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Patient and hospital factors influence surgical approach in treatment of acute cholecystitis

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Abstract

Background Minimally invasive (MIS) cholecystectomies have become standard due to patient and hospital advantages; however, this approach is not always achievable. Acute and gangrenous cholecystitis increase the likelihood of conversion from MIS to open cholecystectomy. This study aims to examine patient and hospital factors underlying differential utilization of MIS vs open cholecystectomies indicated for acute cholecystitis.

Methods This is a retrospective, observational cohort study of patients with acute cholecystitis who underwent a cholecystectomy between 2016 and 2018 identified from the California Office of Statewide Health Planning and Development database. Univariate analysis and multivariable logistic regression models were used to analyze patient, geographic, and hospital variables as well as surgical approach.

Results Our total cohort included 53,503 patients of which 98.4% (n = 52,673) underwent an initial minimally invasive approach and with a conversion rate of 3.3% (n = 1,759). On multivariable analysis advancing age increased the likelihood of either primary open (age 40 to < 65 aOR 2.17; ≥ 65 aOR 3.00) or conversion to open cholecystectomy (age 40 to < 65 aOR 2.20; ≥ 65 aOR 3.15). Similarly, male sex had higher odds of either primary open (aOR 1.70) or conversion to open cholecystectomy (aOR 1.84). Hospital characteristics increasing the likelihood of either primary open or conversion to open cholecystectomy included teaching hospitals (aOR 1.37 and 1.28, respectively) and safety-net hospitals (aOR 1.46 and 1.33, respectively).

Conclusions With respect to cholecystectomy, it is well-established that a minimally invasive surgical approach is associated with superior patient outcomes. Our study focused on the diagnosis of acute cholecystitis and identified increasing age as well as male sex as significant factors associated with open surgery. Teaching and safety-net hospital status were also associated with differential utilization of open, conversion-to-open, and MIS. These findings suggest the potential to create and apply strategies to further minimize open surgery in the setting of acute cholecystitis.

Keywords Acute cholecystitis · Minimally invasive cholecystectomy · Cholecystectomy · Surgical utilization · Hospital volume · Teaching hospital

Minimally invasive (MIS) cholecystectomies, in particular laparoscopic cholecystectomies are the preferred surgical approach for the management of acute cholecystitis. From 2003 to 2014 the rate of open total cholecystectomy decreased from 27.8% to 13.1% in patients with acute cholecystitis while laparoscopic total cholecystectomies increased from 71.9% to 86.0% and laparoscopic-to-open conversions decreased from 10.5% to 7.6% [1]. Compared to laparoscopic cholecystectomies, open cholecystectomies are associated with increased 30-day morbidity, 30-day mortality, surgical site infections, wound dehiscence, pneumonia, and length of stay [2, 3]. Similarly, compared to laparoscopic cholecystectomies, laparoscopic-converted-to-open cholecystectomies have increased 30-day morbidity, surgical site infections, sepsis, and length of stay [3, 4]. Even from an economic perspective there is an advantage to laparoscopic surgery. For example, laparoscopic-converted-to-open cholecystectomies compared with laparoscopic

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cholecystectomies with significantly long operative times are still associated with a 3 day longer length of stay and a 35% increase in hospital charges ($23,946 vs. $32,446; $p < 0.01$) despite lower operating room charges [5].

Despite the benefits of MIS cholecystectomies, this approach is not achieved. Some patients undergo open cholecystectomy initially (primary open cholecystectomy) while others undergo laparoscopic converted to open. A diagnosis of acute and gangrenous cholecystitis, age greater than 40 years, and male sex are all associated with higher incidence of conversion to open cholecystectomy[3, 6] In line with other surgical procedures, there is a volume-outcome relationship for cholecystectomy. One Swedish study reported higher conversion rates for low volume surgeons and higher complications for low volume hospitals [7]. In contrast, high volume hospitals in Scotland were more likely to perform non-elective cholecystectomies and complete more cholecystectomies laparoscopically [8].

This study aims to examine patient and hospital factors underlying differential utilization of MIS cholecystectomies versus open cholecystectomies (primary or converted) indicated for acute cholecystitis using a California Office of Statewide Health Planning and Development (OSHPD; now referred to as the Department of Health Care Access and Information [HCAI]) administrative database.

