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Authors
Masoomi, Hossein
Nguyen, Ninh T
Dolich, Matthew O
et al.

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Laparoscopic Appendectomy Trends and Outcomes in the United States: Data from the Nationwide Inpatient Sample (NIS), 2004–2011

Hossein Masoomi, M.D., Ninh T. Nguyen, M.D., Matthew O. Dolich, M.D., Steven Mills, M.D., Joseph C. Carmichael, M.D., Michael J. Stamos, M.D.

From the Department of Surgery, University of California, Irvine School of Medicine, Irvine, California

Laparoscopic appendectomy (LA) is becoming the standard procedure of choice for appendicitis. We aimed to evaluate the frequency and trends of LA for acute appendicitis in the United States and to compare outcomes of LA with open appendectomy (OA). Using the Nationwide Inpatient Sample database, we examined patients who underwent appendectomy for acute appendicitis from 2004 to 2011. A total of 2,593,786 patients underwent appendectomy during this period. Overall, the rate of LA was 60.5 per cent (children: 58.1%; adults: 63%; elderly: 48.7%). LA rate significantly increased from 43.3 per cent in 2004 to 75 per cent in 2011. LA use increased 66 per cent in nonperforated appendicitis versus 100 per cent increase in LA use for perforated appendicitis. The LA rate increased in all age groups. The increased LA use was more significant in male patients (84%) compared with female patients (62%). The overall conversion rate of LA to OA was 6.3 per cent. Compared with OA, LA had a significantly lower complication rate, a lower mortality rate, a shorter mean hospital stay, and lower mean total hospital charges in both nonperforated and perforated appendices. LA has become an established procedure for appendectomy in nonperforated and perforated appendicitis in all rates exceeding OA. Conversion rate is relatively low (6.3%).

Appendectomy for appendicitis is the most commonly performed emergency operation in the world.[1] In 1983, Semm[2] reported laparoscopic appendectomy (LA) several years before the first laparoscopic cholecystectomy[3]; however, LA was not broadly performed until the success of laparoscopic cholecystectomy was demonstrated. Although LA has been performed more frequently in recent years, the use of LA in the management of acute appendicitis remains controversial. It has not been resolved whether LA is more cost-effective in treating acute appendicitis than the time-proven open appendectomy (OA).1 Using the Nationwide Inpatient Sample (NIS) database, our study was intended 1) to evaluate the trends of use of LA in the United States in all age groups (children, adults, and elderly) and in different types of acute appendicitis (nonperforated and perorated appendicitis); 2) to evaluate the LA to OA conversion rate and trends; and 3) to compare the outcomes of LA versus OA in nonperforated and perforated appendicitis by analyzing four components: postoperative complications, length of hospital stay, inhospital mortality, and total hospital charges.

Methods and Materials

The NIS database is the largest inpatient care database in the United States. More than 1000 hospitals participate in the NIS database, resulting in a database of information from nearly eight million hospital stays each year.4 The NIS database has no information available on complications occurring after discharge. Not all data elements in the NIS are provided by each state data source. Approval for use of the NIS patient level data in this study was obtained from the Human Research Protection of the University of California Irvine and the NIS.

Data Analysis

We analyzed discharge data of patients who underwent appendectomy for suspected acute appendicitis from 2004 to 2011. Patients, hospitalized with a diagnosis of appendicitis who underwent appendectomy, were selected by identifying discharges with International Classification of Disease 9th Revision, Clinical Modification appendectomy codes (laparoscopic: 47.01 and open: 47.09). These patients were divided into perforated and nonperforated groups. We excluded incidental appendectomies and patients who were treated nonoperatively for acute appendicitis. We evaluated the LA trends in perforated versus nonperforated appendicitis in different age groups including children (younger than 18 years old), adults, and the elderly (older than 65 years old). We also evaluated the conversion trends.

Statistical Analysis

All statistical analyses were conducted using SAS Version 9.3 (SAS Institute, Cary, NC). Because the NIS database is a 20 per cent sample of the United States yearly inpatient admissions, weighted samples were used to produce national estimates for all analyses. Multivariate regression analyses were performed to adjust patient characteristics (age, gender, and race) and comorbidities (hypertension, diabetes mellitus, chronic lung disease, chronic kidney disease, liver disease, congestive heart failure, smoking, and obesity) to analyze the influence of the procedure type (LA vs OA) on outcomes. Statistical significance was set at P value < 0.05 and odds ratios with 95 per cent confidence intervals that excluded one.

