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The heavy price of conversion from laparoscopic to open procedures for emergent cholecystectomies☆

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ABSTRACT

Background: Laparoscopic cholecystectomy (LC) is the standard operative intervention for gallbladder disease. Complications may necessitate conversion to an open cholecystectomy (OC). This study aims to determine the cost-consequences of laparoscopic-to-open conversion using a nationally-representative sample.

Methods: Using the National Inpatient Sample (2007–2011), adult patients undergoing emergent LC were identified. Patients undergoing secondary-conversion to OC were subsequently identified. Multivariable regression analyses, accounting for differences in propensity-quintile, mortality, length of stay, and hospital-level factors were then performed to assess for differences in the odds of conversion and total predicted mean costs per index-hospitalization.

Results: Of 225,805 observations, conversion to open occurred in 1.86% ($n = 4203$) of cases. Increased age, African-American ethnicity, public-insurance and teaching-hospital status were associated with a higher likelihood of conversion ($p < 0.05$) after risk-adjustment. Risk-adjusted odds of conversion increased by 34% (95%CI:1.33–1.36) for each day surgery was delayed. Risk-adjusted costs, were 259% higher (absolute-difference $23,358, $p < 0.05$) with conversion. Mortality was higher amongst patients undergoing conversion to open (4.98% vs 0.34%, $p < 0.001$).

Conclusion: Patients undergoing conversion from laparoscopic to open cholecystectomy are at an increased risk of receiving disparate care and increased mortality.

Introduction

More than 700,000 cholecystectomies are performed in the United States every year, making it one of the most common surgical procedures performed.[1,2] Since its introduction more than two decades ago, laparoscopy has become the standard approach in the management of cholecystitis due to associated shorter recovery times, shorter hospital stays and lower total hospitalization costs.[3] However, conversion to an open procedure may be mandated in difficult cases due to failure to progress or inability to define anatomy adequately using a laparoscopic approach.

The benefits of a laparoscopic operation are swiftly lost with conversion to an open procedure, which contributes to significant post-operative morbidity amongst patients. Conversion to an open procedure is reported to occur at a rate of 10–15%, and is also associated with a higher likelihood of death and complications including bile duct injury, bile leak, or bleeding, requiring reoperation or transfusion.[4] Patient-related factors postulated to influence conversion are male gender and increasing age.[5,6] However, practically, intraoperative factors (organ injury or difficult dissection) and surgical judgement (failure to progress) also play a definitive role in the decision to convert.

Previous studies have sought to delineate the factors associated with conversion to an open procedure however the fiscal implications of such remain less well elucidated.[5,6] The aim of this study was to determine the cost of conversion from a laparoscopic to an open cholecystectomy in the non-elective setting. This study also

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sought to determine the underlying factors associated with an increased risk of conversion to an open procedure.

Methods

The National Inpatient Sample (NIS) is the principal all-payer database of hospital billing data in the United States. It is sponsored by the Agency for Healthcare Research and Quality (AHRQ) under the Healthcare Cost and Utilization Project (HCUP) and is publicly accessible. This database represents a 20% stratified-sample of US hospitals carrying information on region, ownership-control, urban/rural location, teaching status, and number of hospital beds available. The sampling frame consists of 90% of all hospital discharges. NIS-provided data allows for determination of national estimates considered representative of 95% of the US patient populace. Age, sex, race/ethnicity, primary payer, length of stay (LOS), total charges, disposition, hospital characteristics are some of the available data elements that can be investigated with up to 15 ICD-9-CM-based procedure and 25 ICD-9-CM diagnosis codes.

Patients undergoing a laparoscopic cholecystectomy as a primary procedure (ICD-9-CM procedure codes 51.23 and 51.24) who were aged 16 years or older were selected and their data from the 2007–2011 NIS was retrospectively queried. Secondary diagnosis and procedure codes were queried for patients undergoing conversion to an open procedure (ICD-9-CM procedure code 51.22 and/or diagnosis code v64.41). The patient population was then divided into two categories namely (i) those undergoing laparoscopic cholecystectomy, and (ii) those necessitating conversion to open. Only patients admitted after an evaluation in the emergency room with the appropriate diagnosis and procedure under investigation were analyzed. Patients transferred in from similar acute care hospitals and patients discharged to other facilities were excluded. This was done so that each patient represented a single hospitalization. Patients undergoing cholecystostomy tube placements and those with diagnoses codes consistent with a common bile duct injury were also excluded. Costs were top-coded to the 75th percentile to decrease the effect of outliers on outcome assessment. Propensity scores were calculated for the two groups that included the study population, accounting for differences in baseline characteristics including age, gender, race/ethnicity, CCI, insurance status, year of admission, weekend admission, and income quartile.

