

Does Laparoscopic Appendectomy Impart an Advantage over Open Appendectomy in Elderly Patients?

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Abstract

Background The use of laparoscopy in the elderly has been increasing in recent years. The data comparing laparoscopic (LA) with open appendectomy (OA) in elderly patients are minimal. We evaluated outcomes of LA versus OA in perforated and nonperforated appendicitis in elderly patients (aged ≥ 65 years).

Methods Using the Nationwide Inpatient Sample database, clinical data of elderly patients who underwent LA and OA for suspected acute appendicitis were evaluated from 2006 to 2008.

Results A total of 65,464 elderly patients underwent urgent appendectomy during this period. The rate of perforated appendicitis was twice as high in elderly patients (50 vs. 25%, $p < 0.01$) and rate of LA in elderly patients was lower (52 vs. 63%, $p < 0.01$) compared with patients younger than aged 65 years. Utilization of LA increased 24% from 46.5% in 2006 to 57.8% in 2008 ($p < 0.01$). In elderly patients with acute nonperforated appendicitis, LA had lower overall complication rate (15.82 vs. 23.49%, $p < 0.01$), in-hospital mortality (0.39 vs. 1.31%, $p < 0.01$), hospital charges (\$30,414 vs. \$34,095, $p < 0.01$), and mean length of stay (3.0 vs. 4.8 days, $p < 0.01$) compared with OA. Additionally, in perforated appendicitis in elderly patients, LA was associated with lower overall complication rate (36.27 vs. 46.92%, $p < 0.01$), in-hospital

mortality (1.4 vs. 2.63%, $p < 0.01$), mean hospital charges (\$43,339 vs. \$57,943, $p < 0.01$), and shorter mean LOS (5.8 vs. 8.7 days, $p < 0.01$).

Conclusions Laparoscopic appendectomy can be performed safely with significant advantages compared with open appendectomy in the elderly and should be considered the procedure of choice for perforated and nonperforated appendicitis in these patients.

Introduction

Appendicitis accounts for the commonest emergency surgical procedures in the nation. Although appendectomy in the elderly accounts for 5–10% of all appendectomies, appendicitis is a concern in geriatrics because the frequency of appendicitis increases with increasing life expectancy [1, 2]. Additionally, the size of the elderly population in the United States is increasing: by 2050, the number of Americans aged 65 years and older is projected to be 88.5 million, more than double its projected population of 40.2 million in 2010 [3]. Therefore, we can expect an increase in the occurrence of appendicitis in the elderly. Challenges presented by acute appendicitis in the geriatric population include a greater perforation rate than younger age groups [4, 5], high morbidity rates [6], and higher mortality [7] compared with younger age groups. The high perforation rate for the elderly results from the difficulty in diagnosing appendicitis in elderly patients due to atypical symptoms, underlying medical conditions, and communication difficulties [5].

For the past century, the conventional management for appendicitis is open appendectomy (OA), which has been a quick, easy, and “fool-proof” procedure. After the development of endoscopy, Semm [8] introduced laparoscopic

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appendectomy (LA) in 1983. Since its introduction, the use of LA has been controversial, but LA has reported advantages over OA, such as better navigation and visualization of the lower abdomen, decreased postoperative pain, shorter hospital stay, faster recovery, and return to normal activities and better cosmetic appearance [9, 10]. Compared with OA, the reported disadvantages of LA are longer operative time, higher surgical costs, and a higher incidence of postoperative abscess formation [10–12]. Considering that the benefits of LA may outweigh the disadvantages, surgeons have been increasingly adopting LA as a substitute for OA, and some authors even recommend LA over OA for acute appendicitis [9, 13].

There is much controversy over the use of LA for the elderly, and few studies have evaluated the outcomes of LA to OA in the elderly population [14–17]. The goals of this study were: (1) to evaluate the utilization of LA in the elderly (≥ 65 years) who underwent appendectomy for acute appendicitis in recent years, and (2) to compare the outcomes of LA versus OA in nonperforated and perforated appendicitis in elderly patients by analyzing four components: postoperative complications, mean length of stay (LOS), in-hospital mortality, and total hospital charges.

