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Original Research

Conversion-to-open in laparoscopic appendectomy: A cohort analysis of risk factors and outcomes

Brendan M. Finnerty, MD [a,*], Xian Wu, MPH [b], Gregory P. Giambrone, MS [c], Licia K. Gaber-Baylis, BA [c], Ramin Zabih, PhD [d], Akshay Bhat, MEng [d], Rasa Zarnegar, MD [a], Alfons Pomp, MD [a], Peter Fleischut, MD [c], Cheguevara Afaneh, MD [a]

[a] Department of Surgery, New York Presbyterian Hospital – Weill Cornell Medicine, 525 E. 68th Street, New York, NY 10065, United States
[b] Department of Healthcare Policy and Research, Division of Biostatistics and Epidemiology, Weill Cornell Medicine, 402 East 67th Street, New York, NY 10065, United States
[c] Department of Anesthesia, New York Presbyterian Hospital – Weill Cornell Medicine, 525 E. 68th Street, New York, NY 10065, United States
[d] Department of Computer Science, Cornell University, 402 Gates Hall, Ithaca, NY 14853, United States

HIGHLIGHTS

- In this retrospective study, we identified pre-operative risk factors for conversion to open in laparoscopic appendectomy.
- The conversion from laparoscopic to open appendectomy cohort had worse outcomes as compared to the primary open cohort.
- These pre-operative factors could help select for patients who may benefit from primary open appendectomy.

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ABSTRACT

Background: Identifying risk factors for conversion from laparoscopic to open appendectomy could select patients who may benefit from primary open appendectomy. We aimed to develop a predictive scoring model for conversion from laparoscopic to open based on pre-operative patient characteristics.
Methods: A retrospective review of the State Inpatient Database (2007–2011) was performed using derivation (N = 71,617) and validation (N = 143,235) cohorts of adults ≥ 18 years with acute appendicitis treated by laparoscopic-only (LA), conversion from laparoscopic to open (CA), or primary open (OA) appendectomy. Pre-operative variables independently associated with CA were identified and reported as odds ratios (OR) with 95% confidence intervals (CI). A weighted integer-based scoring model to predict CA was designed based on pre-operative variable ORs, and complications between operative subgroups were compared.
Results: Independent predictors of CA in the derivation cohort were age ≥40 (OR 1.67; CI 1.55–1.80), male sex (OR 1.25; CI 1.17–1.34), black race (OR 1.46; CI 1.28–1.66), diabetes (OR 1.47; CI 1.31–1.65), obesity (OR 1.56; CI 1.40–1.74), and acute appendicitis with abscess or peritonitis (OR 7.00; CI 6.51–7.53). In the validation cohort, the CA predictive scoring model had an optimal cutoff score of 4 (range 0–9). The risk of conversion-to-open was ≤5% for a score <4, compared to 10–25% for a score ≥4. On composite outcomes analysis controlling for all pre-operative variables, CA had a higher likelihood of infectious/inflammatory (OR 1.44; CI 1.31–1.58), hematologic (OR 1.31; CI 1.17–1.46), and renal (OR 1.22; CI 1.06–1.39) complications compared to OA. Additionally, CA had a higher likelihood of infectious/inflammatory, respiratory, cardiovascular, hematologic, and renal complications compared to LA.

* Corresponding author. Department of Surgery, New York Presbyterian Hospital – Weill Cornell Medicine, 525 E. 68th Street, Box 294, New York, NY 10065, United States.
E-mail addresses: bmf9002@nyp.org (B.M. Finnerty), xiw2011@med.cornell.edu (X. Wu), grg2010@med.cornell.edu (G.P. Giambrone), lig3001@med.cornell.edu (L.K. Gaber-Baylis), rdz@cs.cornell.edu (R. Zabih), akshayubhat@gmail.com (A. Bhat), raz2002@med.cornell.edu (R. Zarnegar), alp2014@med.cornell.edu (A. Pomp), pmf9003@med.cornell.edu (P. Fleischut), cha9043@med.cornell.edu (C. Afaneh).

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Conclusions: CA patients have an unfavorable complication profile compared to OA. The predictors identified in this scoring model could help select for patients who may benefit from primary open appendectomy.