Patient demographics (age, race/ethnicity, sex, median household income quartile for a patient's residential zip code, and insurance status), hospital characteristics (urban vs. rural location, teaching status, geographical region, and hospital bed size), weekend vs. weekday admission, ICD-9-CM diagnostic codes, total charges, hospital specific all-payer cost-to-charge ratios (developed using standardized hospital information on all-payer inpatient cost and charge reported by hospitals to the Center for Medicare and Medicaid Services), lengths of stay following the procedure, mortality, and comorbidities as measured by the Charlson Comorbidity Index (CCI) were collected.[7] The CCI is calculated based on a predetermined weighted formula to provide an estimate of comorbidity and mortality risk.

Patients with missing race/ethnicity information were coded as 'missing' and included in the final analysis. Race/Ethnicity was classified as White, Black, Hispanic, missing, or other. Median household income quartile for a patient's residential zip code is categorized by NIS according to annual income percentiles such that quartile 1 (Q1) corresponds to percentiles 0–25, quartile 2 (Q2) to percentiles 26–50, quartile 3 (Q3) to percentiles 51–75, and quartile 4 (Q4) to percentiles 76–100 within a given year. In 2011, the pre-determined cut points were $1–38,999 (Q1), $39,000–47,999 (Q2), $48,000–63,999 (Q3), and $64,000+ (Q4) in 2011 dollars. Insurance status was categorized as private primary payer, government primary payer, uninsured, and unknown. Geographical region is pre-determined by NIS to include hospitals located in the Northeast, Midwest or North Central, South, and West. The day that a procedure was performed was calculated based on a patient's admission day. Day 1 corresponded to a patient's date of admission and each subsequent day was classified as 2, 3, 4, 5, 6, 7, and >7 days. Days hospitalized then served as a primary independent variable of interest.

Cost was the primary outcome variable which was calculated by determining the product of total charges and corresponding hospital-specific cost-to-charge ratios. Consumer Price Indices were utilized to adjust costs for inflation per year and were changed to 2018 dollars. Reference categories as age group 16–25 years, female, white race/ethnicity, lowest CCI (0), lowest income quartile, private insurance, weekday admission, lowest hospital volume quartile, southern geographic region, rural location, non-teaching status, and hospitalized patients who did not suffer from mortality were used as reference categories for the respective characteristics. Generalized linear models (GLM) were used to estimate predicted mean costs (gamma family, link log, and calculation of average marginal effects). This was done to compare the association of conversion to open surgery on total costs, unadjusted and risk-adjusted which could account for above characteristics acting as possible confounders. These models were also adjusted for calculated propensity score quintiles. Patients undergoing surgery within 48 h and those discharged within 48 h were also analyzed via a similar secondary assessment.

All statistical analyses were conducted using Stata Statistical Software: Release 12 (StataCorp LP, College Station, TX). Two-sided p-values <0.05 were considered statistically significant.

Results

A total of 225,805 records were analyzed, weighted to represent 1,111,885 patients nationally. Average age was 48.5 (±19.1) years with a female preponderance (67.9%). Conversion to open occurred in 1.86% (n = 4203) of cases weighted to represent 206,811 patients nationally. Table 1 describes the demographic and hospital specific differences between the two study populations.

Table 2 compares the unadjusted outcomes between the two study populations. Lengths of hospital stay, total cost of care as well as mortality were higher for patient undergoing conversion to an open procedure. Rate of mortality was 0.34% in the laparoscopy group vs 4.98% in patients undergoing conversion to open ($p < 0.001$). Odds of mortality were found to steadily increase in patients undergoing conversion to open for each day surgery was delayed.

Table 3 demonstrates patient factors influencing the likelihood of conversion. Black patients had a 14% higher risk of conversion to an open procedure when compared to white patients (OR [95% CI]: 1.14 [1.02–1.29], $p = 0.025$). Similarly, patients on government insurance had a 19% higher likelihood of conversion to an open procedure when compared with patients with private insurance (OR [95% CI]: 1.19 [1.10–1.28], $p < 0.001$). Additionally, having one or more comorbidities, and treatment at teaching hospitals were associated with a higher likelihood of conversion (<0.05). Female gender and treatment at a high-volume center were associated with a lower risk of conversion ($p < 0.05$). Weekend admission had no association with the likelihood of conversion (OR [95% CI]:1.00 [0.93–1.07], $p = 0.973$).