Materials and methods

Database

In this study, we used the Nationwide Inpatient Sample (NIS) database. The NIS is the largest inpatient care database in the United States, which consists of a nationally representative sample of approximately 20% of U.S. community hospitals, yielding a sampling frame that comprises approximately 90% of all hospital discharges in the United States. Approximately 1,000 hospitals across the nation participate in the NIS and the NIS includes annual data on approximately 8 million hospital stays. NIS data are collected from hospital discharge abstracts that allow determination of all procedures performed during a given hospital admission. Additionally, the NIS holds discharge information on inpatient hospital stay, including patient characteristics, length of stay, specific postoperative morbidity, and observed and expected in-hospital mortality. The NIS database holds no information on complications arising after discharge. Approval usage for the NIS patient-level data in this study was acquired from the Institutional Review Board of the University of California, Irvine School of Medicine and the NIS.

Data analysis

We analyzed discharge data of elderly patients (≥ 65 years of age) who underwent appendectomy for suspected acute

appendicitis from 2006 to 2008, which are the latest available years of this database. Elderly patients hospitalized with diagnosis of appendicitis who underwent appendectomy were selected by identifying discharges with International Classification of Disease ninth revision (ICD-9) appendectomy codes (laparoscopic: 47.01 and open: 47.09); these patients were admitted emergently with diagnosis of appendicitis. Based on ICD-9 diagnosis codes, these patients were divided into the perforated (540.0, 540.1) or nonperforated (540.09, 541 and 542) groups. Incidental appendectomies, elective appendectomies and patients who were treated nonoperatively for acute appendicitis were excluded from this study. We separately compared the outcomes of LA with OA in perforated and nonperforated appendicitis. Patient characteristics of interest included age, gender, race/ethnicity, and comorbidities. Other data of interest included postoperative complications, length of hospital stay, total hospital charges, and in-hospital mortality.

Statistical analysis

The frequencies of categorical variables are expressed as a percentage of the group of origin. Continuous variables are reported as means $\pm$ standard deviation for patient age, LOS, and total hospital charges. All statistical analyses were conducted using SAS version 9.2 (SAS Institute, Cary, NC). Because the NIS database is a 20% sample of the United States yearly inpatient admissions, weighted samples (NIS variable DISCWT) were used to produce national estimates for all analyses. Appropriate statistical tests were used for both categorical variables (χ^2 analysis) and continuous variables (Student's *t* test) in the univariate analysis comparing demographic and outcomes variables for patients undergoing LA or OA. Multivariate regression analyses were performed to assess the risk-adjusted influence of the type of procedure (LA vs. OA) on postoperative complications, in-hospital mortality, and hospital stay. Statistical significance was set at *p* value < 0.05 .

Results

From 2006–2008, a total of 65,464 elderly patients underwent urgent appendectomy, accounting for 7.7% of all appendectomies. Overall, the mean age was 74 years, 50.4% of the patients were female, and 81% were Caucasian. Compared with patients younger than age 65 years, the rate of perforated appendicitis was twice as high in the elderly patients (50 vs. 25%, $p < 0.01$) and the rate of LA for elderly patients was significantly lower (52 vs. 63%, $p < 0.01$). Utilization of LA in 2008 (57.8%) increased 24% compared with 2006 (46.5%) in patients who

Table 1 Trends of utilization of laparoscopic appendectomy in the elderly in the United States 2006–2008

Rate of laparoscopic appendectomy (%)	Nonperforated appendicitis	Perforated appendicitis	Total
2006	55.9	37.5	46.6
2007	61.5	41	51.2
2008	67.7	47.6	57.9
Overall (2006–2008)	61.9	42.1	52
2008 vs. 2006 (increase)	21%	27%	24%

underwent appendectomy (Table 1). However, this increase in rate was greater for perforated appendicitis (27%).