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1. Introduction

Acute appendicitis is a prevalent disease with an incidence of 9.4 per 10,000 population [1]. Most cases are uncomplicated without sequelae of perforation, but up to 25% of patients present with complicated disease (peritoneal abscess or peritonitis) [1,2]. Since its development by Semm in 1983 [3], laparoscopic appendectomy has gained widespread popularity for definitive treatment, accounting for over 75% of all appendectomies [4]. Moreover, its prevalence for treating complicated appendicitis is increasing, and rates of conversion-to-open range from 1 to 10% [4–8].

The most common reasons for conversion from laparoscopic to open appendectomy are severe inflammatory adhesions either obscuring the anatomy or resulting in friability or perforation [5,7]. Pre-operative variables known to be associated with conversion are male sex [7], advanced age [7,9,10], American Society of Anesthesiologists (ASA) score ≥ 2 [7,10], leukocytosis [9,10], laparoscopic inexperience [5,7], high-grades of appendiceal inflammation or rupture on computed-tomography scan [7,9–11], and diffuse peritonitis [10]. However, the relatively low number of conversions in single-institution cohorts prohibits any meaningful powered analysis to detect a comprehensive list of predictors for conversion. Furthermore, it remains unclear what the differences in post-operative outcomes are between laparoscopic-only appendectomy (LA), conversion from laparoscopic to open appendectomy (CA), and primary open appendectomy (OA).

State Inpatient Databases (SID), Healthcare Cost and Utilization Project (HCUP), is a large-scale inpatient database sponsored by the Agency for Healthcare Research and Quality, which can be used to study hospitalizations and outcomes of diseases that would otherwise be limited by sample size in single-institution cohorts. We sought to use the SID to identify patient parameters associated with conversion from laparoscopic to open appendectomy in a derivation cohort – these variables were then used to create a multivariable scoring model predictive of conversion, which was tested in a validation cohort. Additionally, we aimed to analyze differences in post-operative outcomes and complications of patients undergoing CA compared to LA and OA. We hypothesized that patients who undergo CA may have worse outcomes.

2. Materials and methods

2.1. Study population

Hospitalizations of adults (age $\geq$ 18) diagnosed on admission with acute appendicitis were examined using 2007–2011 SID data in the states of California, Florida, and New York. The Weill Cornell Medicine Institutional Review Board approved this study. SID is an all-payer inpatient database containing discharges from non-federal, non-psychiatric community hospitals. It includes over 100 clinical and non-clinical variables such as patient demographics, pre-existing diagnoses, procedures, in-hospital complications, admission and discharge status, total charge, and length-of-stay (LOS) [12]. All charge data were adjusted to 2015 $US values [13].

International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9M) codes were used to select cases with acute appendicitis with generalized peritonitis (540.0), with peritoneal abscess (540.1), or without mention of peritonitis (540.9); cases with two or more of these conditions were excluded. Complicated appendicitis was defined as either appendicitis with generalized peritonitis or peritoneal abscess. Three mutually exclusive groups were created based on type of appendectomy: laparoscopic-only (LA), conversion from laparoscopic to open appendectomy (CA), and primary open appendectomy (OA). The ICD-9 codes for each operative group were as follows: LA (47.01), CA (V64.41 with 47.01 and/or 47.09), and OA (47.09), as described in prior studies [14]. Records with 47.01 and 47.09 without V64.41, as well as records with V64.41 only were excluded due to ambiguity.

2.2. Outcomes

The primary outcome was to identify significant pre-operative risk factors for conversion from laparoscopic to open appendectomy and subsequently create a scoring model predictive of conversion. Secondarily, post-operative outcomes were analyzed comparing CA to either LA or OA. To identify 30-day readmission, unique patient identifiers were utilized to link records within 30 days of discharge. To ensure only true readmissions were analyzed, clinical classification software (CCS) code 254, denoting rehabilitation visit, was excluded. Furthermore, patients with an admission date in the final quarter of 2011 were excluded from the readmission analysis because appropriate follow-up could not be conducted.

2.3. Covariates

Patient demographics, post-operative LOS, co-morbidities present on admission, and in-hospital events not present on admission were assessed. Baseline co-morbidities were compared using the modified Deyo index [15,16], which adapts the Charlson comorbidity index for predicting adjusted relative risk of one-year mortality and healthcare outcomes.