Risk-adjusted odds of conversion increased by 34% (95%CI: 1.33–1.36) for each day that surgery was delayed (Fig. 1). Risk-adjusted costs, per patient, were 259% higher (absolute difference $23,358, $p < 0.05$) for patients who underwent conversion (see

Table 1
Demographic parameters of the study population further stratified by completion of surgery laparoscopically and conversion to open.

	Overall (n = 225,805)	Laparoscopic Approach (n = 221,602)	Conversion to Open (n = 4203)	p-value
Age, mean (SD)	48.6 (19.1)	48.3 (19.1)	62.9 (16.4)	**<0.001**
Female, n (%)	152,988 (67.7)	151,394 (68.3)	1594 (37.9)	**<0.001**
Race/Ethnicity, n (%)				**<0.001**
• White	121,427 (53.8)	118,906 (53.7)	2521 (60.0)	
• Black	18,378 (8.1)	18,044 (8.1)	334 (7.9)	
• Hispanic	39,044 (17.3)	38,574 (17.4)	470 (11.2)	
• Others	12,011 (5.3)	11,769 (5.3)	242 (5.8)	
• Missing	34,945 (15.5)	34,309 (15.5)	636 (15.1)	
Insurance Status, n (%)				**<0.001**
• Public	95,752 (42.4)	94,518 (42.7)	1234 (29.4)	
• Private	99,375 (44.0)	96,725 (43.6)	2650 (63.0)	
• Uninsured	30,068 (13.3)	29,757 (13.4)	311 (7.4)	
• Missing	610 (0.3)	602 (0.3)	8 (0.2)	
Income Quartile, n (%)				0.421
• 0 to 25th percentile	60,607 (26.8)	59,474 (26.8)	1133 (27.0)	
• 26th to 50th percentile	57,949 (25.7)	56,876 (25.7)	1073 (25.5)	
• 51st to 75th percentile	55,514 (24.6)	54,437 (24.6)	1077 (25.6)	
• 76th to 100th percentile	46,700 (20.7)	45,870 (20.7)	830 (19.7)	
• Missing	5035 (2.2)	4945 (2.2)	90 (2.1)	
Hospital Location, n (%)	197,653 (87.5)	194,049 (87.6)	3604 (85.7)	**<0.001**
Teaching Hospital, n (%)	84,169 (37.3)	82,278 (37.1)	1891 (45.0)	**<0.001**
Hospital Region, n (%)				**<0.001**
• Northeast	34,739 (15.4)	33,955 (15.3)	784 (18.7)	
• Midwest	45,247 (20.0)	44,351 (20.0)	896 (21.3)	
• South	100,939 (44.7)	99,333 (44.8)	1605 (38.2)	
• West	44,881 (19.9)	43,963 (19.8)	918 (21.8)	
Charlson Comorbidity Index, n (%)				**<0.001**
• 0	157,000 (69.5)	154,992 (69.9)	2008 (47.8)	
• 1	44,966 (19.9)	43,856 (19.8)	1110 (26.4)	
• 2	13,141 (5.8)	12,637 (5.7)	504 (12.0)	
• ≥3	10,698 (4.7)	10,117 (4.6)	581 (13.8)	
Hospital Volume, n (%)				**<0.001**
• First Quartile	54,609 (24.2)	53,413 (24.1)	1196 (28.5)	
• Second Quartile	56,195 (24.9)	55,109 (24.9)	1086 (25.8)	
• Third Quartile	56,987 (25.2)	56,000 (25.3)	987 (23.5)	
• Forth Quartile	58,014 (25.7)	57,080 (25.8)	934 (22.2)	

Table 4). To ensure that all captured procedures were performed for acute cholecystitis, sensitivity analyses were performed restricting the study population to diagnosis codes consistent with acute cholecystitis. These demonstrated results consistent with our original analysis with a total cost increase of 293% (Supplemental Table 1).

Amongst those undergoing conversion to open, significant cost increases were seen with each day the surgery was delayed (Fig. 2). Fig. 3 demonstrates that there has been no significant decline in the likelihood of conversion to an open procedure over the years. Fig. 4 demonstrates a steady increase in the likelihood of mortality in patients undergoing conversion for each day that operative intervention was delayed.

Discussion

Multiple authors have attempted to identify risk factors for conversion to OC to aid in risk stratifying patients preoperatively for patients undergoing LC for acute cholecystitis. Variation in the results of these studies have prevented formulation and adoption of guidelines that may assist general surgeons in identifying an ideal approach for the difficult gallbladder.[4,8,9] However, the fiscal implications of conversion to OC have not been well studied. A single center study of 167 patient by Lengyel et al. first attempted to quantify the fiscal burden of conversion of LC to an OC.[8,10] In our analysis of US patients nationally we, unsurprisingly, found that conversion to open cholecystectomy is associated with a 259% higher overall cost of hospitalization. As has been demonstrated in prior studies and has been further verified by our study, increasing age and male gender are associated with an increased risk of conversion. However, race/ethnicity and socio-economic status also appear to play a role that has not previously been noted.

