

Laparoscopic Extracorporeal Appendectomy in Overweight and Obese Children

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ABSTRACT

Background and Objectives: To compare surgical outcomes of overweight and obese patients with acute appendicitis who have undergone single-port extracorporeal laparoscopically assisted appendectomy (SP) with those who have had conventional 3-port laparoscopic appendectomy (TP).

Methods: This single-center retrospective chart review included patients 21 years of age and younger with a preoperative diagnosis of appendicitis who underwent laparoscopic appendectomy from January 2010 through December 2015. Cases of gangrenous and perforated appendicitis were excluded. Subgroup analyses of patients with acute appendicitis were performed. Operative time (OT), length of stay (LOS), and cost were compared between groups stratified by body mass index (BMI) and operative technique.

Results: A total of 625 appendectomies were performed—457 for acute appendicitis. Sixty-eight patients were overweight. The SP technique (n = 30) had shorter OT (median minutes, 41 vs 68; $P < .001$), lower cost (median, \$5741 vs \$8530; $P < .001$), and shorter LOS (median hours, 16 vs 19; $P = .045$) than the TP technique had (n = 38). Seventy patients were obese: 19 were treated with SP and 51 with TP. LOS did not differ significantly between the SP and TP groups, but subjects treated with SP had shorter OT (median minutes, 39 vs 63; $P < .001$) and lower cost (median, \$6401 vs \$8205; $P = .043$).

Conclusions: The SP technique for acute appendicitis was found to have a significantly shorter OT and lower cost in all weight groups. There were minimal differences in LOS. SP should be considered in patients with acute appendicitis, regardless of their weight.

Key Words: Appendectomy, Appendicitis, Obesity, Pediatrics, Laparoscopy.

INTRODUCTION

Acute appendicitis is the most frequent indication for urgent surgery in children.¹ Laparoscopic appendectomy was first introduced in 1983 and has since replaced open appendectomy as the preferred surgical treatment for appendicitis.^{2–4}

Reduced-port and single-incision techniques have become popular in recent years. Procedures such as single-incision multiport laparoscopic technique (SIMPLA) and single-incision pediatric endosurgery (SIPES) involve a single, umbilical incision with 3 laparoscopic ports placed side-by-side through the umbilicus. A variation on this technique involves single-incision laparoscopic surgery (SILS), which allows introduction of multiple laparoscopic instruments into the peritoneal cavity for intracorporeal amputation of the appendix.

The transumbilical laparoscopically assisted extracorporeal amputation of the appendix is an alternative to the aforementioned single-site techniques. Other terms have been coined to describe this technique, such as the “all-in-one” appendectomy, umbilical 1-puncture laparoscopic-assisted appendectomy (UOPLAA), or transumbilical laparo-assisted appendectomy (TULAA). In this study, it is referred to as “single port” (SP).

SP benefits include lower cost, excellent cosmetic results, and shorter operative times (OTs).^{5,6} Despite evidence in support of wider application of SP for acute appendicitis, the use in overweight or obese children is challenging because of the technical difficulties posed by the increased thickness of the abdominal wall. In addition, with the use of SP, there are concerns about increased rates of

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surgical site infections, particularly in obese and overweight patients.

Obesity remains a prominent topic in pediatrics, with 17% of individuals aged 2–19 years diagnosed in the United States. Pre- and postoperative considerations unique to obese and overweight pediatric patients with appendicitis have raised discussion as to the differences in management and outcomes in this patient group.^{7,8} The question that remains is whether the well-established data supporting a less costly, quicker operation with SP can also be applied to obese and overweight children.

MATERIALS AND METHODS

After Institutional Review Board (IRB) approval, a single-center retrospective chart review was performed to identify patients who underwent laparoscopic appendectomy from January 2010 through December 2015. All patients 21 years of age and younger with a preoperative diagnosis of appendicitis were candidates. All procedures were performed by 4 pediatric surgeons at a tertiary referral center. Patients with a postoperative histological diagnosis of acute, perforated, or gangrenous appendicitis; available body mass index (BMI) data; OT and length of stay (LOS); and available cost data were analyzed. Cases in which an appendectomy was not the sole procedure were excluded. In the final cohort, cases of perforated or gangrenous appendicitis were excluded because the sample was small, and the preferential surgical treatment for those conditions is the conventional 3-port technique. The analysis of outcomes therefore included only cases of acute appendicitis.