Results

A total of 2,593,786 patients underwent appendectomy for acute appendicitis during these eight years in the United States. The mean age was 35 years old; the majority of the patients were male (53%) and white (65%). The majority of the patient were adults (66%) followed by children (26%) and the elderly (8%). One-fourth of acute appendicitis cases were perforated. Overall, 61 per cent of the appendectomies were performed laparoscopically. The highest rate of LA was observed in adults (63%) followed by children (58%) and the elderly (49%). Also, LA was performed significantly more in female compared with male patients (61.7vs 59.6%; $P < 0.01$). Although the majority of the appendectomies were performed in nonteaching hospitals (57.7%), the LA rate was significantly higher in teaching hospitals compared with nonteaching

hospitals (62.4 vs 59.1%). The overall rate of conversion to OA from laparoscopic was 6.3 per cent. The conversion rate has slowly decreased from 7.2 per cent in 2004 to 5.6 per cent in 2011. The lowest conversion rate was observed in children (2.8%) followed by adults (6.8%) and the elderly (13.2%). Laparoscopic Appendectomy Trends

The LA use rate increased 73 per cent during the period studied, from 43.3 per cent in 2004 to 75 per cent in 2011. LA use rate increased 66 per cent in nonperforated appendicitis versus 100 per cent in perforated appendicitis. Although the LA rate was higher in adults, the LA rate increased in all age groups. The rate of LA increased more significantly in male patients (84%) compared with female patients (62%). LA use steadily increased in both teaching and nonteaching hospitals (Table 1).

Comparison of Laparoscopic versus Open Appendectomy

All the evaluated postoperative complications were significantly higher in OA groups compared with LA groups except urinary tract infection (UTI) in nonperforated appendicitis. The rate of in-hospital mortality was significantly higher in OA groups compared with LA groups. The mean total hospital charges were significantly higher in OA versus LA in both nonperforated and perforated appendicitis. Also, the mean length of hospital stay was significantly longer in OA versus LA in both nonperforated and perforated appendicitis (Table 2). After adjusting for the variables of patient characteristics, comorbidities, and type of appendicitis, OA was still associated with a significantly higher mortality rate (adjusted odd ratio [AOR], 4.66) and a higher complication rate (AOR, 1.80). All of the evaluated complications were significantly lower for LA except for UTI, which was higher in the LA group (Table 3).

Discussion

Interestingly, LA rate markedly increased from 43.3 per cent in 2004 to 75 per cent in 2011. Also this study demonstrates a significant increase in the LA rate in both nonperforated and particularly in perforated appendicitis. Our study is consistent with an earlier report from Van Hove et al.[5] using the same database (NIS) from 1997 to 2003; they reported that LA was performed in 19.1 per cent of cases in 1997 and increased to 39.7 per cent in 2003. This continued trend can be explained by the fact that 1) surgeons are becoming more skilled and experienced in LA and able to perform more LA even in more complex cases; and 2) more surgeons with training in LA are entering practice.[6]

Our current study shows that the LA rate is increasing in all age groups in both nonperforated and perforated appendicitis. The lower frequency of LA performed in the elderly might be the result of surgeon concern over the use of LA on the elderly because of the use of carbon dioxide pneumoperitoneum needed

TABLE 1. Laparoscopic Appendectomy (LA) Trends in the United States (2004–2011)

Laparoscopic Rate (%)	2004	2005	2006	2007	2008	2009	2010	2011
Overall LA rate	43.3	50.1	53.3	59.7	67.0	66.8	71.6	74.9
Type of appendectomy								
Nonperforated	46.9	53.2	57.1	63.6	70.5	69.6	74.3	77.8
Perforated	32.8	41.0	42.0	47.9	56.2	58.3	63.9	66.6
Age groups								
Children	41.4	47.7	48.4	55.5	66.2	63.3	73.5	73.4
Adults	45.5	52.7	56.5	62.9	68.3	69.7	72.6	76.9
Elderly	31.4	36.8	42.2	46.0	51.6	55.4	58.4	64.5
Gender								
Female	46.1	51.7	55.3	61.1	67.3	67.6	71.6	74.5
Male	40.8	48.6	51.8	58.5	66.8	66.5	71.7	75.1
Teaching status								
Teaching hospital	46.4	51.2	56.5	60.4	68.3	69.2	72.7	75.3
Nonteaching hospital	41.2	49.4	50.8	59.1	66.2	65.1	79.8	74.6

during LA.[7] However, prior studies[8, 9] have shown the safety of LA in elderly patients.With regard to gender, LA was performed more in female patients compared with male patients in earlier years. However, LA has been performed equally in both genders since 2008 in the United States, and it seems that surgeons are more eager to perform LA in male patients in more recent years. Our study shows that the majority of appendectomies are performed in nonteaching hospitals; however, LA use rate is still significantly higher in teaching hospitals. Also, our current study demonstrates a relatively low conversion rate (6.3%). Interestingly, despite performing more LA, in even more complicated cases of acute appendicitis, the rate of conversion has been slowly decreasing during this time period.