We found an overall national rate of conversion from 2007 to 2011 of 1.86%, which is lower than the rates (5–20%) reported by prior studies.[9,11–13] The lower rate of conversion in this contemporary analysis likely results from better familiarity with laparoscopy as it has gained traction in the last two decades with graduating surgical trainees gaining more laparoscopic experience during residency and fellowship training. Abelson et al. suggested that surgeons undergoing an advanced laparoscopic fellowship training have significantly lower conversion rates when compared to the conversion rates of the surgeons that did not undertake the

Table 2
Outcomes further stratified by completion of surgery laparoscopically and conversion to open.

	Overall (n = 225,805)	Laparoscopic Approach (n = 221,602)	Conversion to Open (n = 4203)	p-value
Length of Stay, median [IQR]	3 [2–4]	3 [IQR: 2–4]	7 [IQR:5–12]	**<0.001**
Cost of Care, median [IQR]	9901 [7368–12,844]	9827 [7327–12,708]	21,739 [14,385–37,117]	**<0.001**
Mortality, n (%)	958 (0.4)	749 (0.3)	209 (4.9)	**<0.001**

Table 3
Factors influencing conversion from laparoscopic to open cholecystectomy.

Descriptors	Odds Ratio [95% CI]	p-value
Age	1.03 [1.02–1.03]	**<0.001**
Female (reference: Male)	0.37 [0.34–0.40]	**<0.001**
Race (reference: White)		
• Black	1.14 [1.02–1.29]	**0.025**
• Hispanic	0.98 [0.89–1.09]	0.741
• Others	1.20 [1.04–1.37]	**0.009**
• Missing	0.92 [0.83–1.00]	0.065
Insurance Type (reference: Private)		
• Government	1.19 [1.10–1.28]	**<0.001**
• Uninsured	1.00 [0.89–1.14]	0.958
Income Quartile (reference: 0–25th percentile)		
• 26th to 50th percentile	0.97 [0.89–1.06]	0.519
• 51st to 75th percentile	1.01 [0.93–1.11]	0.699
• 76th to 100th percentile	1.14 [1.02–1.25]	**0.009**
• Missing	1.01 [0.91–1.11]	0.058
Weekend Admission	1.00 [0.93–1.07]	0.973
Charlson Comorbidity Index (reference: 0)		
• 1	1.26 [1.16–1.35]	**<0.001**
• 2	1.39 [1.26–1.56]	**<0.001**
• 3	1.66 [1.49–1.83]	**<0.001**
Hospital Volume (reference: First (lowest) Quartile)		
• Second Quartile	0.91 [0.83–1.00]	**0.055**
• Third Quartile	0.80 [0.73–0.88]	**<0.001**
• Forth Quartile	0.77 [0.72–0.85]	**<0.001**
Hospital Region (reference: Northeast)		
• Midwest	0.80 [0.71–0.88]	**<0.001**
• South	0.71 [0.64–0.77]	**<0.001**
• West	1.21 [1.09–1.33]	**<0.001**
Location (reference: Urban)	0.90 [0.82–0.99]	**0.044**
Teaching status (reference: Rural)	1.58 [1.48–1.69]	**<0.001**
Died	6.68 [5.66–7.88]	**<0.001**

Adjusted for: age, sex, race/ethnicity, income quartile, year of admission, Charlson Comorbidity Index, insurance status, hospital location, teaching status, geographical location, hospital volume, and mortality.

training (1.7% vs 8.5%).[14] The rates reported with laparoscopic training in Abelson et al.'s study is comparable to the rate reported in our study. Given the ubiquitous adoption of laparoscopy in most teaching hospitals, the benefit of dedicated training in laparoscopy might be minimizing, thus bringing conversion rates lower and closer to those reported in this study. According to another study, conversion rates were higher in procedures performed by senior surgeons compared to junior surgeons.[15] The most common reasons cited for conversion to open are severe inflammation or adhesions, difficult anatomy and bleeding.[16] The starkest increase, however, was a 16-fold increase in mortality with conversion from 0.3% for the LC group and 4.9% for the OC group. This increased mortality is not dissimilar to data reported previously by Steiner and colleagues. The advent of laparoscopy lead to a 33% decrease in mortality indicating a benefit to pursuing laparoscopy when feasible in the management of acute cholecystitis.[17]