Materials and methods

Study design

This study is an observational cohort study from data collected from the OSHPD database. The OSHPD collects patient data from nearly 7,000 licensed healthcare facilities in California [9]. Patient data includes patient-level administrative data such as patient discharge data and emergency department data as well as healthcare facility attributes and financial data [10].

We searched the OSHPD database between 2016 and 2018 for patients greater or equal to 18 years of age with a primary diagnosis of acute cholecystitis (ICD-10 codes K80.00, K80.01, K81.0, K81.2, K80.12, K80.13, K82.A1, and K82.A2) who underwent a cholecystectomy (ICD-10 procedure codes 0FB44ZX, 0FB44ZZ, 0FB43ZX, 0FB48ZZ, 0FT40ZZ, 0FT44ZZ, 0FD43ZX, 0FD44ZX, 0FD48ZX). Patients with missing data were excluded. Patients not admitted through the emergency department were also excluded. See Fig. 1 for flow diagram.

Patient population and cohort definitions

Patient, geographic, and hospital characteristics were extracted from the OSHPD database. Patient characteristics included race/ethnicity, insurance payor, age, and sex.

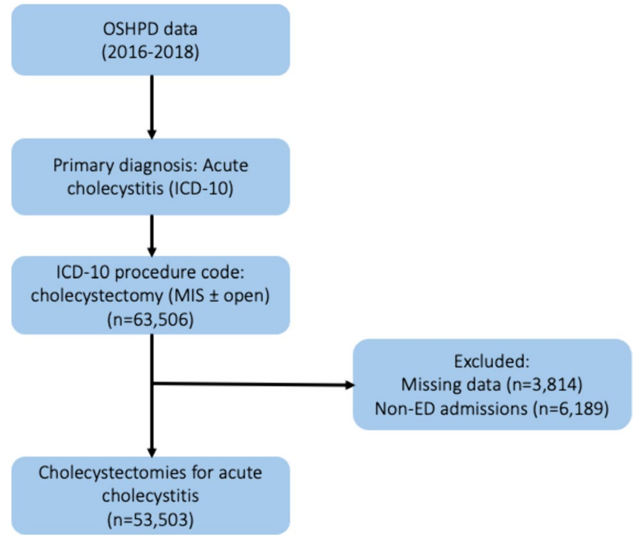

Fig. 1 Flow diagram of database patients. *OSHPD* office of statewide planning and development, *ICD* international classification of disease, *MIS* minimally invasive surgery, *ED* emergency department

Several zip-code-level variables were considered from the American Community Survey by the US Census bureau to capture socioeconomic status, acculturation, and education. These variables included: median income in the patient's census tract, bilingual status of census tract (defined as more than 50% of adults speaking a language other than English in their household), percentage of the population living below the 200 percent poverty threshold in the patient's census tract, and percentage with a bachelor's degree or higher. There was significant multicollinearity between the variable of median income and the other variables including < 200 percent poverty (correlation coefficient, $r = -0.79$) and percentage with bachelor's degree or higher (correlation coefficient, $r = 0.76$). There was no significant collinearity between bilingual status and median income (correlation coefficient, $r = -0.11$), and therefore these two variables (median income and bilingual status) were included in the final model.

Hospital characteristics deemed relevant included hospital size, hospital control (ownership), surgery volume, and presence of resident physicians and were captured from hospital financial annual report data. Collinearity was assessed within each category for both hospital size and surgery volume given multiple variables. One variable from each category was chosen based on clinical judgement and collinearity results. Collinearity of final variables was assessed a second time. Final variables included: number of licensed beds and presence of any resident. Hospital control was deemed clinically significant. Data was then linked to OSHPD data by facility ID.

Of the included patients, three distinct cohorts were identified: minimally invasive cholecystectomy (either laparoscopic or robotic; MIS), primary open cholecystectomy (patients whose cholecystectomy was started open; OC), and MIS-converted-to-open cholecystectomy (CONV). CONV patients were identified as those having ICD-10 procedure codes for both minimally invasive and open cholecystectomies.

Hospital volume was stratified into quartiles based on cholecystectomy volume performed within our total patient cohort.

Cohort comparisons

Patient, geographic, and hospital variables were compared between (1) the MIS and CONV combined cohort and OC cohort, (2) the MIS and CONV cohorts, and (3) the OC and CONV cohorts.

Patient, geographic, hospital variables as well as surgical approach were compared by (1) teaching hospital status, (2) safety-net status, and (3) highest and lowest hospital volume quartiles.

