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ORIGINAL ARTICLE

Laparoscopic Versus Open Appendectomy: An Analysis of Outcomes in 17,199 Patients Using ACS/NSQIP

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Abstract
Background The current study was undertaken to evaluate the outcomes for open and laparoscopic appendectomy using the 2008 American College of Surgeons: National Surgical Quality Improvement Program (ACS/NSQIP) Participant Use File (PUF). We hypothesized that laparoscopic appendectomy would have fewer infectious complications, superior perioperative outcomes, and decreased morbidity and mortality when compared to open appendectomy.
Study Design Using the Current Procedural Technology (CPT) codes for open (44950) and laparoscopic (44970) appendectomy, 17, 199 patients were identified from the ACS/NSQIP PUF file that underwent appendectomy in 2008. Univariate analysis with chi-squared tests for categorical data and *t* tests or ANOVA tests for continuous data was used. Binary logistic regression models were used to evaluate outcomes for independent association by multivariable analysis.
Results Of the patients, 3,025 underwent open appendectomy and 14,174 underwent laparoscopic appendectomy. Patients undergoing laparoscopic appendectomy had significantly shorter operative times and hospital length of stay. They also had a significantly lower incidence of superficial and deep surgical site infections, wound disruptions, fewer complications, and lower perioperative mortality when compared to patients undergoing open appendectomy.
Conclusions Using the ACS/NSQIP PUF file, we demonstrate that laparoscopic appendectomy has better outcomes than open appendectomy for the treatment of appendicitis. While the operative treatment of appendicitis is surgeon specific, this study lends support to the laparoscopic approach for patients requiring appendectomy.

Keywords Laparoscopy · Appendectomy · Complications

Introduction

McBurney first described the surgical treatment of acute appendicitis using the classic right lower quadrant incision in 1894[1]. Subsequently, appendectomy has become one of the most frequently performed abdominal procedures, with about 8% of the population in industrialized countries requiring removal of the appendix over the course of their lifetime[2]. Since the initial reports of the first successful laparoscopic cholecystectomy for the treatment of symptomatic biliary tract disease, virtually every abdominal organ has been approached using minimally invasive surgical techniques[3]. The benefits of smaller incisions and less wound morbidity, less postoperative pain, shorter length of stay (LOS), and earlier return to work when compared to standard open operations to treat the same condition make the laparoscopic approach extremely advantageous. The first laparoscopic appendectomy was performed in 1988 by Semm[4]. However, the laparoscopic approach to appendectomy has not been championed by all surgeons like it has for cholecystectomy and other intra-abdominal organs. This is primarily because the

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benefits of the laparoscopic approach for appendectomy are not quite as obvious as they are for these other procedures. To date, over 50 studies have been undertaken comparing laparoscopic to open appendectomy for the treatment of acute appendicitis[5]. Many of these studies have been underpowered and therefore have failed to show significant differences in outcomes between the two approaches leading to controversy surrounding this particular topic.

The American College of Surgeons: National Surgical Quality Improvement Study (ACS/NSQIP) is a risk-adjusted outcomes program that was initially developed in the early 1990s by the Surgical Service in the Department of Veterans Affairs in response to a Congressional mandate to report risk adjusted surgical outcomes on an annual basis[6]. The results of the program in the Veterans Affairs sector were overwhelmingly positive, demonstrating significant reductions in both morbidity and mortality. This led to a trial in the private sector to determine if the risk adjustment models were applicable to a more heterogeneous population of patients[7]. Ultimately, the American College of Surgeons embraced the program, making it the cornerstone of the College's quality program.

The ACS/NSQIP collects data on 135 variables, including preoperative risk factors, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes for patients undergoing major surgical procedures in both the inpatient and outpatient setting. Using these data, the ACS/NSQIP has been able to develop predictive models that apply to a broad range of surgical procedures. The current study was undertaken to evaluate the outcomes for open and laparoscopic appendectomy using this data set. We hypothesized that laparoscopic appendectomy would have fewer infectious complications, superior perioperative outcomes, and decreased morbidity and mortality when compared to open appendectomy