Increasing age and male gender increase the risk to undergo conversion. This is consistent with previous studies.[18,19] Conversion to open in the elderly is usually not unfavorable. Lo et al. demonstrated that early conversion in elderly patients was associated with improved outcomes.[20] This analysis additionally demonstrates evidence of disparate rates of conversion amongst minority groups and patients with public insurance. This phenomenon, amply demonstrated in the emergency general surgery and trauma literature, speaks to the potential role of socioeconomic status and race on the care patients receive, with a resultant effect on patient outcomes. Correcting for pre-operative differences between groups by using propensity scoring for our multivariate analysis, we found that the conversion group had a 4-days longer length of stay (LOS). This may in part contribute to the increased cost of care seen amongst patients being converted to open, however, as demonstrated in our matched subset analysis, cost increases associated with conversion continued to persist amongst patients undergoing surgery within 48 h, those discharged within 48 h of surgery, or both.

As expected, patients treated at institutions performing a larger volume of laparoscopic cholecystectomies had the lowest likelihood of conversion. This volume-outcome relationship has been previously demonstrated to be true for all facets of surgical care.

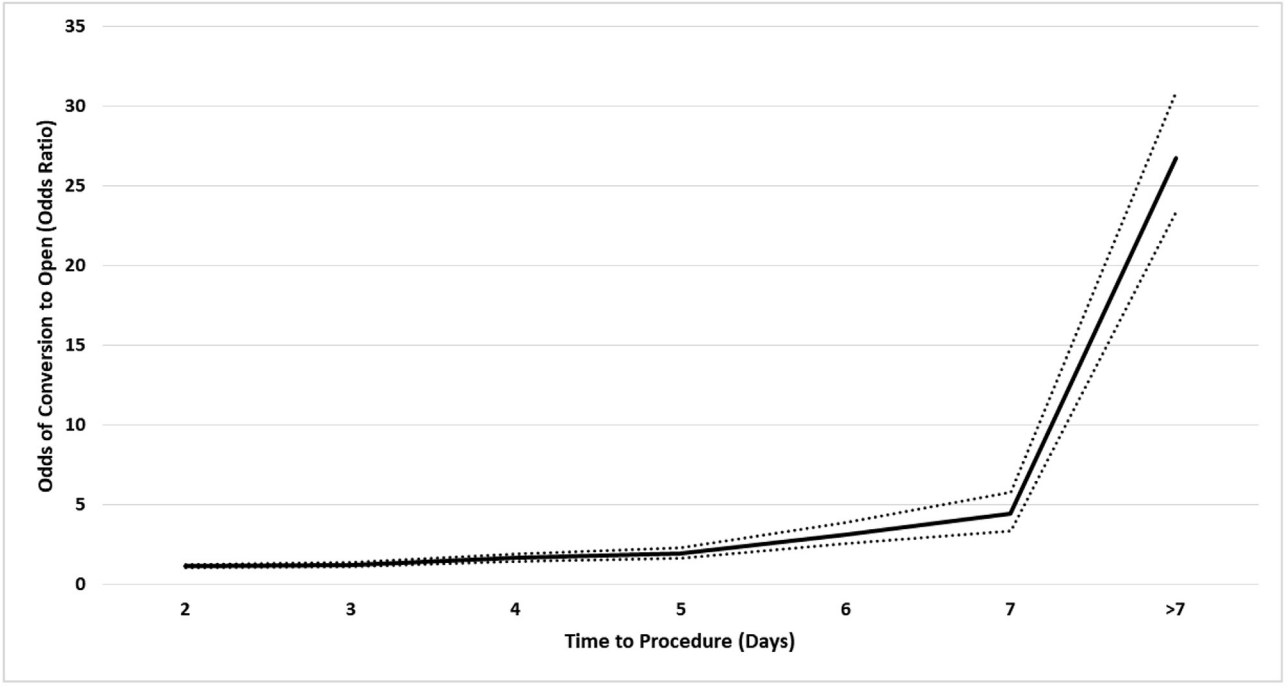


Fig. 1. Odds of conversion to an open procedure with each day's delay in surgery.

Table 4
Risk adjusted costs per index hospitalization for laparoscopic cholecystectomy and conversion to open, with subset analyses to determine risk adjusted costs per index hospitalization for laparoscopic cholecystectomy and conversion to open amongst (i) patients undergoing surgery within 48 h of presentation, (ii) those discharged within 48 h, and (iii) those undergoing surgery within 48 h followed by discharge within 48 h.