Two different operative techniques were performed: single-port extracorporeal laparoscopically assisted appendectomy (SP) and conventional 3-port laparoscopic appendectomy (TP), with intracorporeal appendiceal amputation and retrieval in an Endo catch bag (Medtronic, Minneapolis, Minnesota, USA). Patients were not randomized to either technique. Surgical technique was decided based on surgeon preference. Using age- and gender-adjusted percentiles for BMI, we classified the patients as underweight or normal weight (BMI less than the 85th percentile, or less than 25 kg/m² for patients age 20 and older), overweight (BMI ranging from the 85th to the 94th percentiles, or 25–29 kg/m² for patients age 20 and older), or obese (BMI at or above the 95th percentile, or at or above 30 kg/m² for patients age 20 and older).

Outcomes analyzed for each group included OT in minutes (time of incision to time of dressing application),

hospital LOS in hours (from postoperative care unit [PACU] discharge time to hospital discharge time), total cost of hospitalization, surgical site infection (SSI) with postoperative need for antibiotics, postoperative ileus (defined as no return of bowel function within 2 days), conversion from SP to TP or TP to open, and intraoperative complications including vascular, urethral, or hollow viscus injury.

Operative Technique for SP

The umbilicus is everted, and a vertical intraumbilical incision is made. According to the Hasson technique, an 11-mm Covidien STEP trocar (Medtronic) is placed into the abdominal cavity. Capnoperitoneum with CO₂ is established to a pressure of 12–15 mm Hg. The 10-mm offset Storz operating laparoscope (Karl Storz, El Segundo, California, USA) is introduced and, if necessary, the cecum is mobilized with a blunt 5-mm grasper. The tip of the appendix is grasped, the pneumoperitoneum released, and the appendix exteriorized through the umbilical incision. In case of a severely inflamed or thick appendix, the fascial defect is enlarged before exteriorization. The mesoappendix is clamped, tied off, and divided. The base of the appendix is doubly ligated with a long-lasting polydioxanone suture and amputated extracorporeally. The mucosal stump is allowed to retract into the peritoneal cavity. Completion laparoscopy confirms correct position of the cecum, hemostasis, and proper seal of the appendiceal stump. The umbilical ring is closed using a figure-of-eight polyglactin suture and the umbilical skin approximated with simple interrupted absorbable monofilament. Bupivacaine is subcutaneously injected and a simple vacuum dressing with gauze and a bio-occlusive film is applied.⁹

Operative Technique for TP

Placement of the umbilical trocar and establishment of capnoperitoneum are identical with the SP technique. A 5-mm port is inserted in the left lower quadrant, and a second 5-mm port is placed in the suprapubic region. A window in the mesoappendix is bluntly created at the base, and the appendix and mesoappendix are stapled with a 10-mm MultiFire Endo GIAstapler (Medtronic). The appendix is retrieved in an Endo Catch bag (Medtronic). Closure, local anesthesia, and wound dressing are as described for SP.⁹

Statistical Methods

For BMI, age- and gender-adjusted BMI z-scores, percentiles, and percentage of the 95th percentile of age- and

gender-adjusted BMI computed for patients under the age of 20 years from year 2000 growth charts, we used a program provided by the Centers for Disease Control and Prevention (Atlanta, Georgia, USA).¹⁰

Data are expressed as medians and ranges for continuous variables, and counts and percentages for categorical variables. BMI and procedure groups were compared on the continuous outcomes cost, LOS, and OT (nonparametric Kruskal-Wallis test) and on binary outcomes of infection and procedure conversion (χ^2 and Fisher's exact tests). Sample sizes for individual variables reflect missing data. All analyses were performed on a complete-case basis. All tests were 2-tailed and performed at a significance level of $P < .05$. SAS 9.4 software (SAS Institute, Cary, North Carolina, USA) was used for all analyses.

RESULTS

A total of 625 appendectomies were performed, 263 by SP and 362 by TP (**Table 1**). Patients in the SP and TP groups did not differ significantly in age, but patients in the SP technique group were more likely to be female than were patients in the TP group (44% vs 33%; $P = .005$). Patients in the SP group were also more likely to have acute versus perforated or gangrenous appendicitis than were patients in the TP group (83% vs 66%; $P < .001$). There were 39 patients with gangrenous appendicitis, 15 of which were overweight or obese. There were 129 patients with perforated appendicitis, 34 of which were overweight or obese. Because of the aforementioned bias that favors treating gangrenous or perforated appendicitis with the TP technique and the limited number of cases of perforated or gangrenous appendix in overweight and obese children, the subgroup analysis was limited to 457 cases of acute appendicitis.