Laparoscopic versus open appendectomy in acute nonperforated appendicitis

Table 2 shows patients' characteristics and perioperative outcomes in non-perforated appendicitis. Within the non-perforated appendicitis population, there were a total of 32,783 elderly patients of whom 20,301 underwent LA (61.9%) and 12,482 underwent OA (38.1%). The average age for LA was slightly lower than OA (LA: 73.0 vs. OA: 74.0 years). In both groups, the majority of the patients were Caucasian (LA: 80 and OA: 81.1%). The overall postoperative complication rate for the OA group was significantly higher than the LA group (OA: 23.49 vs. LA: 15.82%, $p < 0.01$). The majority of the postoperative complications (pneumonia, acute renal failure, respiratory failure, deep vein thrombosis, ileus, abdominal abscess, wound infection, and bowel obstruction) were significantly higher for the OA group than the LA group. In-hospital mortality rate was lower for LA than OA (LA: 0.39 vs. OA: 1.31%, $p < 0.01$). The mean length of stay for the LA group was shorter than the OA group (LA: 3.0 vs. OA: 4.8 days, $p < 0.01$). Additionally, total hospital charges were lower for the LA group than the OA group (LA: \$30,414 vs. OA: \$34,095, $p < 0.01$).

Laparoscopic versus open appendectomy in acute perforated appendicitis

Table 3 lists patients' characteristics and perioperative outcomes of perforated appendicitis. Within the population, there were a total of 32,680 patients, of whom 13,765 underwent LA (42.1%) and 18,915 underwent OA (57.9%). Like nonperforated appendicitis, the LA group had a slightly lower mean age than OA (LA: 73.5 vs. OA: 74.7 years, $p < 0.01$). For both procedures, the majority of the patients were Caucasian (LA: 83.6 and OA: 80.6%) and LA was performed slightly more frequently on women

Table 2 Acute nonperforated appendicitis in elderly patients (≥ 65 years): laparoscopic (LA) vs. open appendectomy (OA), 2006–2008

Patient characteristics and outcomes	LA (<i>N</i> = 20,301)	OA (<i>N</i> = 12,482)	<i>p</i> value
Demographics (%)			
Mean age (year)	73.0	74.0	<0.01
Female	52.98	51.15	<0.01
Race			
Caucasian	80.0	81.1	<0.01
African American	3.7	4.3	
Hispanic	8.4	7.5	
Asian–Pacific Islander	4.9	4.6	
Native American	0.5	0.4	
Other	2.5	2.1	
Comorbidities (%)			
Diabetes mellitus	15.8	17.8	<0.01
Hypertension	62.4	60.2	<0.01
Congestive heart failure	5.5	8.1	<0.01
Chronic pulmonary disease	14.4	17.5	<0.01
Liver disease	0.9	0.8	0.23
Chronic renal failure	5.0	5.9	<0.01
Alcohol abuse	0.7	1.1	0.03
Peripheral vascular disease	4.8	5.7	<0.01
Postoperative complications (%)			
Urinary tract infection	2.79	2.98	0.33
Pneumonia	1.88	2.4	0.01
Acute renal failure	2.34	3.23	<0.01
Respiratory failure	2.14	4.24	<0.01
Myocardial infarction/angina	0.63	0.75	0.15
Deep vein thrombosis	0.14	0.31	<0.01
Pulmonary emboli	0.12	0.15	0.41
Ileus	7.3	10.76	<0.01
Abdominal abscess	0.51	1.62	<0.01
Wound infection	0.43	1.14	<0.01
Bowel obstruction	0.96	3.38	<0.01
Overall complication rate (%)	15.82	23.49	<0.01
Length of stay (days)			
Mean	3	4.8	<0.01
Median	2	3	
Mortality, %	0.39	1.31	<0.01
Mean total hospital charge (\$)	30,414	34,095	<0.01

(51%), whereas OA was performed more on men (53.5%; $p < 0.01$). Like nonperforated appendicitis, the overall postoperative complication rate was lower in the LA group than the OA group (LA: 36.27 vs. OA: 46.92%, $p < 0.01$).