	Overall (n = 225,805)	Procedure Performed within 48 h (n = 156,501)	Length of Stay ≤48 h (n = 103,483)	Procedure Performed within 48 h with LOS ≤48 h (n = 90,189)
		Cost ($ [95% Confidence Interval])		
Laparoscopic Approach	10,026 [10,011–10,041]	9680 [9663–9697]	8489 [8470–8508]	8670 [8650–8690]
Conversion to Open	36,029 [34,571–37,486]	25,369 [24,220–26,517]	13,680 [12,103–15,257]	11,900 [10,705–13,096]
Percentage Increase	*259%*	*162%*	*61%*	*37%*

Adjusted for: propensity score quintiles, hospital location, teaching status, geographical location, hospital volume, and mortality.
Propensity scores accounted for differences in patient-level: age, sex, race/ethnicity, income quartile, year of admission, Charlson Comorbidity Index and insurance status.
All costs adjusted to 2018 US dollars using consumer price indices for the corresponding year.

Additionally, urban centers were seen to have lower rates of conversion, however interestingly, patients treated at teaching institutions had a higher likelihood of conversion. Although care at teaching hospitals has historically been demonstrated to be associated with better outcomes,[21] it is difficult to determine if the presence of surgical trainees confers an increased likelihood to conversion and warrants further study. The presence of surgical trainees is associated with increased operative time for routine procedures, however, this has not been linked to poor surgical outcomes.[22,23] The authors of this study believe that increased operative time should not be construed as a reason to convert to OC if progress is being made when surgical trainees are involved. Additionally, we did not find a 'weekend effect' to influence conversion to open as has been previously reported for operative procedures conducted on weekends.[24,25]

The likelihood of conversion has not diminished over the years as demonstrated by this study. In fact, it has remained stable over time. It also demonstrates that even though the odds of conversion increase surreptitiously, if the procedure is delayed more than a week, the cost increases associated with conversion are seen much earlier in patients from delayed intervention. This phenomenon was previously demonstrated by Schwartz and colleagues wherein significant cost increases were seen with each day surgery was delayed.[26] Zafar et al. additionally noted that early operative intervention (within 48 h of presentation) was associated with the best outcomes in patients with acute cholecystitis.[27] This study of a nationally representative cohort demonstrates, as Lengyel et al..[8,10] alluded to in the past, that conversion to open from a laparoscopic procedure confers significant risks as well as cost increases. Prolonged laparoscopic time due to difficult anatomy and associated dissection should not be interpreted as a need to electively convert if progress is being made, unless deemed appropriate for patient safety.[10] Furthermore, delaying surgery ultimately allows the inflammatory process to persist and lends to a hostile operative field making conversion to open more likely. Ashfaq et al. reported on their experience with the "difficult gallbladder" noting that LC