Materials and Methods

To address the question of laparoscopic versus open appendectomy, we utilized the ACS/NSQIP Participant Use File (PUF file) from 2008, which contains de-identified patient data for over 250,000 surgical cases performed at the 250+ hospitals that participate in ACS/NSQIP at the present time. Using the Current Procedural Technology (CPT) codes for open (44950) and laparoscopic (44970) appendectomy, we reviewed 17,199 patients that underwent appendectomy in 2008. ACS/NSQIP assesses a total of 43 demographic and preoperative risk factors, 13 preoperative laboratory values, 14 perioperative risk factors, and 28 postoperative complications for each patient. For the purposes of the current study, demographic variables including age, race, gender, American Society of Anesthesia (ASA) status, and body mass index (BMI) were compared between the two groups. The following preoperative risk factors were also assessed; presence or absence of hypertension, emergency, diabetes mellitus type II (DM), tobacco use, and pregnancy. Postoperative outcomes and complications evaluated include operative time, LOS, surgical site infections, pneumonia, renal insufficiency and acute renal failure, urinary tract infection, deep venous thrombosis (DVT), presence of sepsis or septic shock, and 30-day mortality.

All statistical calculations were performed using SPSS Version 14.0 (SPSS, Inc., Chicago, IL, USA). To identify clinical variables associated with the outcomes of superficial or deep incisional surgical site infection, wound disruptions, organ space infection, sepsis, septic shock, or 30-day mortality, univariate analysis with chi-squared tests for categorical data and *t* tests or ANOVA tests for continuous data were used. Binary logistic regression models were used to evaluate outcomes for independent association by multivariable analysis. Patients with missing data were excluded from multivariable analysis. Further, patients with an ASA classification of five or moribund were also excluded from multivariable analysis. A P value <0.05 in multivariable analysis was used to determine final significance in all analyses.

Results

Patient Demographics

Patient demographics are detailed in Table 1. A total of 17,199 patients were identified from the 2008 PUF file that met the criteria listed in the "Materials and Methods" section; 3,025 patients underwent open appendectomy and 14,174 underwent laparoscopic appendectomy. The mean age of patients undergoing open appendectomy was about 2.5 years greater than that of patients undergoing laparoscopic appendectomy. In addition, a significantly higher percentage of non-white patients underwent open appendectomy. Patients undergoing laparoscopic appendectomy were more commonly female; however, a significantly higher percentage of pregnant females underwent open appendectomy. Finally, patients in the laparoscopic group had a higher BMI.

Patients undergoing open appendectomy had a significantly higher incidence of hypertension but there was no difference in the incidence of DM between the two groups. Patients in the open appendectomy group trended toward a higher ASA classification and more commonly underwent their appendectomy in emergency circumstances. There was no difference in the incidence of tobacco use between the two groups. There was a higher incidence of contaminated wounds in the laparoscopic group and dirty wounds in the open group. The preoperative serum albumin and creatinine were statistically

Table 1 Patient demographics

Variable	Subset	Totals	Open appendectomy	Laparoscopic appendectomy	*P* value
Patients		17,199	3025	14174	
Mean age			40.5	37.9	<0.001
Gender (%)	Male	8,836 (51.4)	1,644 (54.3)	7,192 (50.7)	<0.001
	Female	8,363 (48.6)	1,381 (45.7)	6,982 (49.3)	
Race (%)	White	13,701 (79.7)	2,263 (74.8)	11,438 (80.7)	<0.001
	Other	3,498 (20.3)	762 (25.2)	2,736 (19.3)	
ASA class (%)	1	6,120 (35.6)	994 (32.9)	5,126 (36.2)	<0.001
	2	9,123 (53.0)	1,587 (52.5)	7,536 (53.2)	
	3	1,765 (10.3)	398 (13.2)	1,367 (9.6)	
	4	154 (0.9)	40 (1.3)	114 (0.8)	
	5	2 (0)	2 (0.1)	2 (0)	
	Unknown	29 (0.2)	4 (0.1)	29 (0.2)	
Wound classification (%)	Clean/contaminated	5,918 (34.4)	975 (32.2)	4,943 (34.9)	<0.001
	Contaminated	8,215 (47.8)	1,399 (46.2)	6,816 (48.1)	
	Dirty	3,066 (17.8)	651 (21.5)	2,415 (17.0)	
Mean BMI	26.5		26.2	26.6	0.02
Diabetes (%)	None		2,882 (95.3)	13,620 (96.1)	0.05
	Oral		87 (2.9)	305 (2.2)	
	Insulin		56 (1.9)	249 (1.8)	
Smoking (%)	No	13,487 (78.4)	2,378 (78.6)	11,109 (78.4)	0.78
	Yes	3,712 (21.6)	647 (21.4)	3,065 (21.6)	
HTN (%)	No	14,381 (83.6)	2,430 (80.3)	11,951 (84.3)	<0.001
	Yes	2,818 (16.4)	595 (19.7)	2,223 (15.7)	
Pregnant (%) (only females)	No	8,089 (96.7)	1,282 (92.8)	6,807 (97.5)	<0.001
	Yes	274 (3.3)	99 (7.2)	175 (2.5)	
Emergency (%)	No	4,520 (26.3)	737 (24.4)	3,783 (26.7)	0.01
	Yes	12,679 (73.7)	2,288 (75.6)	10,391 (73.3)	
Mean creatinine		0.90	0.89	0.93	<0.001
Mean albumin		4.2	4.2	4.1	<0.001
Mean WBC		13.0	13.0	12.9	0.30