Table 1.
Patient Characteristics by Appendectomy Technique

Factor	Total (N = 625)	Single Port (n = 263)	Triple Port (n = 362)	P
Sex, n (%)				0.005 ^a
Male	389 (62)	147 (56)	242 (67)	
Female	236 (38)	116 (44)	120 (33)	
Age (years), median (min, max)	12 (2, 21)	12 (2, 21)	12 (3, 20)	0.96 ^b
Type of appendicitis, n (%)				<0.001 ^a
Acute	457 (73)	217 (83)	240 (66)	
Gangrenous	39 (6)	17 (6)	22 (6)	
Perforated	129 (21)	29 (11)	100 (28)	
BMI category, n (%)				0.009 ^a
Underweight or normal weight	438 (70)	198 (75)	240 (66)	
Overweight	88 (14)	37 (14)	51 (14)	
Obese	99 (16)	28 (11)	71 (20)	
BMI-for-age percentile*, median (min, max)	70 (0, 100)	63 (0, 100)	73 (0, 100)	0.014 ^b
Cost, median (min, max)	7842 (3122, 88,020)	6266 (3122, 32,311)	8927 (3408, 88,020)	<0.001 ^b
LOS (hours), median (min, max)	22 (1, 346)	20 (1, 244)	23 (1, 346)	<0.001 ^b
OP (minutes), median (min, max)	58 (16, 227)	40 (16, 227)	67 (27, 191)	<0.001 ^b
Converted, n (%)	21 (3)	18 (7)	3 (0.8)	<0.001 ^a
Infection, n (%)	32 (5)	17 (6)	15 (4)	0.19 ^a

$P < .05$ indicates significant results.

*Data not available for all subjects; n = 2 subjects with missing BMI-for-age percentile.

^aPearson's χ^2 test.

^bKruskal-Wallis test.

No intraoperative complication, iatrogenic perforation, abscess, or postoperative ileus was found in SP treatment of acute appendicitis.

In 38 overweight patients treated with TP, 35 required 1 stapler load, 2 required 2 reloads, and 1 required 1 reload. The average cost of stapler use in this cohort was \$224.37 per patient and the average stapler loads used was 1.13 per patient. In 51 obese patients treated with TP, 41 needed 1 stapler load, 8 needed 1 reload, and 2 needed 2 reloads. The average cost of stapler use in this cohort was \$234.11 per patient, and the average stapler loads used was 1.23 per patient.

Results for under- and normal-weight patients with acute appendicitis (n = 319) are summarized in **Table 2**. Subjects treated with the SP technique (n = 168) had shorter OT (median minutes, 39 vs 60; $P < .001$), shorter LOS (median hours, 18 vs 20; $P = .001$), and lower cost (median, \$5841 vs \$7812; $P < .001$) than did subjects treated with the STP technique (n = 151).

Table 3 summarizes findings for overweight patients with acute appendicitis (n = 68). Overweight patients treated with the SP technique (n = 30) had shorter OT (median minutes, 41 vs 68; $P < .001$), lower cost (median, \$5741 vs \$8530; $P < .001$), and shorter LOS (median hours, 16 vs

19; $P = .045$) than did overweight patients treated with the TP technique (n = 38).

Among all patients with acute appendicitis, 70 were obese (**Table 4**). Obese patients treated with the SP technique (n = 19) had shorter OT (median minutes, 39 vs 63; $P < .001$) and lower cost (median, \$6401 vs \$8205; $P = .043$) than did subjects treated with the TP technique (n = 51). LOS did not differ significantly between obese patients treated with SP or TP.

In all patients with acute appendicitis who underwent SP (n = 217), BMI groups did not differ significantly in LOS, OT, and cost (**Table 5**). There were 3 conversions from SP to TP in obese patients (16%), 1 in overweight patients (3%), and 2 in under- or normal-weight patients (1%; $P = .009$). There were no conversions from SP or TP to open procedures.

DISCUSSION

Although data show that laparoscopic appendectomy is the procedure of choice versus open appendectomy for treatment of acute appendicitis in obese children,¹¹ there are limited data supporting the use of SP with the associated cost and time benefits in the pediatric overweight and obese population.

Table 2.
Characteristics of Under- or Normal-Weight Patients by Appendectomy Technique

Factor	Total (N = 319)	Single Port (n = 168)	Triple Port (n = 151)	P
Sex, n (%)				0.22 ^a
Male	183 (57)	91 (54)	92 (61)	
Female	136 (43)	77 (46)	59 (39)	
Age (years), median (min, max)	12 (3, 21)	13 (3, 21)	12 (3, 18)	0.14 ^b
BMI-for-age percentile*, median (min, max)	51 (0, 85)	49 (0, 85)	56 (1, 85)	0.21 ^b
Cost, median (min, max)	6879 (3122, 38,526)	5841 (3122, 12,944)	7812 (3429, 38,526)	<0.001 ^b
LOS (hours), median (min, max)	20 (1, 213)	18 (1, 130)	20 (1, 213)	0.001 ^b
OP (minutes), median (min, max)	49 (16, 113)	39 (16, 98)	60 (27, 113)	<0.001 ^b
Converted, n (%)	2 (0.6)	2 (1)	0 (0)	0.50 ^c
Infection, n (%)	10 (3)	6 (4)	4 (3)	0.64 ^a

$P < .05$ indicates significant results.