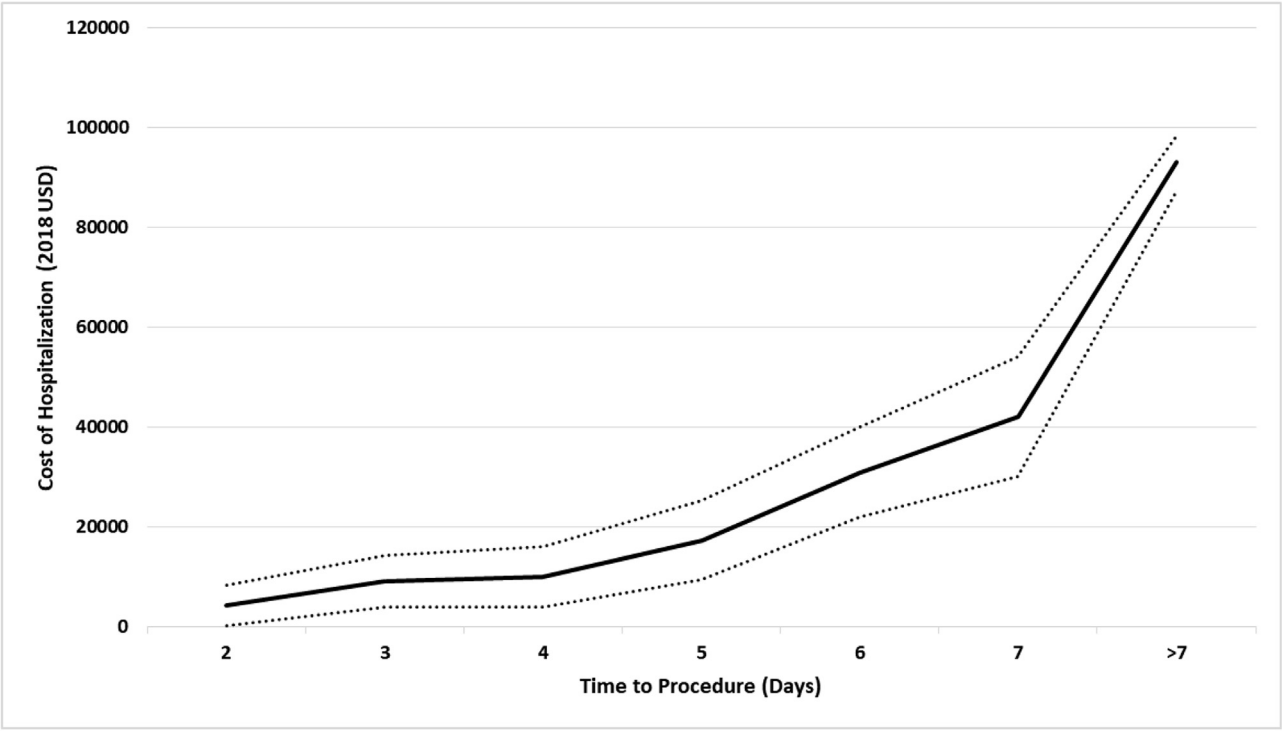
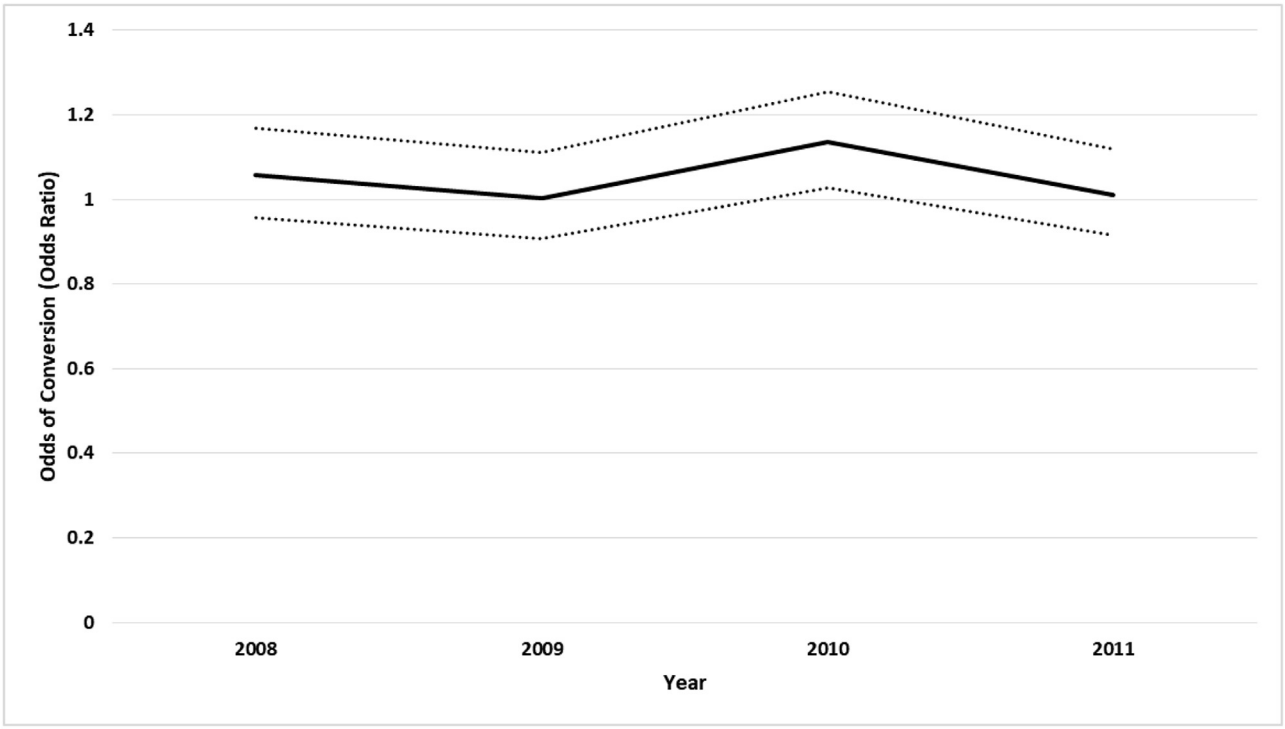


Fig. 2. Cost increases with each day's delay in surgery amongst patients undergoing conversion to an open procedure.