BMI body mass index, *ASA* American Society of Anesthesiologists, *WBC* white blood cell count, *HTN* hypertension, *NIDDM* non-insulin dependent diabetes, *IDDM* insulin dependent diabetes mellitus

different between the two groups; however, the values were well within normal limits. Preoperative white blood cell count (WBC) was elevated in both groups, and not statistically different.

Perioperative Outcomes

Table 2 documents the perioperative outcomes for patients undergoing appendectomy. Mean operating time was significantly shorter in those patients that underwent a laparoscopic appendectomy. Patients undergoing laparoscopic appendectomy also had a significantly lower incidence of returning to the OR in the postoperative period and had a significantly shorter postoperative LOS. The impact of various demographic factors and operative approach on LOS and operative time was next evaluated using a multivariable model (Table 3). In this model, the laparoscopic approach was found to independently influence both operative time ($p<0.001$) and length of stay ($p<0.001$) in patients undergoing appendectomy. Operative time was also independently influenced by male gender, BMI, wound classification, emergency status, ASA classification, and preoperative serum albumin level. In addition, LOS was independently influenced by patient age, BMI, wound classification, ASA classification, preoperative serum albumin and preoperative WBC.

Postoperative Occurrences

Table 4 documents the postoperative occurrences for the study population. Patients undergoing open appendectomy had significantly higher rates of superficial and deep surgical site infections (SSI), and wound disruptions. Patients undergoing laparoscopic appendectomy had a

Table 2 Perioperative outcomes

	Open appendectomy	Laparoscopic appendectomy	*P* value
Patients	3025	14174	
Mean LOS	3.1 days	1.8 days	<0.001
Mean OP time	56.8 min	50.5 min	<0.001
Return to OR (%)	60 (2.0)	177 (1.2)	0.002

LOS length of stay, *OP* operative

higher rate of organ space infection, but this did not reach statistical significance (p=0.114). Patients undergoing open appendectomy were also significantly more likely to develop pneumonia, DVT, sepsis, septic shock, and death in the postoperative period when compared to patients who underwent laparoscopic appendectomy.

We next performed a multivariable analysis of various demographic factors and the operative approach to determine their impact on these wound occurrences (Table 5). The laparoscopic approach was found to be independently associated with a lower incidence of superficial SSIs (p<0.001, OR 0.30), deep SSIs (p<0.001, OR 0.26), and wound disruptions (p=0.03, OR 0.26). Operative approach however was not found to be an independent predictor for organ space infections. Other factors found to independently predict the incidence of superficial SSIs included wound classification and diabetes status. In the case of deep SSIs, DM status and preoperative serum albumin were found to be independent predictors. Factors that were found to independently predict the incidence of organ space infections included wound classification and preoperative WBC level.

Table 6 demonstrates the results of a multivariable analysis that was undertaken to determine the impact of various demographic factors and operative approach on the occurrence of sepsis, septic shock, and mortality for patients undergoing appendectomy. The operative approach was not found to independently predict the occurrence of sepsis or septic shock, but it was found to be a weak independent predictor of postoperative mortality (n=20). Other factors that were found to be independent predictors of septic shock included patient age, ASA class, and preoperative serum albumin level. Wound classification and preoperative serum albumin were found to be independent predictors of sepsis. In addition to operative approach, male gender, patient age, ASA classification, and preoperative serum albumin level were found to be independent predictors of postoperative mortality following appendectomy.