2.4. Statistics

Patient demographics and clinical characteristics were reported as frequencies or proportions for categorical data, means ± standard deviation (SD) for continuous parametric variables, and medians [interquartile ranges (IQR)] for continuous nonparametric variables. Differences in preoperative and postoperative characteristics between groups (LA, CA, and OA) were evaluated by the Pearson's chi-square test, two-sample *t*-test, Wilcoxon rank-sum test, ANOVA, or Kruskal-Wallis test, as appropriate.

Multivariable regression modeling was used to identify significant factors associated with CA among patients who received LA and CA. One-third of the LA and CA patients were used as the derivation cohort (N = 71,617), and the validation cohort consisted of the remaining patients (N = 143,235). Risk factors were selected based on clinical relevance that were also found to be significant in univariate analysis, including patient demographics, comorbidities, and acute appendicitis subtype by ICD-9 code as identified on admission. Each risk factor was subsequently tested individually via likelihood ratio tests in order of decreasing Wald p-values; those with $p < 0.05$ during backwards elimination were retained in the model until a parsimonious model was obtained. The six variables most predictive of conversion in the initial multivariable regression model (age ≥ 40, male sex, black race, diabetes, obesity, and complicated appendicitis) were included in a final multivariable logistic regression model. An integer-based scoring system was then created based on the odds ratio estimates from the final logistic model. In order to simplify for clinical use, four points were assigned to a diagnosis of complicated appendicitis since the odds ratio for diagnosis was roughly four times that of other variables in the logistic model, and one point was assigned to each of the other variables. Points for each risk factor were summed to obtain a total score. The performance of the scoring system was assessed with discrimination and calibration using the validation cohort. For comparison, one logistic regression model was constructed using the same risk factors as in the prediction model but using data from the validation cohort and another logistic regression model was fitted including the total score as a continuous variable. Discrimination was evaluated using the receiver operating characteristic (ROC) curve and the area under the ROC curve (c-statistic), while calibration was assessed using the Brier score. Sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) were calculated at different risk score cutoff values using the entire cohort; the optimal cutoff value was determined by the largest Youden index (sensitivity + specificity−1).

Lastly, multivariable logistic regression models were constructed to evaluate the association between type of procedure (CA vs. LA, CA vs. OA) with post-operative morbidities and 30-day readmission in the entire cohort. Post-operative morbidity was identified by a coded diagnosis of an acute complication during the hospitalization. Complications were classified into five categories: (1) infectious/inflammatory (wound infection, sepsis, pneumonia, peritoneal abscess, adhesive bowel obstruction), (2) respiratory (mechanical ventilation < 96 h, mechanical ventilation ≥ 96 h, re-intubation, pulmonary embolism), (3) cardiovascular (myocardial infarction, shock, stroke), (4) hematologic (transfusion, post-operative hemorrhage), (5) renal (acute renal failure). All models were adjusted for patient demographics, acute appendicitis by ICD-9 code, co-morbidities, and acute concomitant illnesses. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of procedure type (CA vs. LA, CA vs. OA) were reported. SAS version 9.3 (SAS Institute, Inc., Cary, NC) was used to perform all statistical analyses. All P-values are two-sided with statistical significance evaluated at the 0.05 alpha level.

3. Results

3.1. Demographics

Between 2007 and 2011, 279,327 patients underwent appendectomy. Of these, 203,654 (73%) were LA, 11,198 (4%) were CA, and 64,475 (23%) were OA. Table 1 summarizes patient demographics compared between LA, CA, and OA subgroups on univariate analysis. The mean (±SD) age of the entire cohort was 40.8 ± 16.7 years and 49.8% were male. CA patients were more commonly male and 40 years of age or older. Race distribution for the entire cohort was 50.4% white, 24.2% Hispanic, 5.7% black, 4.2% Asian or Pacific Islander, 4.4% Native American or other, and 11.1% unknown − CA patients had a higher likelihood of being white or black race. Lastly, the frequencies of Deyo Scores equal to 0, 1 and 2 + for the entire cohort were 90%, 7.2%, and 2.7%, respectively; the CA group had the highest proportion of Deyo score ≥2, while the LA group had the lowest.

Table 1
Patient demographics (Univariate analysis).