Statistical analysis

All relevant patient characteristics (race/ethnicity, insurance payor, age, sex), geographic characteristics (zip-code income, residence in a bilingual zip-code, and residence in a zip-code with less than median PCP ratio), hospital characteristics (hospital size, hospital control, safety-net status, and teaching hospital status), and surgical approach (MIS, primary open, and conversion to open) were included in univariate analysis. Chi-squared and Wilcoxon rank sum tests were used to analyze categorical and median data, respectively. Kruskall-Wallis was used to analyze median data in Table 1 which compared all three surgical approach cohorts. Multivariable logistic regression models were used to analyze patient, geographic, and hospital variables as well as surgical approach using a cutoff p-value less than 0.20. All patient, geographic, and hospital characteristics were included in multivariable logistic regression for analysis of primary open cholecystectomy patients versus conversion patients.

Results

We identified a total of 53,503 patients who underwent a cholecystectomy for acute cholecystitis from 2016 to 2018. Most cholecystectomies were completed via MIS or CONV (98.4%, n = 52,673) with a conversion rate of 3.3% (n = 1759). A total of 1.6% (n = 830) of patients underwent a primary open cholecystectomy. See Table 1 for patient, geographic, and hospital characteristics by surgical approach for acute cholecystitis.

On multivariable analysis of patient, geographic, and hospital characteristics between MIS or CONV patients versus OC patients, age ≥ 40 ($p < 0.001$), and male sex ($p < 0.001$), safety-net status ($p < 0.001$), and teaching hospital ($p < 0.001$) were positive predictors of OC. Patients with Medicare were 1.34 times more likely (95% CI [1.04–1.73]) to have an OC than those with private insurance. As age increased above 40 years, patients had higher odds of OC (age 40 to < 65 aOR 2.17 95% CI [1.76–2.68]; age $\geq$ 65 aOR 3.00 95% CI [2.23–4.02]). Decreasing hospital cholecystectomy volume did not demonstrate a direct trend of higher odds of OC, however compared to the hospitals with the highest quartile cholecystectomy volume, those with the lowest quartile cholecystectomy volume had higher odds of OC (aOR 1.45 95% CI [1.19–1.76]).

Similarly, on multivariable analysis of MIS versus CONV patients, age ≥ 40 ($p < 0.001$), male sex ($p < 0.001$), safety-net status ($p < 0.001$), and teaching hospital ($p < 0.001$) were positive predictors of CONV. Patients with Medicare had a higher aOR of 1.20 (95% CI [1.01–1.44]) of undergoing a CONV than those with private insurance. A trend in increased CONV was seen with increasing age (age 40 to < 65 aOR 2.20 95% CI [1.90–2.54]; age $\geq$ 65 aOR 3.15 95% CI [2.57–3.86]). Compared to the hospitals with the highest quartile cholecystectomy volume, those with the lowest quartile cholecystectomy volume had higher odds of CONV (aOR 1.36 95% CI [1.18–1.55]).

Of note, no patient or geographic characteristics were statistically significantly different between OC and CONV patients. See Fig. 2 for complete multivariable analysis of predictors between surgical approaches (including MIS compared to OC or CONV).

Subgroup multivariable analysis of teaching and safety-net status as well as hospital cholecystectomy volume was performed to determine their effect on surgical approach (see Fig. 3). Compared to non-teaching hospitals, teaching hospitals had higher odds of performing OC and CONV (aOR 1.38 95% CI [1.17–1.64] and aOR 1.23 95% CI [1.10–1.38], respectively). Safety-net hospitals were also more likely to perform OC and CONV compared to non-safety-net hospitals (aOR 1.50 95% CI [1.24–1.83] and aOR 1.29 95% CI [1.13–1.48], respectively). When compared with the highest quartile of cholecystectomy volume, the lowest quartile hospitals had higher odds of performing OC and CONV (aOR 1.76 95% CI [1.28–2.42] and aOR 1.46 95% CI [1.19–1.80]).