Table 3 Acute perforated appendicitis in elderly patients (≥ 65 years): laparoscopic (LA) vs. open appendectomy (OA), 2006–2008

Patient characteristics and outcomes	LA (N = 13,765)	OA (N = 18,915)	<i>p</i> value
Demographics (%)			
Age (year)	73.5	74.7	<0.01
Female	51	46.5	<0.01
Race			
Caucasian	83.6	80.6	<0.01
African American	3.9	6.4	
Hispanic	5.7	6.4	
Asian–Pacific Islander	3.7	3.8	
Native American	0.4	0.6	
Other	2.7	2.2	
Comorbidities (%)			
Diabetes mellitus	16.0	16.7	0.09
Hypertension	62.1	60	<0.01
Congestive heart failure	9.3	13	<0.01
Chronic pulmonary disease	16.9	20	<0.01
Liver disease	0.9	0.9	0.97
Chronic renal failure	6.3	8.3	<0.01
Alcohol abuse	1.3	1.7	<0.01
Peripheral vascular disease	4.6	6.1	<0.01
Perioperative complications (%)			
Urinary tract infection	3.2	3	0.29
Pneumonia	3.43	5.27	<0.01
Acute renal failure	6.49	10.19	<0.01
Respiratory failure	5.37	9.76	<0.01
Myocardial Infarction/angina	0.67	1.12	<0.01
Deep vein thrombosis	0.25	0.51	<0.01
Pulmonary emboli	0.33	0.35	0.88
Ileus	22.66	25.11	<0.01
Abdominal abscess	1.35	3.75	<0.01
Wound infection	0.67	2.66	<0.01
Bowel obstruction	2.4	6.93	<0.01
Overall complication rate (%)	36.27	46.92	<0.01
Length of stay (days)			
Mean	5.8	8.7	<0.01
Median	4	7	
Mortality (%)	1.4	2.63	<0.01
Mean total hospital charge (\$)	43,339	57,943	<0.01

The OA group was associated with significantly higher postoperative complications, such as pneumonia, acute renal failure, respiratory failure, myocardial infarction/

Table 4 Risk adjusted analyses of outcome of laparoscopic (LA) vs. open appendectomy (OA)

Outcomes	AOR (95% CI)	<i>p</i> value
In-hospital mortality	0.53 (0.45–0.62)	<0.01
Complication rate	0.69 (0.67–0.73)	<0.01
Urinary tract infection	1.04 (0.93–1.16)	0.48
Pneumonia	0.8 (0.73–0.89)	<0.01
Acute respiratory failure	0.58 (0.54–0.64)	<0.01
Acute renal failure	0.72 (0.66–0.78)	<0.01
Deep vein thrombosis	0.7 (0.5–0.98)	0.04
Pulmonary embolism	1.12 (0.76–1.64)	0.55
Myocardial infarction	0.78 (0.64–0.95)	0.01
Ileus	0.85 (0.8–0.89)	<0.01
Abdominal abscess	0.33 (0.28–0.38)	<0.01
Wound infection	0.32 (0.26–0.38)	<0.01
Bowel obstruction	0.34 (0.31–0.38)	<0.01
Length of hospital stay	0.39 (0.37–0.41)	<0.01

AOR adjusted odds ratio, CI confidence interval

angina, deep vein thrombosis, ileus, abdominal abscess, wound infection, and bowel obstruction. Urinary tract infection and pulmonary emboli were not statistically significantly different between the two groups. Similar to nonperforated appendicitis, the mortality rate in the LA group was lower than the OA group (LA: 1.4 vs. OA: 2.63%, $p < 0.01$). The mean length of stay was shorter for the LA group than the OA group (LA: 5.8 vs. OA: 8.7 days, $p < 0.01$). Total charges were less for the LA group than the OA group (LA: \$43,339 vs. OA: \$57,943, $p < 0.01$).