	LA (%) (N = 203,654)	CA (%) (N = 11,198)	OA (%) (N = 64,475)	P-value
Sex, Male	48.8%	56.1%	51.8%	<0.0001[a]
Age, by category, y				
18–29	33.3%	16.7%	32.0%	<0.0001[a]
30–39	21.6%	15.8%	20.0%	
40–59	31.6%	40.5%	30.3%	
60+	13.6%	26.9%	17.7%	
Race				
White	51.3%	57.7%	46.3%	<0.0001[a]
Hispanic	23.5%	22.2%	26.8%	
Black	5.4%	7.8%	6.3%	
Asian or Pacific islander	4.2%	4.0%	4.0%	
Native American or other	4.3%	3.6%	4.7%	
Unknown	11.2%	4.8%	11.9%	
Deyo index				
0	90.8%	84.4%	88.7%	<0.0001[a]
1	7.1%	9.8%	7.3%	
2+	2.2%	5.8%	4.0%	

LA, laparoscopic-only appendectomy; CA, conversion from laparoscopic to open appendectomy; OA, primary open appendectomy.
Percents may not sum to 100% due to rounding.
[a] Statistically significant between all groups.

3.2. Admission characteristics

Table 2 summarizes admission diagnoses between operative subgroups by univariate analysis. The primary diagnoses for the entire cohort were acute appendicitis without peritonitis (75.3%), with peritoneal abscess (9.4%), and with generalized peritonitis (15.3%). CA patients were more likely to have complicated appendicitis, with over 66% having either peritonitis or intra-abdominal abscess diagnosed upon admission. By univariate analysis, the CA group had a higher prevalence of co-morbidities such as diabetes, obesity, hypertension, coronary artery disease (CAD), current/former smoker, chronic obstructive pulmonary disease (COPD), dyslipidemia, and anemia. They also had a higher likelihood of acute conditions upon admission such as sepsis, hypovolemia, electrolyte disturbances, renal failure, and respiratory failure. Notably, the CA and OA groups had similar rates of shock, acidosis, and pneumonia, which were higher compared to LA. The median post-operative LOS was 2 days (IQR 1–3) for the entire cohort; the CA group had the longest hospitalization, while LA had the shortest. The median total charges were $33,444 (IQR $22,191–$48,537); the CA group accrued the most costs while OA accrued the least. Over 95% of the entire cohort was discharged home, with the CA group having a higher rate of home healthcare dispositions and transfer to outside facilities.

3.3. Predictors of conversion from laparoscopic to open appendectomy

Supplementary Table S1 summarizes the pre-operative predictors of CA by multivariable logistic regression in a derivation cohort (N = 71,617) consisting of patients undergoing LA or CA; to minimize confounding, OA patients were assumed not to be candidates for laparoscopy pre-operatively and thus they were excluded. Age ≥40, male sex, black race, complicated appendicitis, diabetes, and obesity were positive predictors for conversion from laparoscopic to open appendectomy. Each significant variable was assigned one point for the scoring model, with the exception of

Table 2
Admission characteristics (Univariate analysis).

	LA (%) (N = 203,654)	CA (%) (N = 11,198)	OA (%) (N = 64,475)	P-value
Diagnoses				
Acute Appendicitis				
Without peritonitis	80.3%	33.4%	67.0%	<0.0001[a]
With peritoneal abscess	6.7%	30.7%	14.3%	
With generalized peritonitis	13.0%	35.9%	18.8%	
Comorbidities				
Diabetes	5.1%	10.6%	6.6%	<0.0001[a]
Obesity	6.8%	13.2%	7.1%	<0.003[a]
Hypertension	17.1%	31.9%	19.2%	<0.0001[a]
Coronary artery disease	3.0%	6.3%	4.1%	<0.0001[a]
Smoker	10.6%	13.1%	10.6%	<0.0001[b]
COPD	6.3%	9.0%	6.7%	<0.0002[a]
Dyslipidemia	10.0%	17.4%	9.7%	<0.02[a]
Anemia (chronic)	1.9%	4.3%	3.2%	<0.0001[a]
Acute conditions				
Sepsis	0.8%	3.2%	2.3%	<0.0001[a]
Volume depletion	1.9%	3.9%	3.2%	<0.0002[a]
Fluid electrolyte imbalance	4.6%	10.6%	7.6%	<0.0001[a]
Acute renal failure	0.9%	3.0%	2.1%	<0.0001[a]
Acute respiratory failure	0.4%	1.4%	1.1%	<0.014[a]
Shock	0.1%	0.5%	0.6%	<0.0001[c]
Pneumonia	0.2%	0.6%	0.5%	<0.0001[c]
Acidosis	0.1%	0.4%	0.4%	<0.0001[c]
Hospitalization				
Postoperative LOS, median (IQR), d	1 (1–2)	5 (3–7)	2 (1–4)	<0.0001[a]
Total charges, median (IQR), $US	33,650 (22,820–47,604)	54,290 (34,648–81,508)	30,537 (19,222–46,637)	<0.0001[a]
Discharge disposition				
Routine	97.5%	83.7%	91.4%	<0.0001[a]
Transfer to short-term hospital	0.1%	0.5%	0.3%	
Transfer to other	0.7%	3.5%	2.5%	
Home health care	1.4%	11.7%	5.0%	
Other or AMA	0.3%	0.6%	0.7%	

