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# Laparoscopic vs Open Appendectomy in Children

## *Outcomes Comparison Based on Age, Sex, and Perforation Status*

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**Hypothesis:** Outcomes of laparoscopic appendectomy (LA) will be similar to open appendectomy (OA) in children of all ages.

**Design:** Retrospective cohort study using discharge abstract data.

**Setting:** Twelve regional hospitals in Southern California.

**Patients:** Seven thousand six hundred fifty patients underwent appendectomy for acute appendicitis (LA = 3551, OA = 4099).

**Intervention:** Laparoscopic appendectomy or OA.

**Main Outcome Measures:** Thirty-day morbidity (wound infection, abscess drainage, and readmission) and length of hospitalization.

**Results:** Use of laparoscopy increased from 22% in 1998 to 70% in 2007. Overall, patients undergoing LA were older (mean [SD] age, 12.8 [3.2] vs 10.4 [3.7] years; $P < .001$) and had a lower perforation rate (24% vs 34%; $P < .001$). Multivariable logistic regression demonstrated a decreased odds ratio for wound infection (odds ratio, 0.6; 95% confidence interval, 0.5-0.8) and abscess drainage (odds ratio, 0.6; 95% confidence interval, 0.4-0.7) following LA compared with OA. Multivariable linear regression also showed decreased length of hospitalization following LA compared with OA.

**Conclusion:** Now the preferred operation for children with appendicitis, LA was associated with a decreased risk of wound infection, abscess drainage, and length of hospitalization compared with OA.

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SINCE THE ADOPTION OF LAPAroscopic appendectomy (LA) for appendicitis, there has been continuing controversy over its benefits over open appendectomy (OA).[1-13] In pediatric patients, the laparoscopic approach is still not considered standard of care because the recovery has been comparable with OA. Furthermore, there may be increased costs associated with LA.[14]

The role of laparoscopy in the management of perforated appendicitis continues to be controversial. Some studies have demonstrated an increased risk of intra-abdominal abscess and wound infections for perforated appendicitis treated with LA, while others have demonstrated noninferiority.[1-13] Furthermore, the studies evaluating the laparoscopic approach for pediatric perforated appendicitis are mainly retrospective. Thus, the purpose of this study was to compare outcomes of LA vs OA in pediatric patients for both perforated and nonperforated appendicitis. We also wanted to determine if outcomes between the 2 techniques were different based on age.

## METHODS

Following institutional review board approval, a retrospective review of all patients younger than 18 years undergoing LA or OA for appendicitis between 1998 and 2007 at 12 hospitals was performed. Patient factors collected included age (years), sex (male or female), race/ethnicity (black, Asian, Hispanic, or white), and the presence of perforation (nonperforated or perforated). Outcome variables were wound infection, postoperative abscess drainage, readmission within 30 days, and initial length of hospitalization (LOH). Outcomes between patients who underwent LA and OA were compared. Those who had interval appendectomy or appendectomy as part of another procedure were excluded. Patients with incomplete data or classified into another race/ethnic group were also excluded.

Patient data were collected in an Excel database (Microsoft Excel; Microsoft Corporation, Redmond, Washington) and translated into native SAS format using DBMS/Copy

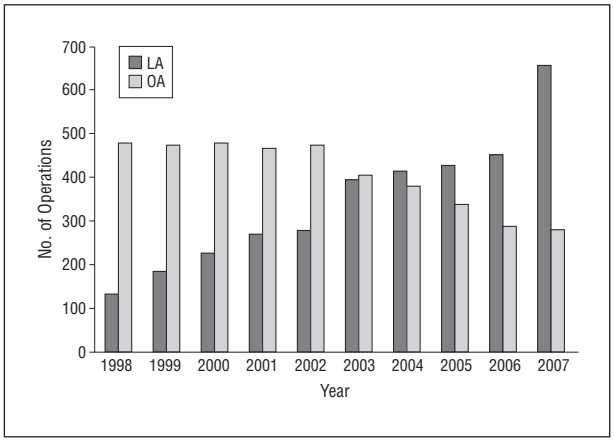


**Figure.** Use of laparoscopic appendectomy (LA) vs open appendectomy (OA) over time.

(Dataflux Corporation, Cary, North Carolina). Statistical analyses were performed using SAS version 9 (SAS Institute Inc, Cary).

Descriptive statistics were evaluated for all variables. For continuous, normally distributed data, means and standard deviations are reported and are compared using *t* tests. When the data were not normally distributed, continuous variables are reported as medians with interquartile ranges and are compared using the nonparametric Wilcoxon rank sum test. Categorical variables were compared using the $\chi^2$ test or Fisher exact test, as appropriate. After stratifying age into 3 groups, young (<5 years); middle (5-12 years); and older (>12 years), outcomes of LA were compared with OA.