Risk-adjusted outcomes

Table 4 shows multivariate regression analyses for outcomes of LA versus OA. After adjusting for other variables (patient characteristics, comorbidities and type of appendicitis), the LA group remained associated with lower in-hospital mortality (adjusted odds ratio [AOR] 0.53; 95% confidence interval [CI] 0.45–0.62; $p < 0.01$), overall complication rate (AOR 0.67; 95% CI 0.67–0.73; $p < 0.01$), and shorter LOS (AOR 0.39; 95% CI 0.37–0.41; $p < 0.01$) compared with the open group. Also, all of the evaluated complications were lower in the LA group than the OA group, except urinary tract infection and pulmonary emboli, but no significant difference was found between groups.

Discussion

This study is the most recent nationwide sample comparing the outcome of LA and OA for appendicitis in the elderly.

Only a few studies have compared the outcomes of OA and LA and have highlighted the advantages of LA in the elderly. Our results show that the rate of LA in the geriatric population was 52% in patients who underwent appendectomy for acute appendicitis. Guller et al. [14] conducted a nationwide administrative study from 1998 to 2000 comparing LA to OA in patients older than 65 years, yielding a 15.6% LA rate. Contrasting these past findings to 57.9% LA in 2008 from our study indicate that the rate of LA in the elderly is increasing, although it still does not equal to our rate of LA in patients younger than aged 65 years, which is 63%. For nonperforated appendicitis, the rate of LA (61.9%) was higher than OA, but in perforated appendicitis, the rate of LA (42.1%) was lower than OA. This suggests that in cases of perforated appendicitis, surgeons may prefer the time-proven open approach and consider the laparoscopic approach as unsafe in these situations.

The lower frequency of LA performed on the elderly might be due to surgeons concern over the use of LA on the elderly because of the use of carbon dioxide pneumoperitoneum needed during LA. Carbon dioxide pneumoperitoneum may have depressive effects on renal and cardiopulmonary functions, particularly in the elderly [18]. Also, it is hypothesized that infection may be spread intraperitoneal when an intra-abdominal infection is present during insufflations of carbon dioxide [19]. However, looking at our data, postoperative complications, such as abdominal abscess formation, acute renal failure, respiratory failure, pneumonia, angina, and pulmonary emboli, were significantly lower for LA than OA in both perforated and nonperforated cases. These findings indicate that pneumoperitoneum during LA carries no apparent risk to elderly patients.

According to our data, the rate of perforation amongst elderly patients was twice as high as for adults younger than aged 65 years. Perforation is a major cause of morbidity and mortality for appendicitis in the elderly and can be attributed to delays in therapy caused by diagnostic difficulties and diminished sensorium [6]. Atypical presentation in the elderly reportedly results from blunted physiological response and distressed T-cell function, which lead to higher perforation rates in the elderly [20]. Additionally, perforation in the elderly might be caused by lymphoid tissue atrophy and the thinning of the abdominal wall [20]. Diagnostic discrepancies greatly influence the perforation rate of appendicitis in the elderly population. This link was described by Dickerson et al. [4] in a retrospective analysis of 113 elderly patients, which showed a decrease perforation rate over 10 years from 72 to 51% by utilizing computed tomography (CT) scanning on seriously ill patients for early diagnosis. Considering the high perforation rate of appendicitis in geriatrics, the laparoscopy is

an effective tool that can be utilized for early diagnosis of suspected appendicitis.