LA, laparoscopic-only appendectomy; CA, conversion from laparoscopic to open appendectomy; OA, primary open appendectomy; LOS, length of stay; IQR, interquartile range; d, day; AMA, against medical advice.
Percents may not sum to 100% due to rounding.
[a] Statistically significant between all groups.
[b] Statistically significant between Converted vs. Laparoscopic and Converted vs. Direct-Open.
[c] Statistically significant between Laparoscopic vs. Converted and Laparoscopic vs. Direct-Open.

complicated appendicitis being assigned four points, which were based on odds ratio estimates from the multivariable logistic regression model (Supplementary Table S1). The multivariable prediction model was tested on a validation cohort (N = 143,235); notably, there were no differences in procedure type, sex, age, race, appendicitis subtype, or co-morbidities between derivation and validation cohorts. The ROC curve of the validation cohort is displayed in Supplementary Fig. S1 – the model's Brier score is 0.047, indicating a good fit. The highest Youden index (0.47) indicated that the optimal cutoff was a total score of 4. For a score less than 4, there was ≤5% risk of conversion to open, whereas a score ≥4 was associated with a 10–25% observed rate of conversion (Fig. 1). The model's sensitivity, specificity, NPV, and PPV were 71%, 77%, 98%, and 15%, respectively, to predict conversion from laparoscopic to open at this cutoff.

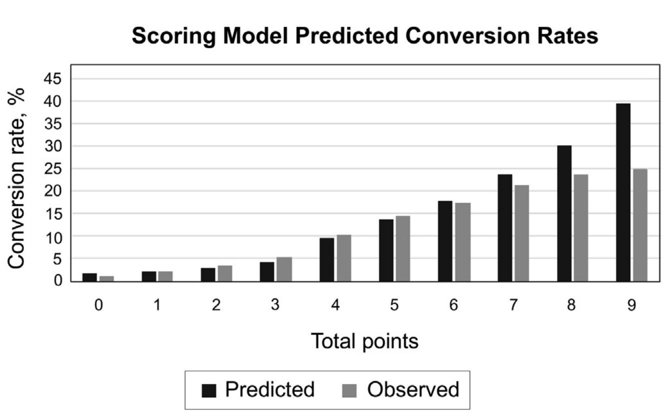

Fig. 1. Predicted and observed conversion rates in the conversion from laparoscopic to open predictive model (validation cohort).

3.4. Post-operative outcomes

Table 3 summarizes the post-operative patient outcomes and complications on univariate analysis between all operative subgroups in the entire cohort, as well as a composite outcomes multivariable analysis comparing CA vs. LA and CA vs. OA (controlling for sex, age, race, diabetes, obesity, hypertension, heart disease, smoker, COPD, dyslipidemia, anemia, sepsis, volume depletion, fluid electrolyte imbalance, acute renal failure, shock, pneumonia, myocardial infarction, and acidosis). Most complications were significantly higher in the CA cohort on univariate analysis. On multivariable analysis, 30-day re-admission was more likely in CA compared to both LA and OA. On composite outcomes multivariable analysis, CA had a higher likelihood of infectious/inflammatory, respiratory, cardiovascular, hematologic, and renal complications compared to LA. Furthermore, CA had a higher likelihood of infectious/inflammatory, hematologic, and renal complications compared to OA; however, there were no differences in respiratory or cardiovascular complications.

Table 3
Post-operative composite outcomes analysis.