*Data were not available for all subjects; n = 1 subject with missing BMI-for-age percentile.

^aPearson's χ^2 test.

^bKruskal-Wallis test.

^cFisher's exact test.

Table 3.
Characteristics of Overweight Patients with Acute Appendectomy by Technique

Factor	Total (N = 68)	Single Port (n = 30)	Triple Port (n = 38)	P
Sex, n (%)				0.089 ^a
Male	48 (71)	18 (60)	30 (79)	
Female	20 (29)	12 (40)	8 (21)	
Age (years), median (min, max)	13 (6, 20)	11 (6, 17)	15 (7, 20)	0.008 ^b
BMI-for-age percentile*, median (min, max)	90 (85, 95)	91 (85, 95)	90 (85, 94)	0.080 ^b
Cost, median (min, max)	7629 (3675, 26,414)	5741 (3675, 26,414)	8530 (4945, 13,826)	<0.001 ^b
LOS (hours), median (min, max)	18 (1, 71)	16 (1, 54)	19 (9, 71)	0.045 ^b
OP (minutes), median (min, max)	60 (19, 116)	41 (19, 94)	68 (43, 116)	<0.001 ^b
Converted, n (%)	1 (1)	1 (3)	0 (0)	0.44 ^c
Infection, n (%)	4 (6)	2 (7)	2 (5)	0.99 ^c

P < .05 indicates significant results.

*Data not available for all subjects; n = 1 subject with missing BMI-for-age percentile.

^aPearson's χ^2 test.

^bKruskal-Wallis test.

^cFisher's exact test.

Table 4.
Characteristics of Obese Patients with Acute Appendectomy by Technique

Factor	Total (N = 70)	Single Port (n = 19)	Triple Port (n = 51)	P
Sex, n (%)				0.57 ^a
Male	48 (69)	14 (74)	34 (67)	
Female	22 (31)	5 (26)	17 (33)	
Age (years), median (min, max)	12 (4, 17)	12 (4, 16)	12 (6, 17)	0.26 ^b
BMI-for-age percentile, median (min, max)	98 (95, 100)	98 (96, 100)	98 (95, 100)	0.64 ^b
Cost, median (min, max)	7861 (3408, 20,066)	6401 (3458, 15,711)	8205 (3408, 20,066)	0.043 ^b
LOS (hours), median (min, max)	20 (1, 100)	20 (12, 43)	20 (1, 100)	0.62 ^b
OP (minutes), median (min, max)	61 (19, 147)	39 (19, 147)	63 (33, 144)	<0.001 ^b
Converted, n (%)	3 (4)	3 (16)	0 (0)	0.018 ^c
Infection, n (%)	3 (4)	2 (11)	1 (2)	0.18 ^c

P < .05 indicates significant results.

^aPearson's χ^2 test

^bKruskal-Wallis test.

^cFisher's exact test.

Knott et al¹² concluded that a single-incision procedure was not recommended for obese children, because of longer OTs, longer LOS, and increased hospital costs.

However, their technique is slightly different than the one applied in our study, with a larger incision of 1 to 2 cm, 1 camera port, and 1 independent fascial stab incision for a

Table 5.
Characteristics of Patients With SP Acute Appendectomy by BMI Group

Factor	Total (N = 217)	Under- or Normal Weight (n = 168)	Overweight (n = 30)	Obese (n = 19)	P
Sex, n (%)					0.25 ^a
Male	123 (57)	91 (54)	18 (60)	14 (74)	
Female	94 (43)	77 (46)	12 (40)	5 (26)	
Age (years), median (min, max)	12 (3, 21)	13 (3, 21)	11 (6, 17)	12 (4, 16)	0.23 ^b
Cost, median (min, max)	5878 (3122, 26,414)	5841 (3122, 12,944)	5741 (3675, 26,414)	6401 (3458, 15,711)	0.46 ^b
LOS (hours), median (min, max)	18 (1, 130)	18 (1, 130)	16 (1, 54)	20 (12, 43)	0.13 ^b
OP (minutes), median (min, max)	39 (16, 147)	39 (16, 98)	41 (19, 94)	39 (19, 147)	0.48 ^b
Converted, n (%)	6 (3)	2 (1)	1 (3)	3 (16)	0.009 ^c
Infection, n (%)	10 (5)	6 (4)	2 (7)	2 (11)	0.33 ^a

*Data not available for all subjects; n = 1 subject with missing BMI-for-age percentile.

