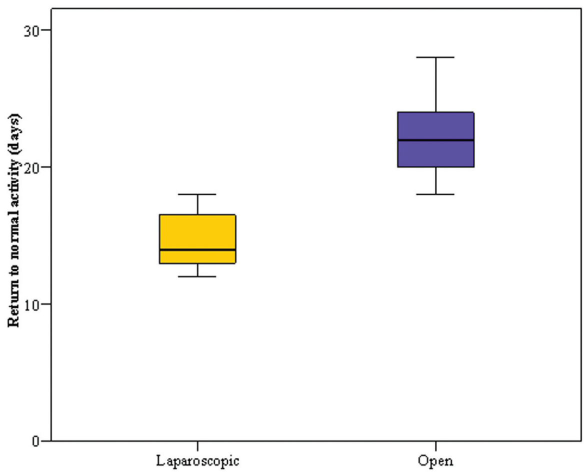
Summarized in Table 7 and Fig. 7.

Figure 6



Comparison among the two studied groups according to time to start oral (days).

Figure 7



Comparison among the two studied groups according to return to normal activity (days).

Incidence of postoperative paralytic ileus

As regard paralytic ileus, it occurred in three (15%) patients in group A. In group B, six (30%) patients had

Table 7 Comparison among the two studied groups according to Postoperative hospital stay and return to normal activity

	Laparoscopic (*n*=20)	Open (*n*=20)	Test of significance	*P*
Stay (days)				
Min. – Max.	3.0–7.0	4.0–10.0		
Mean±SD.	4.75±1.25	7.05±1.88	*t*=4.559*	<0.001*
Median (IQR)	4.50 (4.0–6.0)	7.0 (5.50–8.50)		
Return to normal activity (days)				
Min. – Max.	12.0–18.0	18.0–28.0		
Mean±SD.	14.80±1.94	22.15±2.81	*U*= 9.622*	<0.001*
Median (IQR)	14.0 (13.0–16.50)	22.0 (20.0–24.0)		

IQR, Inter quartile range; SD, Standard deviation; *U*, Mann Whitney test. *P*: *P* value for comparing among the two studied groups.
*: Statistically significant at *P*less than or equal to 0.05.

paralytic ileus. There was no significant difference among the two groups ($P=0.451$).

Incidence of postoperative IAA

In group A, two (10%) patients had intraabdominal abscess postoperative. In group B, one (5%) patient had Intraabdominal abscess (IAA) postoperative. There was no significant difference among two groups ($P=1.00$).

Incidence of wound complications

In group A, two (10%) patients developed wound complication while in group B seven (35%) patients developed wound complication postoperative. There was no significant difference among the two studied groups ($P=0.127$).

Incidence of need for readmission

In group A, only one (5%) patient needed for readmission while in group B two (10%0 patients needed for readmission. There was no significant difference among two groups ($P=1.00$) Table 8.

Table 8 Comparison among the two studied groups according to postoperative parameters

	Laparoscopic (*n*=20) Number (%)	Open (*n*=20) Number (%)	χ^2	*P*
Ileus	3 (15.0)	6 (30.0)	1.290	^{FE}P=0.451
IAA	2 (10.0)	1 (5.0)	0.360	^{FE}P=1.000
Wound complications	2 (10.0)	7 (35.0)	3.584	^{FE}P=0.127
Need for admission	1 (5.0)	2 (10.0)	0.360	^{FE}P=1.000

FE, Fisher Exacts; χ^2, Chi square test. *P*: *P* value for comparing among the two studied groups. *: Statistically significant at *P* less than or equal to 0.05.

Discussion

General surgeons have long held the misconception that laparoscopic appendectomy should not be administered to patients who have complicated appendicitis. Concerns over the technical requirements, the high rate of conversion, the challenge of ligation the stump of the appendix, and the considerable risk of postoperative intraabdominal abscess has led to a preference for the open procedure in such instances Lin and colleagues [11]. Through a prospective double-blinded randomized controlled trial, our study has been carried out to compare the postoperative outcomes of LA in cases of complicated appendicitis to those in the OA control group in order to provide answers to these questions.

The concept ‘complicated appendicitis‘ needs additional description in the literature because it can manifest in a variety of complications including perforation, peri appendicular abscess, mass, and peritonitis, each of which requires a distinct method of treatment Gomes and colleagues [1]. Complicated appendicitis is associated with longer hospital stays and increased morbidity rates. A significant risk of postoperative septic complications, such as intra-abdominal abscesses formation and surgical site infections, have been associated with complicated appendicitis Schlottmann and colleagues [12].

The precise date of the first LA for complicated appendicitis in adults is uncertain. In complicated appendicitis, Wullstein and colleagues were the first to demonstrate its possibility, while Towfigh and colleagues reported the first prospective research in 2006 [13,14]. Numerous authors have verified the viability and safety of LA in complicated appendicitis, and some have even advocated that this procedure became standard in the field of complicated appendicitis Lin and colleagues, Wullstein and colleagues, Yu and colleagues, Lim and colleagues [11,13,15–21].