	Univariate analysis				Multivariable analysis	
	LA (%) (N = 203,654)	CA (%) (N = 11,198)	OA (%) (N = 64,475)	P-value	CA vs. LA OR (95% CI)	CA vs. OA OR (95% CI)
Hospitalization						
30-day Readmission	4.3%	9.0%	5.7%	<0.0001	1.32 (1.22–1.43)[a]	1.29 (1.19–1.41)[a]
Infectious/Inflammatory						
Overall	1.1%	7.1%	3.0%	<0.0001	2.68 (2.45–2.94)[a]	1.44 (1.31–1.58)[a]
Wound infection	0.4%	3.6%	1.3%	<0.0001		
Sepsis	0.3%	1.9%	1.0%	<0.0001		
Pneumonia	0.4%	1.7%	1.0%	<0.0001		
Peritoneal abscess	0.1%	0.4%	0.1%	<0.0001		
Bowel obstruction	0.1%	0.8%	0.2%	<0.0001		
Respiratory						
Overall	0.6%	3.4%	2.2%	<0.0001	2.17 (2.16–2.18)[a]	1.02 (0.89–1.16)
Mechanical ventilation	0.5%	3.1%	2.0%	<0.0001		
<96 h	0.4%	2.3%	1.2%	<0.0001		
> = 96 h	0.1%	0.8%	0.8%	<0.0001		
Re-intubation	0.4%	1.9%	1.4%	<0.0001		
Pulmonary embolism	0.1%	0.5%	0.4%	<0.0001		
Cardiovascular						
Overall	0.5%	1.9%	1.1%	<0.0001	1.61 (1.37–1.90)[a]	1.00 (0.85–1.18)
Myocardial infarction	0.3%	1.2%	0.7%	<0.0001		
Shock	0.1%	0.6%	0.5%	<0.0001		
CVA/Stroke	0.03%	0.1%	0.1%	<0.0001		
Hematologic						
Overall	1.0%	4.4%	2.5%	<0.0001	2.33 (2.08–2.62)[a]	1.31 (1.17–1.46)[a]
Transfusion	0.9%	3.6%	2.4%	<0.0001		
Hemorrhage	0.3%	1.1%	0.2%	<0.0001		
Renal						
Acute Renal Failure	0.8%	3.0%	1.5%	<0.0001	1.63 (1.43–1.85)[a]	1.22 (1.06–1.39)[a]

LA, laparoscopic-only appendectomy; CA, conversion from laparoscopic to open appendectomy; OA, primary open appendectomy; OR, odds ratio; CI, confidence interval; CVA, cerebrovascular accident.
[a] $P < 0.02$.

4. Discussion

While the proportion of appendectomies performed laparoscopically continues to rise, the conversion rate has remained steady at approximately 5%. The ability to identify patients at highest risk of conversion can aid surgeons in selecting patients who may benefit from primary open appendectomy, thereby potentially reducing operative time, morbidity, and costs. Although the decision to convert from laparoscopic to open appendectomy in the operating room can be subjective and dependent on individual surgeon skill, identifying objective pre-operative parameters associated with conversion can provide a lower threshold for proceeding with the potentially inevitable open approach, mitigating costs and morbidity.

Our study identified age ≥40, male sex, black race, diabetes, obesity, and a pre-operative diagnosis of complicated appendicitis as independent risk factors for CA on multivariable analysis. Prior studies have shown several of these patient variables, amongst others, to be associated with CA, specifically: male sex [7], older age [7,9,10], ASA class > 2 [7,10], leukocytosis [9,10], laparoscopic inexperience [5,7], inflammation or free air on CT scan [7,9–11], and diffuse peritonitis [10]. Since most conversions are determined by the degree of intra-operative inflammation, our analysis identifies patient demographics and co-morbidities that may predispose the patient to having more severe appendicitis requiring conversion.

One of the main objectives of this study was to develop a clinical tool that would allow surgeons to estimate the risk of conversion from laparoscopic to open appendectomy based on objective and readily available pre-operative patient parameters. Using the independent pre-operative parameters identified in our analysis, we developed an integer-based scoring model predictive of conversion to open and validated it in a randomized cohort. The model was a good fit, as determined by a Brier score of 0.047. It also performed well with an optimal total score of 4 (ranging 0–9) achieving a sensitivity, specificity, NPV, and PPV of 71%, 77%, 98%, and 15%, respectively, to predict conversion from laparoscopic to open at this cutoff. Not surprisingly, complicated appendicitis was the strongest predictor of conversion in our cohort and was assigned 4 points in the scoring system. Our model's results are largely driven by this parameter: if complicated appendicitis is not present (score < 4), the risk of conversion to open is ≤ 5%. However, if complicated appendicitis is present (score ≥ 4), there is at least a 10–25% risk of conversion depending on the presence of additional independent predictors.