^aPearson's χ^2 test,

^bKruskal-Wallis test.

^cFisher's exact test.

working instrument. Separate placement of laparoscope and dissecting instrument is technically more challenging and time consuming compared to a single transumbilical incision for a 10-mm working port in the SP technique. In addition, a larger incision and more extensive subcutaneous dissection could account for increased pain, leading to longer hospital time and higher postoperative infection rate.

In the cohort of patients with acute appendicitis who underwent SP, outcomes did not differ significantly in cost, LOS, and OTs between weight groups. Within the group of obese patients who underwent the SP operation, we found a significantly higher number of conversions from SP to TP than in the normal and overweight patients. The higher conversion rate of 16% in the obese SP group reflects that SP may not be optimal for all patients, particularly for obese patients. We do not consider this conversion rate to be a reason to avoid initiating the appendectomy with the SP technique in obese patients, as the SP technique requires umbilical access identical with TP, and laparoscopy is not abandoned.

The data support our experience that the SP technique is applicable in the obese and overweight groups compared with the normal-weight group and that body habitus as an independent factor should not have a negative impact when deciding in favor of or against the SP technique.

Our study was limited by its retrospective nature and included procedures performed by 4 surgeons, resulting in selection bias. Patients may have been preferentially selected for the SP or TP technique based on body habitus or surgeon's preference.

Cost

We found that the SP technique had a lower overall hospitalization cost for the treatment of appendicitis in all weight groups. SP is a less costly technique than conventional TP is, in agreement with the findings of Stylianou et al⁵ and Kulaylat et al.¹³

Those groups specifically studied whether surgeon-directed, disposable supply cost, and fully loaded operating cost accounts for the lower expense of the SP technique.⁵ Overall hospitalization cost was used in our study, as we feel it accounts for postprocedural complications.

A stapler was used for TP at our institution, whereas others may use Endoloops (Ethicon, Somerville, New Jersey, USA) or free ties. One might postulate that using a stapler accounts for the increase in cost compared to SP. When the average cost of the stapler was deducted from the cost of TP, the median cost of SP remained significantly lower in the overweight group (\$5741 vs \$8306; $P < .001$). In the obese group, the median cost of SP

remained less costly but did not reach significance (\$6401 vs \$7971; $P = .087$).

Operative Time

Median OT for the SP technique for acute appendicitis in previous studies ranged from 24 to 33 minutes.^{5,6} Codrich et al¹⁴ reported a median OT of 52 minutes for all types of appendicitis. Our median operating time for SP treatment of appendicitis was consistent with previous studies at 40 minutes. Many procedures were performed by surgical residents for whom the cases were the first attempt at using the SP technique.

Length of Stay

The minimal difference in LOS for SP and TP among the 3 weight groups is consistent with that in another study.¹⁵ Three of 4 surgeons routinely kept patients overnight after laparoscopic appendectomy. However, it has been shown that, after SP appendectomy, patients can be safely discharged from the recovery room on the day of surgery.¹⁶ In our institution, same-day discharge after laparoscopic appendectomy for acute appendicitis is standard practice.

Surgical Site Infections

In her cohort of 131 patients, Stanfill et al¹⁵ reported no difference in postoperative wound infection rates between the SP and TP techniques, although the patients were not stratified by weight. Their rate of SSIs in obese patients with acute appendicitis treated with SP was higher (11%) than in normal-weight (4%) and overweight (7%) patients, but the difference did not reach significance. The rate of SSI in obese patients in our study was comparable with general rates of infection after the SP technique.^{5,13,17} All SSIs fully resolved after a 5- to 10-day course of oral antibiotics. Given the full resolution of the SSIs and the few side effects of the antibiotics, we favor SP as the technique of choice.

Intraoperative Complications

Consistent with a previous study,¹⁸ no intraoperative complications were observed with the SP technique. The TP technique resulted in 1 case of bladder injury due to trocar placement. There was no postoperative ileus in the SP group.

CONCLUSION

The SP technique for acute appendicitis was found to have a significantly shorter OT and cost in all weight

groups. It also resulted in shorter LOS in the normal and overweight groups and was not significantly different in the obese cohort. SP in obese patients is comparable to TP and should be considered in overweight and obese patients with acute appendicitis.

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