For both perforated and nonperforated appendicitis, the frequency of postoperative complications were significantly lower in the LA groups than the OA groups. Also, risk-adjusted analysis showed the advantage of LA on complication rate compared with the OA group (AOR 0.69; 95% CI 0.67–0.73; $p < 0$). Previous studies also have found that the rate of postoperative complications for LA were significantly lower for perforated and nonperforated appendicitis [14, 17]. However, Harrell et al. [15] had a lower complication rate for LA in nonperforated appendicitis ($p = 0.04$) but similar complication rates for LA and OA in perforated appendicitis ($p = 0.97$). Similarly, mortality rates were significantly lower for LA in both perforated and nonperforated appendicitis. Prior studies based on large administrative databases also have reported lower mortality rates for LA [14, 15, 17]. Guller et al. [14] showed a 2.4% mortality rate for OA versus 0.5% for LA. Harrell et al. [15] reported a 1.98% lower mortality difference for LA in perforated cases (1.0 vs. 2.98%) and a 0.8% lower LA difference in nonperforated cases (0 vs. 0.8%).

The length of hospital stay was shorter for the LA groups in both perforated (2.9 days shorter) and nonperforated appendicitis (1.8 days shorter) compared with the OA groups. Also, risk-adjusted analysis for LOS showed that LA remained with shorter LOS (AOR 0.39; 95% CI 0.37–0.41; $p < 0.01$). Previous studies also have reported significantly lower LOS by approximately 3–4 days for LA in perforated and nonperforated appendicitis [14, 15, 17]. However, Wang et al. [16] reported similar LOS of approximately 5 days for both OA and LA. Similar to LOS, hospital charges were significantly lower for LA in perforated and nonperforated appendicitis. For nonperforated appendicitis, hospital charges were less for LA by approximately \$3,600. However, for perforated appendicitis, the differences in hospital charges were more distinct: LA was less than OA by approximately \$14,500. Based on these findings, reduced hospitalization for LA might have contributed to the lower hospital charges found for LA. Only one study evaluated costs when comparing OA to LA in the elderly. Based on a statewide administrative database, Harrell et al. [15] reported that although the actual surgical procedure of LA was more expensive than OA, the overall hospital charges for LA and OA were similar. They further reported that for perforated appendicitis, LA and OA had similar costs ($p = 0.93$) and for nonperforated appendicitis the hospital charges were higher for LA than OA. Whereas the operative costs of LA were more expensive than OA, expenses from hospital stay and hospital care skewed the overall hospital costs.

The limitations of this study are similar to other studies using large administrative databases. The NIS only

provided information for inpatient hospital events; post discharge complications, post discharge mortality, readmission, and length of operative time were not documented. Additionally, it would be interesting to determine the appendiceal malignancy rate in this age group; however, no data are available about exact pathologic reports, including the rate of appendiceal malignancy in this patient population, which could be different in LA and OA groups. The breakdown of operation costs relative to hospital stay was unknown. Case selection bias also is a factor that cannot be discerned, and it is certainly possible or even likely that choice of LA versus OA was influenced by patient presentation. Additionally, the conversion rate of LA to OA during the operation was not determined. Although we were unable to eliminate the effect of selection bias or conversion rate of LA to OA in our patient population, using multivariate regression analyses considering patient characteristics, comorbidities and type of appendicitis showed the superiority of LA compared with OA in terms of morbidity and mortality. Despite these limitations, this study provides a large sample size with statistical data that show definite advantages of LA over OA.

Our findings demonstrated that the benefits of LA are highly significant for elderly patients. Utilization of LA in the United States has increased 24% between 2006 and 2008 in the elderly, but still lags behind its use in younger patients. LA was associated with lower morbidity, lower mortality rates, lower hospital stay, and reduced hospital charges compared with OA. This study has shown that LA is advantageous for elderly patients compared with OA in many factors and even suggests that LA is likely safer for elderly patients. LA should be considered the procedure of choice for elderly patients with nonperforated and perforated appendicitis. Additional prospective, randomized studies should be conducted to confirm the superiority of LA in the elderly.

Conflicts of interest All authors have no conflicts of interest or financial ties to disclose.

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