Table 1 Patient, geographic, and hospital characteristics by surgical approach

Characteristic	Total	MIS (%)	OC (%)	CONV (%)	p-value
	53,503 (100.0)	50,914 (95.2)	830 (1.6)	1,759 (3.3)	
Patient characteristics					
Race/Ethnicity, N†					p < 0.001
White	18,078 (33.8)	17,102 (33.6)	319 (38.4)	657 (37.4)	
Hispanic	26,938 (50.4)	25,759 (50.6)	374 (45.1)	805 (45.8)	
Black or African American	2,091 (3.9)	1,976 (3.9)	43 (5.2)	72 (4.1)	
Asian/Pacific Islander	4,017 (7.5)	3,784 (7.4)	64 (7.7)	169 (9.6)	
Other	2,379 (4.4)	2,293 (4.5)	30 (3.6)	56 (3.2)	
Insurance, N†					p < 0.001
Private	16,536 (30.9)	15,873 (31.2)	199 (24.0)	464 (26.4)	
Medicare	12,482 (23.3)	11,482 (22.6)	325 (39.2)	675 (38.4)	
Medicaid	21,697 (40.6)	20,882 (41.0)	277 (33.4)	538 (30.6)	
Self-Pay	1,540 (2.9)	1,485 (2.9)	11 (1.3)	44 (2.5)	
Other	1,248 (2.3)	1,192 (2.3)	18 (2.2)	38 (2.2)	
Age†					p < 0.001
< 40 years	17,631 (33.0)	17,246 (3.9)	124 (14.9)	261 (14.8)	
≥ 40 years, < 65 years	23,232 (43.4)	22,068 (43.3)	372 (44.8)	792 (45.0)	
≥ 65 years	12,640 (23.6)	11,600 (22.8)	334 (40.2)	706 (40.1)	
Sex, (Male) N†	19,605 (36.6)	18,203 (35.8)	441 (53.1)	961 (54.6)	p < 0.001
Geographic characteristics					
Zip-code income§, median [IQR]	$66,253 [$52,330, $86,415]	$66, 253 [$52,330, $86,415]	$64,058 [$50,155, $85,975]	$66,498 [$51,516, $88,034]	p = 0.0395
Bilingual zip-code¶, N†	18,006 (33.6)	17,139 (33.7)	283 (34.1)	584 (33.2)	p = 0.889
PCP ratio# below median, N†	31,993 (59.8)	30,366 (59.6)	530 (63.9)	1,097 (62.4)	p = 0.004
Hospital characteristics					
Hospital control, N†					p < 0.001
Investor	9,629 (18.0)	9,075 (17.8)	155 (18.7)	399 (22.7)	
County/city	5,352 (10.0)	5,064 (10.0)	110 (13.2)	178 (10.1)	
Non-profit	36,304 (67.8)	34,680 (68.1)	517 (62.3)	1,107 (62.9)	
District	2,218 (4.2)	2,095 (4.1)	48 (5.8)	75 (4.3)	
Hospital size (licensed beds), median [IQR]	343 [212, 456]	343 [212, 456]	345 [207, 456]	347 [209, 456]	p = 0.4128
Safety-net status, (yes) N†	13,465 (25.2)	12,715 (25.0)	262 (31.6)	488 (27.7)	p < 0.001
Teaching hospital, (yes), N†	23,516 (44.0)	22,276 (43.8)	412 (49.6)	828 (47.1)	p < 0.001
Cholecystectomy volume†					p < 0.001
Quartile #1 (highest)	13,256 (24.8)	12,658 (24.7)	195 (23.5)	403 (22.9)	
Quartile #2	13,308 (24.9)	12,819 (25.2)	147 (17.7)	342 (19.4)	
Quartile #3	13,513 (25.3)	12,855 (25.2)	210 (25.3)	448 (25.5)	
Quartile #4 (lowest)	13,426 (25.1)	12,582 (24.7)	278 (33.5)	566 (32.2)	

MIS minimally invasive surgery, *OC* primary open cholecystectomy, *CONV* conversion from MIS to OC, *ED* emergency department, *IQR* interquartile range, *PCP* primary care physician

†Percentages for represent column percentages with denominators shown at the top of each column

§Median income in the patient's zip-code

¶Bilingual status defined as > 50% of zip-code speaking a language other than English

#Ratio of the total population to the number of PCPs in the patient's county

Discussion

Minimally invasive surgery, particular laparoscopy, is the favored approach for cholecystectomy in the setting of acute cholecystitis due to its superior patient outcomes and decreased hospital costs. However, a subset of MIS cholecystectomies continues to be converted to open surgery due to safety concerns. To decrease these risks altogether,