After univariate analyses were performed, a multivariable logistic analysis was performed to delineate the predictors of wound infection, postoperative abscess drainage, and readmission within 30 days, after adjusting for potential confounders. Similarly, a multivariable linear regression analysis was performed to delineate the predictors for LOH.

## RESULTS

Overall, 7650 patients were included in this study (LA=3551, OA=4099). Use of LA increased significantly over the study period from 22% in 1998 to 70% in 2007 (**Figure**). This increase was seen across all age groups.

A comparison of LA and OA was performed as seen in **Table 1**. Overall, older children were more likely to have LA (age: LA, 12.8 [3.2] years vs OA, 10.4 [3.7] years; $P<.001$), whereas a higher percentage of male patients had OA (LA, 58% vs OA, 63%; $P<.001$). Patients with perforated appendicitis were more likely to undergo OA (LA, 24% vs OA, 34%; $P<.001$). Length of hospitalization, wound infection rates (LA, 2.4% vs OA, 5.2%; $P<.001$), and readmission rates (LA, 3.2% vs OA, 4.5%; $P=.002$) were lower following LA. There was no difference in the rate of abscess drainage between LA and OA.

Since the perforation rate was significantly different between the 2 techniques, we also analyzed the data after stratifying by perforation status (**Table 2**). For nonperforated appendicitis, patients who had LA were older (mean [SD] age, LA, 10.2 [1.9] years vs OA, 6.9 [1.7] years; $P<.001$), had a slightly shorter LOH (mean [SD], LA, 1.7 [1.5] days vs OA, 2.1 [1.6] days; $P<.001$), and a lower wound infection rate (mean, LA, 1.3% vs OA, 2.7%; $P=.003$) compared with OA. There were no differences in the rates of abscess drainage or readmission between LA and OA in patients with nonperforated appendicitis.

For perforated appendicitis, patients who had LA were again older (mean [SD] age, LA, 11.9 [3.6] years vs OA, 7.6 [2.8] years; $P<.001$), had shorter LOH (mean [SD], LA, 5.0 [3.0] days vs OA, 5.7 [3.4] days; $P<.001$), and a lower wound infection rate (LA, 5.7% vs OA, 9.2%; $P=.004$). There were no differences in the rates of postoperative abscess drainage or readmission between LA and OA for patients with perforated appendicitis.

Since age was also significantly different between the LA and OA cohorts, data were stratified and analyzed across age groups (<5 years, 5-12 years, >12 years) as seen in **Table 3**. Morbidity and LOH were similar in the young (<5 years) and middle (5-12 years) age groups for both perforated and nonperforated appendicitis. In older children (>12 years) with nonperforated appendicitis, the wound infection rate was lower for LA (LA, 1.1% vs OA, 3.5%; $P=.001$). In older children with perforated appendicitis, abscess drainage was lower (LA, 8.0% vs OA, 17.5%; $P<.001$) and LOH was shorter (LA, 4.8 [3.4] days vs OA, 5.6 [3.7] days; $P=.001$).

**Table 1. Comparison of LA vs OA for All Patients**

| | No. (%) | | |
|---|---|---|---|
| | LA (n=3551) | OA (n=4099) | *P* Value |
| Age, y, mean (SD) | 12.8 (3.2) | 10.4 (3.7) | <.001 |
| Male | 2071 (58) | 2597 (63) | <.001 |
| Hispanic | 2169 (61) | 2704 (66) | <.001 |
| African American | 187 (5.3) | 209 (5) | .84 |
| White | 1044 (29) | 1021 (25) | <.001 |
| Perforated | 839 (24) | 1393 (34) | <.001 |
| Wound infection | 86 (2.4) | 201 (5.2) | <.001 |
| Abscess drainage | 93 (2.6) | 111 (2.7) | .91 |
| Readmission | 112 (3.2) | 186 (4.5) | .002 |
| LOH, d, median (IQR) | 2 (1-3) | 2 (1-4) | <.001 |

Abbreviations: IQR, interquartile range; LA, laparoscopic appendectomy; LOH, length of hospitalization; OA, open appendectomy.