This study also demonstrated that CA patients are at significant risk for poorer outcomes, longer LOS, and higher healthcare costs. On multivariable analysis controlling for patient demographics, acute appendicitis by ICD-9 code, co-morbidities, and acute concomitant illnesses, CA patients experienced higher rates of infectious/inflammatory, hematologic, and renal complications when compared to both LA and OA; cardiovascular and respiratory complications were similarly elevated in the CA and OA groups. This reflects that, similar to OA patients, CA patients comprise a sick patient population who are more commonly afflicted with complicated appendicitis and its sequelae. Several studies have also reported significantly higher complication rates in CA patients ranging from 8% to 34% compared to 5–9% in LA patients, typically including intra-abdominal abscess, surgical site infection, ileus, and pneumonia [8,10,17]. Notably, however, our data demonstrate that conversion patients may be at risk for additional morbidity compared to patients undergoing OA, possibly due to longer operative times, limitations of the laparoscopic approach, or more baseline co-morbidities. While a major limitation of the SID database is its inability to evaluate parameters like operative time or specific indications for conversion, we did find that the converted cohort in this study had more co-morbidities, suggesting a possible predilection for post-operative complications.

Lastly, we found that post-operative LOS was longest and total charges per patient were most expensive in the CA group. While this report is the first to demonstrate the high expense of patients undergoing CA, we also found that OA was significantly less expensive than the LA group. Prior cost analyses have conflicting findings regarding the costs of LA versus OA: some demonstrate higher costs for LA [18,19], OA [20], and no difference between approach [19,21,22]. These differences are likely attributable to the variable ages, co-morbidities, severities of appendicitis, and complications between cohorts. It remains unclear, however, whether the 10% additional cost of LA in our study undercuts or exceeds the expected increased societal costs associated with OA (e.g. delayed return-to-work) and unrealized late complications inherent to open surgery (e.g. bowel obstructions, hernias). Moreover, it is important to take into consideration that facility fees vary from hospital to hospital. Nevertheless, the elevated costs of the CA group likely reflect the longer length-of-stay, additional operating room costs for laparoscopic equipment [23], and higher complication rates within that group, thus highlighting the economic importance of preventing complications potentially by proceeding directly to OA.

Our study is limited by the inability of the SID to analyze patient-specific data that could provide additional insight into conversion from laparoscopic to open appendectomy, including symptomatology, hemodynamics, imaging features, laboratory values, operative and postoperative variables, surgeon experience, and indication for conversion. We are also limited by the retrospective nature of the SID database, as well as other inherent limitations of this administrative database including coding errors and the lack of long-term or outpatient follow-up variables. Lastly, although the SID database provides a large sample size to examine a comprehensive list of post-operative complications by univariate analysis, we are limited by the high false positive rate associated with analyzing a large number of outcomes (i.e. complications) by multivariable regression; thus we pursued a composite multivariable outcomes analysis to overcome this limitation.

5. Conclusion

We have developed a scoring model to estimate the risk of conversion to open during laparoscopic appendectomy based on clinically relevant and readily available pre-operative patient characteristics, including age $\geq$40, male sex, black race, diabetes, obesity, and a pre-operative diagnosis of complicated appendicitis. Furthermore, we have found that the converted patient population is at risk for higher rates of post-operative morbidity, even when compared to those undergoing the primary open approach. Therefore, the predictors identified here could help select for patients who may benefit from primary open appendectomy.

Ethical approval

Weill Cornell Medicine Institutional Review Board approved all study activities.

Protocol # 1308014181.

Author contribution

BMF: Participated in research design, data analysis, drafting of the manuscript, and critical revision of the manuscript. No conflict of interest.

XW: Participated in data acquisition, data analysis, and critical revision of the manuscript. No conflict of interest.

GPG: Participated in research design, data acquisition, data analysis, and critical revision of the manuscript. No conflict of interest.

LGB: Participated in data acquisition, data analysis, and critical revision of the manuscript. No conflict of interest.

RZ: Participated in research design and critical revision of the manuscript. RZ has ownership in a company named “Analytical Care”.

AB: Participated in research design and critical revision of the manuscript. AB has ownership in a company named “Analytical Care”.

RZ: Participated in research design and critical revision of the manuscript. No conflict of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ijsu.2017.03.016.

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