Discussion

The current study is the largest of its kind to focus on outcomes for appendectomy based on operative approach. We hypothesized that laparoscopic appendectomy would have fewer infectious complications, superior perioperative outcomes, and decreased morbidity and mortality when

Table 3 Multivariable statistical analysis calculating odds ratios for the categorical outcomes OP time (> 60 min) and LOS (>2 days)

		Op time (>60min)	LOS (> 2days)
Gender	Male	1.17 (0.01)	0.94 (0.29)
Age		1.01 (0.01)	1.0 (<0.001)
BMI		1.03 (< 0.001)	1.0 (0.11)
Smoker		0.95 (0.21)	1.1 (0.21)
Wound class	Clean/contaminated	Ref	Ref
	Contaminated	0.88 (0.01)	0.77 (<0.001)
	Dirty	1.91 (<0.001)	5.20 (<0.001)
Diabetes	None	Ref	Ref
	Oral	1.22 (0.15)	1.71 (0.001)
	Insulin	1.42 (0.02)	1.75 (0.001)
Emergency		0.91 (0.07)	0.92 (0.20)
ASA Class	4	0.64 (1.10)	< 0.001 (4.56)
	3	0.36 (1.06)	< 0.001 (1.41)
	2	0.10 (1.11)	0.09 (1.16)
	1	Ref	Ref
Albumin		0.80 (<0.001)	0.55 (<0.001)
WBC		1.00 (0.74)	1.03 (0.001)
Laparoscopic		0.80 (<0.001)	0.35 (<0.001)

Op operative, *LOS* length of stay, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *WBC* white blood cell count

Binomial logistic regression model with p values listed in parentheses

Table 4 Postoperative wound occurrences, morbidity and mortality

	Open appendectomy	Laparoscopic appendectomy	P value
Total	3,025	14,174	
Superficial surgical site infection (%)	120 (4.0)	170 (1.2)	<0.001
Deep incisional surgical site infection (%)	36 (1.2)	33 (0.2)	<0.001
Occurrences wound disruption (%)	10 (0.3)	8 (0.1)	<0.001
Organ space infection (%)	38 (1.3)	234 (1.7)	0.114
Pneumonia (%)	17 (0.6)	36 (0.3)	0.01
Progressive renal insufficiency (%)	5 (0.2)	10 (0.1)	0.11
Acute renal failure (%)	3 (0.1)	9 (0.1)	0.50
UTI (%)	14 (0.5)	57 (0.4)	0.64
DVT (%)	11 (0.4)	15 (0.1)	0.001
Sepsis (%)	42 (1.4)	135 (1.0)	0.03
Septic shock (%)	10 (0.3)	19 (0.1)	0.02
Deaths (%)	10 (0.3)	10 (0.1)	<0.001

UTI urinary tract infection, *DVT* deep venous thrombosis

compared to open appendectomy. To address this hypothesis we utilized the ACS/NSQIP Participant Use File from 2008, which contains de-identified patient data for over 250,000 surgical cases performed at the 250+ hospitals that participate in ACS/NSQIP at the present time.

Using the CPT codes for open and laparoscopic appendectomy, we identified over 17,000 patients that underwent an appendectomy at an ACS/NSQIP participating hospital in 2008. This study shows that in a large cohort, an overwhelming number underwent laparoscopic appendectomy, suggesting that the laparoscopic approach has become the preferred method for appendectomy at this time. Patients undergoing laparoscopic appendectomy were slightly younger, more commonly Caucasian and female, and had a slightly higher BMI when compared to patients that underwent an open appendectomy.