Recent studies have found LA to have lower complication rates than OA for appendicitis or found no difference between the two procedures, yet none of these studies adequately distinguished between perforated and nonperforated appendicitis.[10–12] Sporn et al.[6] examined LA versus OA using the NIS from 2000 to 2005 and reported higher complications in the LA group for perforated appendicitis (odds ratio [OR], 1.07; 95% confidence interval [CI], 1.00 to 1.14; P = 0.05) and no difference in overall complication rate between procedures for perforated appendicitis (OR, 1.01; 95% CI, 0.96 to 1.06; P = 0.74). However, we found that the overall frequency of postoperative complications was significantly lower for LA than OA in both perforated and nonperforated appendicitis. All the evaluated complications were significantly lower

TABLE 2. Comparison of Outcomes in Open (OA) versus Laparoscopic Appendectomy (LA)

Outcomes	Nonperforated			Perforated		
Postoperative Complication (%)	OA	LA	*P* Value	OA	LA	*P* Value
Overall	10.82	5.28	<0.01	27.65	20.39	<0.01
Urinary tract infection	1.20	1.28	0.02	1.52	1.39	0.05
Pneumonia	1.03	0.44	<0.01	2.42	1.44	<0.01
Acute respiratory failure	1.63	0.44	<0.01	3.52	1.54	<0.01
Acute kidney injury	1.18	0.41	<0.01	3.40	1.78	<0.01
Myocardial infarction	0.18	0.08	<0.01	0.47	0.21	<0.01
Venous thromboembolism	0.27	0.04	<0.01	0.26	0.13	<0.01
Cerebrovascular accident	0.08	0.03	<0.01	0.13	0.07	<0.01
Ileus	5.13	2.18	<0.01	16.49	14.08	<0.01
Abdominal abscess	1.17	0.25	<0.01	3.59	1.61	<0.01
Wound infection	0.40	0.09	<0.01	0.60	0.16	<0.01
Early bowel obstruction	1.53	0.29	<0.01	3.72	1.56	<0.01
Postoperative bleeding	0.44	0.32	<0.01	0.43	0.37	0.08
In-hospital mortality rate (%)	0.39	0.05	<0.01	0.60	0.16	<0.01
Mean length of stay (days)						
Mean	3.6	1.8	<0.01	6.3	4.5	<0.01
Median	2	1		5	4	
Total hospital charges ($)						
Mean	27,491	23,996	<0.01	39,390	35,321	<0.01
Median	16,519	20,167		26,860	27,594	

TABLE 3. Multivariate Regression Analyses for Outcome of Open versus Laparoscopic Appendectomy

Outcomes	AOR (95% CI)	*P* Value
In-hospital mortality	4.66 (4.33–5.01)	<0.01
Complication rate	1.80 (1.78–1.82)	<0.01
Urinary tract infection	0.96 (0.93–0.98)	<0.01
Pneumonia	1.84 (1.79–1.89)	<0.01
Acute respiratory failure	2.77 (2.70–2.85)	<0.01
Acute renal failure	2.13 (2.07–2.19)	<0.01
Venous thromboembolism	3.70 (3.40–4.0)	<0.01
Myocardial infarction	1.77 (1.65–1.90)	<0.01
Ileus	1.58 (1.57–1.60)	<0.01
Abdominal abscess	3.08 (3.0–3.17)	<0.01
Wound infection	2.84 (2.71–2.97)	<0.01
Bowel obstruction	3.48 (3.39–3.58)	<0.01

AOR, adjusted odds ratio; CI, confidence interval.

in the LA group except UTI, which was significantly higher in the nonperforated appendicitis LA group compared with OA. Similarly, Xiaohang et al.[13] in a meta-analysis of randomized controlled trials showed a higher rate of UTI in LA compared with OA. This might be related to more frequent urinary catheterization in patients undergoing LA. One of the main concerns over postoperative complications for LA includes abdominal abscess formation, largely based on earlier reports. [14] Our study shows that the abdominal abscess rates were significantly lower for LA than OA in perforated and nonperforated appendicitis (Table 1).

The limitations of this study are similar to other retrospective studies using administrative databases. The NIS database is compiled from discharge abstract data and is limited to in-hospital data without outpatient follow-up data. For example, any complications or readmissions that occurred after discharge such as abscess would not be captured in this database. The NIS database has no information about length of operation; therefore, we were unable to compare this factor between LA and OA groups. Breakdown of operating costs relative to hospital stay was unknown. Because this is a retrospective study, case selection bias is also a factor which cannot be discerned, and it is certainly possible or even likely that choice of LA versus OA was influenced by patient presentation or surgeon preference. Lastly, we were unable to identify specific reasons for conversions; Was it was unsafe to proceed with laparoscopic surgery? Were there intraoperative complications? Was there equipment failure?

In conclusion, LA has become an established procedure for perforated and nonperforated appendicitis in all age groups in the United States with use rates exceeding OA. Three-fourths of all appendectomies for acute appendicitis were performed laparoscopically in 2011, and the rate of LA to OA conversion is low (6.3%). LA was associated with superior outcomes compared with OA, is safe and effective in the management of perforated and nonperforated appendicitis, and should be considered the procedure of choice in acute appendicitis in all groups of patients.

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Address correspondence and reprint requests to Michael J. Stamos, M.D., Department of Surgery, 333 City Boulevard West, Suite 1600, Orange, CA 92868.
E-mail: mstamos@uci.edu.