**Table 2. Thirty-Day Morbidity and LOH Following LA and OA for Nonperforated and Perforated Appendicitis**

| | No. (%) | | *P* Value |
|---|---|---|---|
| | LA | OA | |
| Nonperforated appendicitis | 2711 | 2605 | |
| Age, y, mean (SD) | 10.2 (1.9) | 6.9 (1.7) | <.001 |
| LOH, d, mean (SD) | 1.7 (1.5) | 2.1 (1.6) | <.001 |
| Readmission | 52 (1.9) | 61 (2.9) | .33 |
| Wound infection | 35 (1.3) | 71 (2.7) | .003 |
| Abscess drainage | 18 (0.7) | 13 (0.5) | .52 |
| Perforated appendicitis | 838 | 1393 | |
| Age, y, mean (SD) | 11.9 (3.6) | 7.6 (2.8) | <.001 |
| LOH, d, mean (SD) | 5.0 (3.0) | 5.7 (3.4) | <.001 |
| Readmission | 60 (7.2) | 125 (9) | .24 |
| Wound infection | 48 (5.7) | 129 (9.2) | .004 |
| Abscess drainage | 71 (8.5) | 98 (7) | .23 |

Abbreviations: LA, laparoscopic appendectomy; LOH, length of hospitalization; OA, open appendectomy.

**Table 3. Outcomes of LA and OA Based on Age and Perforation Status**

| | No. (%) | | | | | |
|---|---|---|---|---|---|---|
| | Nonperforated | | | Perforated | | |
| | LA | OA | *P* Value | LA | OA | *P* Value |
| **Age, <5 y** | | | | | | |
| Sample size | 21 | 151 | | 31 | 231 | |
| LOH, d, mean (SD) | 3.2 (2.1) | 2.7 (3.8) | .49 | 5.6 (2.4) | 6.7 (4.1) | .58 |
| Readmission | 2 (9.5) | 5 (3.3) | .18 | 2 (6.4) | 35 (15) | .31 |
| Wound infection | 0 | 7 (4.6) | .62 | 3 (9.7) | 19 (8.2) | .70 |
| Drainage | 0 | 1 (0.7) | >.99 | 1 (3.2) | 26 (11.2) | .18 |
| **Age, 5-12 y** | | | | | | |
| Sample size | 983 | 1604 | | 373 | 833 | |
| LOH, d, mean (SD) | 1.8 (4.1) | 1.9 (2.0) | .14 | 5.2 (3.4) | 5.6 (3.7) | .001 |
| Readmission | 23 (2.3) | 40 (2.5) | .88 | 23 (6.2) | 67 (8) | .33 |
| Wound infection | 16 (1.6) | 36 (2.2) | .33 | 21 (5.6) | 72 (8.6) | .08 |
| Drainage | 6 (0.6) | 8 (0.5) | .82 | 35 (9.4) | 73 (8.8) | .74 |
| **Age, >12 y** | | | | | | |
| Sample size | 1707 | 998 | | 436 | 506 | |
| LOH, d, mean (SD) | 1.6 (4.1) | 1.8 (2.0) | .10 | 4.8 (3.4) | 5.6 (3.7) | .001 |
| Readmission | 27 (1.6) | 20 (2.4) | .39 | 35 (8) | 50 (9.9) | .42 |
| Wound infection | 19 (1.1) | 29 (3.5) | .001 | 27 (6.2) | 41 (8.1) | .29 |
| Drainage | 12 (0.7) | 5 (0.5) | .62 | 35 (8) | 89 (17.5) | <.001 |

Abbreviations: LA, laparoscopic appendectomy; LOH, length of hospitalization; OA, open appendectomy.

**Table 4. Multivariable Logistic Regression of Factors Affecting Postoperative Wound Infection and Abscess Drainage**

| | OR (95% CI) |
|---|---|
| Wound infection | |
| Age | 1.00 (0.97-1.04) |
| Male | 1.2 (0.9-1.5) |
| Perforated | 4.3 (3.4-5.5) |
| LA vs OA[a] | 0.6 (0.5-0.8) |
| Abscess drainage | |
| Age | 1.02 (0.99-1.05) |
| Male | 1.1 (0.9-1.5) |
| Perforated | 4.2 (3.3-5.3) |
| LA vs OA[a] | 0.6 (0.4-0.7) |

Abbreviations: CI, confidence interval; LA, laparoscopic appendectomy; OA, open appendectomy; OR, odds ratio.
[a] Interpretation: after adjusting for age, sex, and perforation status, LA was associated with a decreased OR for wound infection and need for abscess drainage.

**Table 5. Multivariable Linear Regression of Factors Affecting LOH**

| | Parameter Estimate | *P* Value |
|---|---|---|
| Age | −0.05 | <.001 |
| Male | −0.10 | .11 |
| Perforation | 3.6 | <.001 |
| LA vs OA[a] | −0.23 | .001 |

Abbreviations: LA, laparoscopic appendectomy; LOH, length of hospitalization; OA, open appendectomy.
[a] Interpretation: after adjusting for age, sex, and perforation status, LA was associated with an LOH that was 5 to 6 hours shorter than for OA.