Although there are statistically significant demographic differences between the patient populations in this study, the sheer number of patients in each group may have led to

Table 5 Multivariable analysis calculating odds ratios for factors affecting wound occurrences

		Wound disruptions	Superficial SSI	Deep SSI	Organ space SSI
Gender	Male	1.1 (0.83)	1.3 (0.18)	1.15 (0.64)	1.11 (0.53)
Age		0.99 (0.66)	1.0 (0.67)	1.0 (0.75)	0.99 (0.81)
BMI		1.0 (0.90)	1.0 (0.32)	1.02 (1.15)	1.0 (0.87)
Smoker		1.1 (0.90)	1.0 (0.75)	0.75 (0.45)	1.16 (0.42)
Wound class	Clean/Contaminated	Ref	Ref	Ref	Ref
	Contaminated	1.39 (0.70)	0.98 (0.89)	0.68 (0.29)	1.9 (0.02)
	Dirty	4.68 (0.07)	1.72 (0.007)	1.0 (0.92)	10.7 (<0.001)
Diabetes	None[15]	Ref	Ref	Ref	Ref
	Oral	1.0 (<0.001)	1.9 (0.07)	0.04 (2.89)	1.1 (0.83)
	Insulin	1.0 (<0.001)	2.1 (0.03)	2.2 (0.22)	0.44 (0.25)
Emergency		4.3 (0.16)	0.95 (0.74)	1.50 (0.27)	1.11 (0.59)
ASA Class	4	26.1 (0.04)	1.7 (0.30)	1.0 (0.99)	0.34 (0.30)
	3	4.8 (0.18)	1.5 (0.08)	2.0 (0.18)	1.23 (0.34)
	2	7.0 (0.08)	1.88 (0.003)	2.5 (0.06)	0.95 (0.82)
	1	Ref	Ref	Ref	Ref
Albumin		0.85 (0.74)	0.85 (0.25)	0.52 (0.01)	0.85 (0.28)
WBC		1.0 (0.83)	1.03 (0.06)	1.04 (0.21)	1.04 (0.03)
Laparoscopic		0.26 (0.03)	0.30 (< 0.001)	0.26 (<0.001)	1.29 (0.27)

BMI body mass index, *ASA* American Society of Anesthesiologists, *WBC* white blood cell count

Binomial logistic regression model with p values listed in parentheses

Table 6 Multivariable analysis of factors calculating odds ratios affecting mortality, sepsis and septic shock

		Mortality[a]	Sepsis	Septic Shock[a]
Gender	Male	4.8 (0.02)	1.1 (0.7)	1.7 (0.21)
Age		1.06 (0.01)	1.0 (0.88)	1.07 (<0.001)
BMI		1.0 (0.94)	1.02 (0.14)	1.02 (0.38)
Smoker		1.3 (0.67)	1.4 (0.11)	1.65 (0.34)
Wound class	Clean/contaminated	Ref	Ref	Ref
	Contaminated	0.21 (0.73)	1.1 (0.75)	0.87 (0.84)
	Dirty	0.56 (0.37)	5.1 (<0.001)	1.85 (0.31)
Diabetes	None	Ref	Ref	Ref
	Oral	1.5 (0.61)	0.85 (0.76)	1.3 (0.71)
	Insulin	0.99 (<0.001)	0.49 (0.33)	0.4 (0.40)
Emergency		1.3 (0.62)	0.23 (0.78)	1.82 (0.26)
ASA Class	4	(0.98)	1.6 (0.46)	(0.98)
	3	(0.98)	1.1 (0.78)	(0.98)
	2	(0.98)	1.1 (0.71)	(0.98)
	1	Ref	Ref	Ref
Albumin		0.36 (0.004)	0.61 (0.01)	0.37 (<0.001)
WBC		1.0 (0.88)	1.0 (0.24)	1.0 (0.39)
Laparoscopic		0.28 (0.03)	0.90 (0.68)	0.51 (0.15)

BMI body mass index, *ASA* American Society of Anesthesiologists, *WBC* white blood cell count

Binomial logistic regression model with p values listed in parentheses

[a] Odds ratios were not reported for mortality (n=20, 0.1%) and septic shock (n=29, 0.2%) given the disproportionately small number of events divided between the four ASA classifications

the statistical differences while the "biological relevance" of these differences is questionable. One potential explanation for the younger age and higher percentage of females undergoing laparoscopic appendectomy is the intraabdominal visualization provided by the laparoscopic approach. This is a major advantage in the case of diagnostic dilemmas that are more common in young females with lower abdominal pain. The difference in race between the two groups is difficult to explain and cannot be definitively answered given the current data set. We show that there was a significant trend towards a higher ASA score and dirty wound classification in patients undergoing an open appendectomy. This data might suggest that the more difficult appendectomies or appendectomies in sicker patients were performed open.