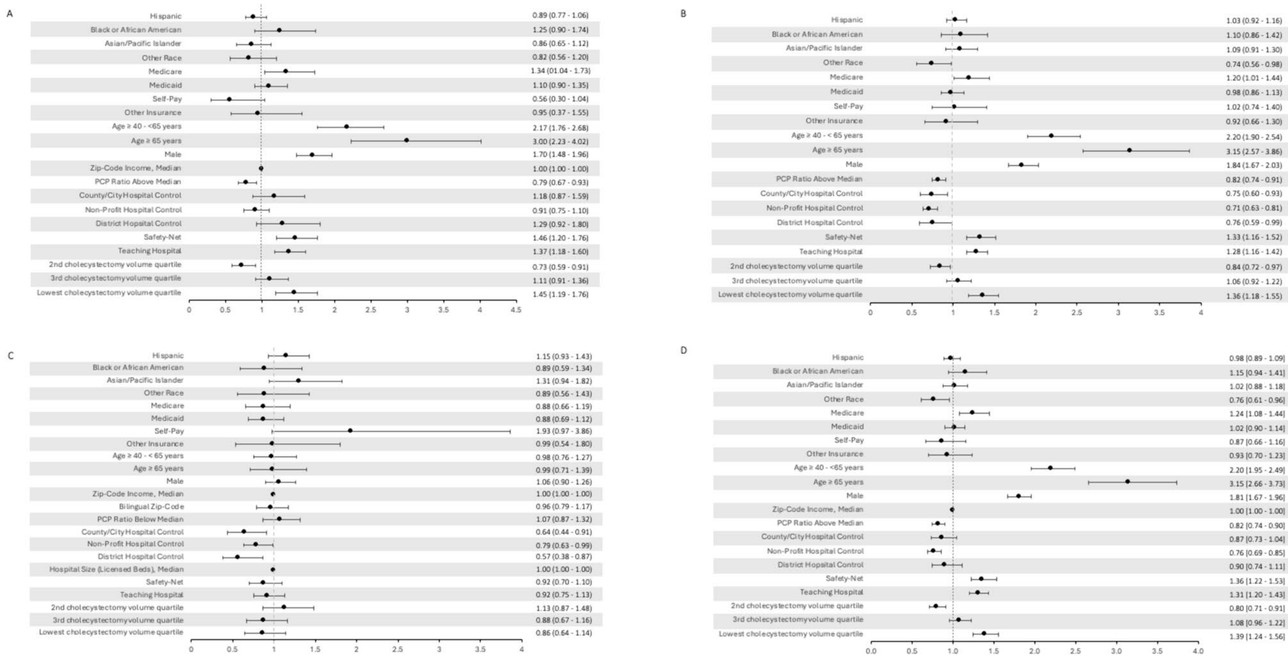

Fig. 2 Multivariable analysis of predictors between surgical approaches; **A** MIS + CONV compared to OC; **B** MIS compared to CONV; **C** OC compared to CONV (all characteristics included in multivariable analysis; **D** MIS compared to OC + CONV