In the current study, the LA group’s operative time was significantly longer. Rapidly forming adhesions to the nearby omentum and bowel act as a host defense to localize the inflammatory reaction. While these adhesions can be easily dissected during open surgery, it may take more time during laparoscopy due to the patient's placement, the narrow space, and the challenge of correctly positioning instruments to release these adhesions Yu and colleagues, Horvath and colleagues [15,16].

The difference in operating time between early and late cases was significantly reduced as the learning curve improved; although, it was still longer than that in OA group. There is general agreement that learning curve and surgical skill are related to operating time Yu and colleagues, Horvath and colleagues, Lim and colleagues [15,16,21].

Contrary to popular opinion, we believe that intraoperative situations are the primary driver of conversion rather than the surgeon's experience. Despite the surgeons' skill, in our study intraoperative bleeding happened in three (15%) patients compared with two (10%) patients, though it was minor, due to dissection of adhesions and mesoappendix and were controlled by simple hemostatic techniques. One (5%) patient had to be converted, which was a case of appendicular mass, because of dense fibrosis and adhesions between appendix and cecum. In the literature, the conversion rate varies from 0 to 47% Fukami and colleagues, Katsuno and colleagues, Lim and colleagues, Tiwari and colleagues [17,18,21–27].

Postoperative pain was evaluated using a VAS score and the patient's need for effective, affordable analgesics such ketorolac sodium ampoules. In addition, suction of CO_2 from the abdominal cavity and pneumoperitoneum at low-pressure were employed in all patients to decrease postoperative pain, along with limited manipulation and minimized trauma Sauerland and colleagues, Ge and colleagues [24,28]. This study showed that LA had a major advantage in reducing postoperative pain.

Our findings are in accordance with previous studies that highlighted the perceived benefits of laparoscopic appendectomy in decreasing wound-related complications Khiria and colleagues, Horvath and colleagues, Lim and colleagues, Kirshtein and colleagues [5,16,21,25]. Extraction in prepared gloves, wound protector devices or Endobags reduced surgical site infection. On the other hand, Taguchi and colleagues and Edwards and colleagues have found no significant difference in wound complication among OA and LA in complicated appendicitis [25,29].

According to Asarias and colleagues postoperative IAA formation is five times more prevalent following complicated appendicitis [30]. However, the incidence of postoperative IAA formation didn't significantly differ among OA and LA in complicated appendicitis. To reduce the incidence of IAA, Some operative considerations were suggested as low-pressure pneumoperitoneum, which is thought to prevent bacterial translocation to the bloodstream Evasovich and colleagues, Gurtner and colleagues [31,32], aspiration of pus early in the operation, and performing a sound adhesiolysis to prevent missing pus pockets. The Aspiration-irrigation method is conducted to remove any contaminated fluid until clear aspirate is obtained, followed by appropriate drainage. Multiple drains may not be preferred by many surgeons.

Horvath and colleagues attributed the greater prevalence of IAA following LA, to the application of the excessive irrigation without proper aspiration, whereas Gupta and colleagues blamed extensive irrigation and vigorous handling of the contaminated appendix for raising the risk of IAA [16,33]. In contrary, Reid and colleagues alongside with Piskun and colleagues thought that IAA had multiple causes as well as that the severity of contamination and inflammation inside the abdomen instead of a particular technical problem in the process of appendectomy determined how they developed Dimitriou and colleagues [26,34].

In our cases, an adequate amount of irrigation fluid was used. It was provided under direct laparoscopic view in little amounts followed by suction and that procedure was continued until fluid became clear. Irrigation has been correlated with the increase in IAAs. However, other studies concluded that the development of IAA does not have a distinct relation to irrigation and aspiration solely Taguchi and colleagues, St Peter and colleagues [35,36].

Return of peristalsis postoperatively and time to start oral were significantly reduced, two to three days, in patients after LA, then after OA. We noted that the probability of ileus was higher but not significant in OA, in concordance to the literature, this may be due to Laparoscopy's restricted handling of small bowel Garcia-Caballero and Vara-Thorbeck, Schwenk and colleagues [37,38].

Patients in LA group had less hospital stay, and were able to return to their normal activity 6 to 7 days sooner than those in the OA group. This is consistent with literature, stating the strong impact of LA over OA Lin and colleagues, Towfigh and colleagues, Yu and colleagues, Fukami and colleagues, Katsuno and colleagues, Galli and colleagues, Tiwari and colleagues, Ge and colleagues [11,14,15,17,18,20, 27,28].

Together, these findings provide more concrete proofs that laparoscopy is appropriate for managing complicated appendicitis as in acute appendicitis because patients get the well-known benefits of the minimal invasive surgery and in the same time don't have a higher probability of postoperative IAA than OA.

Conclusion

From the results of this study, laparoscopy should be considered in the setting of complicated appendicitis, as superior to open approach, with lesser postoperative pain, earlier return of peristalsis and resumption of oral intake, shorter length of stay at hospital, earlier restoration of physical activity and lesser morbidity. If proper precautions are taken, the potential for intra-abdominal collection shouldn't prevent laparoscopic surgeons from performing this surgical technique on a regular basis Fig. 7.

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Conflicts of interest

No conflict of interest.

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