Although there are statistically significant demographic differences between the patient populations in this study, the "biological relevance" is questionable. To more accurately assess the relationship and effects of these demographic factors on perioperative results, we incorporated already established multivariable models on our desired outcomes. We confirm that well-established variables that have been shown to influence surgical outcomes in other studies (e.g., preoperative albumin, wound classification, and ASA score), also significantly influence outcomes for appendectomy in this study, lending credibility to our statistical analysis[8–12].

However, in our multivariable model, we also incorporated operative approach, and found that while intuitive pre-operative factors were still predictive, operative approach was also associated with outcomes. Specifically, we found that the laparoscopic approach was associated with a lower incidence of superficial and deep SSIs, and a lower incidence of wound disruptions in patients undergoing appendectomy. Although organ space infections were slightly higher in the laparoscopic group, this did not reach statistical significance. In a retrospective analysis performed on 11,662 admissions from 22 hospitals comparing open and laparoscopic appendectomy, Brill et al.[13] failed to show any difference in the risk for wound related infection for patients undergoing laparoscopic appendectomy. However, they did show an increase in abscess formation in the laparoscopic group. In a small randomized prospective study of 252 patients, Olmi et al.[14] demonstrated a lower wound infection rate in patients undergoing laparoscopic appendectomy. The infectious complication that has been most frequently associated with laparoscopic appendectomy in many studies is intra-abdominal abscess or organ space infection[5].

The results of this study also show that laparoscopic appendectomy was performed on average 6 min faster than open appendectomy. This contradicts previous prospective studies showing longer operative times for laparoscopic appendectomy[15,16]. This may be due to changing practice patterns and increased laparoscopic skill level in surgeons. This study also demonstrates a significantly shorter LOS that was more than 1 day shorter than the mean LOS for an open appendectomy. Ignacio et al.[17] performed a randomized prospective trial comparing laparoscopic and open appendectomy. The trial was more directed towards evaluating postoperative LOS, pain, and return to work, and did not focus on postoperative complications. The trial was very small in number and failed to show any benefit for LOS, perceived pain postoperatively, and return to work between the two operations. Moberg et al.[18] also performed a randomized prospective trial comparing laparoscopic to open appendectomy. The primary end-point evaluated was time to full recovery, with secondary endpoints including complications, operating time, LOS and functional status. The study failed to show any significant differences between patients that underwent an open or laparoscopic appendectomy. Although operative time was shorter in the group that underwent a laparoscopic appendectomy, because the study was under-powered, the difference was not statistically significant. A meta-analysis of all randomized prospective trials undertaken between 1995 and 2006 confirmed that laparoscopic appendectomy is safe and results in a faster return to normal activities with fewer wound complications at the expense of a longer operating time[19].

Finally, this study shows that patients undergoing laparoscopic appendectomy have a lower mortality rate and have a lower risk for sepsis and septic shock when compared to patients undergoing open appendectomy, although in the multivariable model laparoscopic appendectomy was only found to be weakly predictive of mortality. This has not been previously described and is likely secondary to the large number of patients included in the current study as compared to most other randomized prospective trials which contain far fewer patients. This question obviously cannot be addressed in a non-randomized, retrospective study. However, our multivariable model attempted to control for perioperative risk factors which may influence mortality and yet these results suggest that the laparoscopic approach is associated with a lower mortality.

The main drawback of this study is that it is retrospective in nature. Because the database is retrospective, we could not control for surgeon preference and experience relative to operative approach which could have an influence on the outcomes for the various procedures. The patient groups are statistically different, although we attempted to control for these differences using our multivariable modeling. In addition, the PUF file does not clearly identify those patients that have undergone a lap-converted to open appendectomy which may have some influence on the outcomes for the entire open appendectomy group. Finally, there is no way to control for operative volume (high volume vs. low-volume centers) or for potential geographic or socioeconomic differences using this database. Clearly a large, adequately powered, randomized prospective trial comparing laparoscopic to open appendectomy would be the best means to definitively examine our hypothesis. Several randomized prospective trials have been undertaken to date and because they have suffered from small numbers of patients, they have failed to definitively resolve the issue. This study, although retrospective in nature, has such a large sample size that the findings add relevant new information to an ongoing debate.