Results of the multivariable logistic regression are summarized in **Table 4**. After adjusting for age, sex, and perforation status, perforated appendicitis and the open technique increased the odds ratio for wound infection. Similar results were seen with respect to postoperative abscess drainage. Multivariable linear regression demonstrated that perforated appendicitis, a younger age, and the open technique were all associated with increased LOH (**Table 5**).

## COMMENT

Laparoscopic appendectomy has become the preferred method for the management of appendicitis.[1,14] Similar to a recent analysis of the California state database where a 2.8-fold increase in the use of LA from 1999 to 2006 was demonstrated,[1] the current study showed a significant and dramatic rise in all age groups in the use of LA over the last decade from 22% in 1998 to 70% in 2007. Despite being the preferred method for the treatment of appendicitis, it is unclear if LA results in superior outcomes.

Previous studies looking at LA vs OA in children have led to mixed results. It was initially shown that LA was associated with an increased risk for postoperative intra-abdominal abscess in children with perforated appendicitis.[2] Similar results were also demonstrated in a large database analysis for both perforated and nonperforated appendicitis.[1] However, other studies have not confirmed this finding.[3-13] A recent meta-analysis of 23 prospective and retrospective studies suggested that LA was associated with decreased postoperative complications.[13] When analyzing only the prospective studies, however, there were no significant differences in postoperative morbidity between LA and OA. One reason for the contradicting outcomes may be the lack of power in the majority of these studies. For example, if the wound infection rate associated with OA is 5% (as seen in this study), to see a 50% relative reduction at a 5% significance level and 80% power,

a randomized controlled study would require nearly 1000 patients in each arm. To date, the largest prospective randomized trial comparing LA with OA in children enrolled just over 500 patients for the entire study.[3] Conversely, studies with huge population databases (eg, >20 000 patients) may show a statistically significant difference but without a clinically significant difference. In a recent database study containing nearly 100 000 patients, LA was associated with a statistically significant increased risk of intra-abdominal abscess drainage[1] from 3.8% with OA to 4.9% in LA in children with perforated appendicitis, but the clinical relevance of this difference is questionable.

The purpose of this study was to compare outcomes of LA and OA based on perforation status and age. We specifically looked at infectious complications based on perforation status. For children with nonperforated appendicitis, the wound infection rate was 2 times higher following OA, whereas the rate of abscess drainage was similar for both LA and OA. We found similar results in children with perforated appendicitis.

Although the use of LA increased over our study period, when the analyses were stratified by age, the adoption of LA occurred much later in younger children. In this study, pediatric surgeons cared for children younger than 6 years and general surgeons cared for children older than 6 years. Reflecting the influence of newly trained general and pediatric surgeons, almost all children, even those younger than 6 years, are currently treated with LA. In addition, general surgeons appear to be more willing to perform LA in younger and smaller children. Despite the increasing performance of LA in younger children, it is still not certain whether the outcomes are superior to OA. It appears that the main benefit of LA is in children older than 12 years, since in these older children, LA was associated with decreased wound infections in cases of nonperforated appendicitis. Furthermore, in children older than 12 years with perforated appendicitis, there was a lower rate of abscess drainage with LA.

Cost may also be an important factor when comparing LA with OA. In general, increased costs are due to higher rates of complications or longer LOH.[14] In this study, LA was associated with a shorter LOH for both nonperforated and perforated appendicitis. Although we did not perform a formal cost analysis, we believe that the cost of LA may be lower since both morbidity and LOH were lower. Since the readmission rates were similar between LA and OA, we would expect minimal differences with respect to overall LOH and cost. Increased operative time may also lead to higher cost. We did not specifically look at operative times in this study; however, recent studies have shown that the operative times for LA are similar to OA.[3,13] Furthermore, as institutions gain more experience with laparoscopic techniques in children, LA operative times will become less of a factor and in some instances shorter than OA.[15]

Our study is limited for a number of reasons, in addition to those listed earlier. Our data are based on a retrospective review of a discharge database, and the *International Classification of Diseases, Ninth Revision* code of each diagnosis and procedure was not independently validated. We could not control for the different surgeons' preference or experience with respect to operative technique. The LA and OA cohorts were not randomized groups, and thus, there was potential for confounding. However, we adjusted for age, sex, race, and perforation status using multivariable analysis. Finally, we did not obtain negative appendectomy rates from this database nor could we determine the duration of symptoms prior to presentation.

Overall, LA was associated with decreased wound infections and shorter LOH compared with open appendectomy. However, these findings were mainly seen in children older than 12 years.

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