*LC: Laparoscopic cholecystectomy; OC: Open cholecystectomy

Fig. 3. Odds of conversion from LC to OC over the years (reference: 2007). *LC: Laparoscopic cholecystectomy; OC: Open cholecystectomy.

could be safely completed in such patients with an associated increased operative time but no increase in morbidity or mortality.[16]

The study is limited in its use of an administrative dataset to study the US patient population. The NIS is the largest all-payer database of US patients and hospitals and allows for evaluation of assessment of national effects, however it lacks important clinical and biological data that can be included during risk-adjustment. Furthermore, given the nature of the database, information regarding surgeon experience or expertise could not be obtained. Information on patient access to care was similarly not possible to glean from the available data, making it difficult to determine whether a delayed presentation to the hospital leading to a more severe disease presentation was partly responsible in those

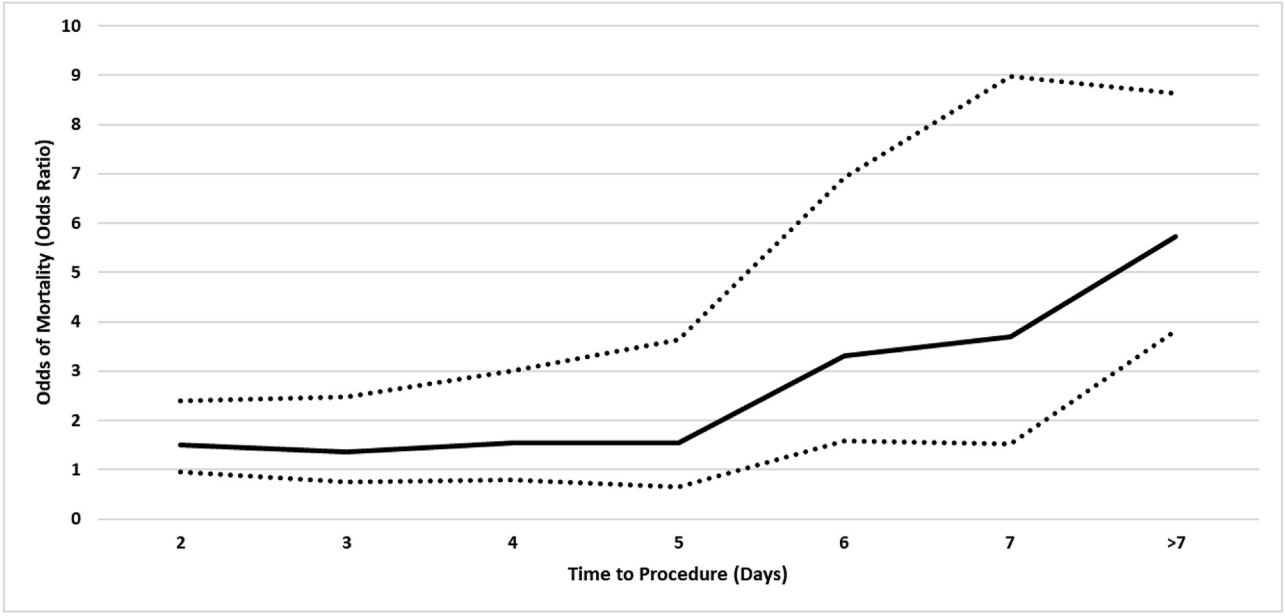


Fig. 4. Odds of mortality with each days delay to operative intervention amongst patients undergoing conversion to open.

patients undergoing conversion to open. An additional limitation was the inability to glean length of operation due to a lack of operative details available, directly or indirectly, from within the dataset. Similarly, it was difficult to determine the occurrence of specific intraoperative complications that led to conversion to an open procedure.

The results of this analysis on a nationally representative patient sample suggest conversion from LC to OC is associated with a significant increase in cost of hospitalization. Delaying surgical intervention in patients presenting with acute cholecystitis only serves to increase the risk of conversion. Race/ethnicity and insurance status appear to imply a higher likelihood of conversion, adding to a growing body of literature delineating surgical disparities. It is the opinion of the authors of this study that in this era of intimate familiarity with laparoscopy as part of surgical training, efforts at continuing a cholecystectomy to conclusion laparoscopically should be made prior to converting to open if deemed safe and if sufficient operative headway is being made. However, further study may be warranted to test this claim. The authors hope that the results of this study will aid surgical decision making intraoperatively when faced with a difficult gallbladder.

Author contributions

AAS, TMF, GW, DT, MW and EEC were involved in conceptualization and developing a research hypothesis. AAS, UFB, GW, MP and WN were involved in data collection and analysis. AAS, UFB, MP, GW and WN contributed to writing the manuscript. MW, MP, DT, EEC and TMF provided critical feedback in finalizing the manuscript. All authors reviewed the manuscript and have provided their approval for submission.

Conflicts of interest

The authors have no conflicts of interest or disclosures to report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2018.12.038.

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