In conclusion, using the ACS/NSQIP PUF file from 2008, we have shown that patients undergoing laparoscopic appendectomy have fewer infectious complications, shorter operative times and hospital LOS, fewer complications, and lower perioperative mortality when compared to patients undergoing open appendectomy. While the choice of operation for treatment of appendicitis will remain surgeon specific, this study lends support to the laparoscopic approach for patients requiring appendectomy.

References

1. McBurney C. IV. The incision made in the abdominal wall in cases of appendicitis, with a description of a new method of operating. Annals of Surgery 1894; 20(1):38.
2. Addiss D, Shaffer N, Fowler B, Tauxe R. The epidemiology of appendicitis and appendectomy in the United States. American journal of epidemiology 1990; 132(5):910.
3. Reddick E, Olsen D, Daniell J, et al. Laparoscopic laser cholecystectomy. Laser Medicine and Surgery News and Advances 1989; 7(1):38–40.
4. Semm K. Pelviscopic appendectomy. Deutsche medizinische Wochenschrift (1946) 1988; 113(1):3
5. Sauerland S, Lefering R, Neugebauer E. Laparoscopic versus open surgery for suspected appendicitis. Cochrane Database Syst Rev 2004; 4:6699–6701.
6. Khuri S, Daley J, Henderson W, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. Annals of Surgery 1998; 228 (4):491.
7. Fink A, Campbell Jr D, Mentzer Jr R, et al. The National Surgical Quality Improvement Program in non-veterans administration hospitals: initial demonstration of feasibility. Annals of Surgery 2002; 236 (3):344.
8. Biondo S, Ramos E, Deiros M, et al. Prognostic factors for mortality in left colonic peritonitis: a new scoring system1. Journal of the American College of Surgeons 2000; 191(6):635–642.
9. Tabatabai A, Hashemi M, Mohajeri G, et al. Incidence and risk factors predisposing anastomotic leak after transhiatal esophagectomy. Annals of Thoracic Medicine 2009; 4(4):197.
10. Yamamoto T, Allan R, Keighley M. Risk factors for intra-abdominal sepsis after surgery in Crohn's disease. Diseases of the Colon & Rectum 2000; 43(8):1141–1145.
11. Esteban Varela J, Wilson S, Nguyen N. Laparoscopic surgery significantly reduces surgical-site infections compared with open surgery. Surgical Endoscopy 2010: 24 (2): 270–276
12. Culver D, Horan T, Gaynes R, et al. Surgical wound infection rates by wound class, operative procedure, and patient risk index. The American Journal of Medicine 1991; 91(3):S152–S157.
13. Brill A, Ghosh K, Gunnarsson C, et al. The effects of laparoscopic cholecystectomy, hysterectomy, and appendectomy on nosocomial infection risks. Surgical Endoscopy 2008; 22(4):1112–1118.
14. Olmi S, Magnone S, Bertolini A, Croce E. Laparoscopic versus open appendectomy in acute appendicitis: a randomized prospective study. Surgical Endoscopy 2005; 19(9):1193–1195.
15. Katkhouda N, Mason RJ, Towfigh S, et al. Laparoscopic versus open appendectomy: a prospective randomized double-blind study. Ann Surg 2005; 242(3):439–48; discussion 448–50.

16. Minne L, Varner D, Burnell A, et al. Laparoscopic vs open appendectomy: prospective randomized study of outcomes. Archives of Surgery 1997; 132(7):708.
17. Ignacio R, Burke R, Spencer D, et al. Laparoscopic versus open appendectomy: what is the real difference? Results of a prospective randomized double-blinded trial. Surgical Endoscopy 2004; 18(2):334–337.
18. Moberg A, Berndsen F, Palmquist I, et al. Randomized clinical trial of laparoscopic versus open appendicectomy for confirmed appendicitis. British Journal of Surgery 2005; 92(3):298–304.
19. Bennett J, Boddy A, Rhodes M. Choice of approach for appendicectomy: a meta-analysis of open versus laparoscopic appendicectomy. Surgical Laparoscopy Endoscopy & Percutaneous Techniques 2007; 17(4):245.