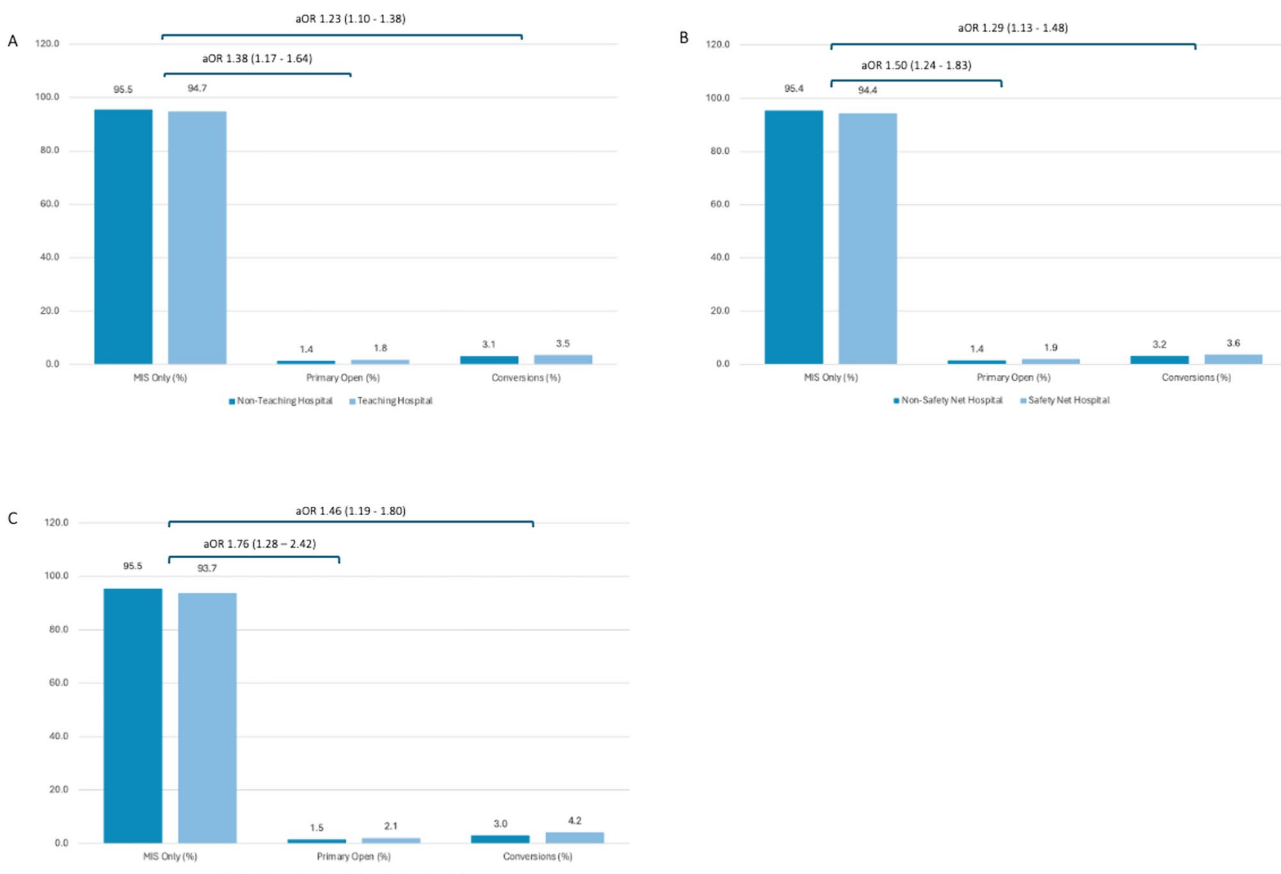

Fig. 3 Multivariable analysis of surgical approach by teaching status (**A**), safety-net status (**B**), and highest quartile compared to lowest quartile cholecystectomy volume hospital (**C**)

some surgeons choose to start a cholecystectomy open from the onset. In an effort to reduce the incidence of OC and CONV, we evaluated patient, geographic, and hospital characteristics associated with OC and CONV.

In the present study, there were strong patient and hospital characteristics predictive of both OC and CONV. With respect to patient level factors, we found that male sex and advancing age increased the likelihood of both OC and CONV. Importantly, our study is consistent with previous studies indicating that older patients and those of male sex are more likely to undergo an OC or CONV [6, 11, 12]. These same characteristics—increasing age and male sex—are also known risk factors for more advanced acute cholecystitis pathology such as gangrenous, emphysematous, and perforated cholecystitis [13–16]. Unfortunately, ICD-10 codes for gangrenous and perforated cholecystitis were not available during study period and therefore could not be consistently applied across our data.

When evaluating hospital characteristics associated with surgical approach, we found that patients presenting to teaching hospitals or safety-net hospitals were more likely to undergo both OC and CONV than those presenting to non-teaching hospitals or non-safety-net hospitals. It is unclear what the relationship is between teaching status and these outcomes. Rather than speculate on this finding, we feel more granular research into patient pathology and comorbidities, and the decision-making processes and hospital staffing in the management of acute cholecystitis is advantageous. Consistent with the volume outcome relationship present in other surgical procedures, we found that lower cholecystectomy volume hospitals had a higher likelihood of OC and CONV.

Performing the safest operation for the patient remains paramount even if conversion to open is required. In acute cholecystitis, the most commonly reported reasons to convert to open surgery from laparoscopy are inflammation, adhesions, and variant biliary and vascular anatomy [6, 12]. Intraoperative bleeding, Mirizzi syndrome, and bile duct injury are less common causes [12]. There has been a strong effort led by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) to improve the safety of cholecystectomies while reducing conversions by ensuring identification of critical anatomy by obtaining the critical view of safety [17]. Recent developments in artificial intelligence (AI) have allowed for systems to sense safe and dangerous zones of dissection during laparoscopic cholecystectomies which further enable the surgeon to confidently to obtain the critical view of safety [18–20]. However, these AI systems are not widely available at this time.

Robotic-assisted laparoscopic surgery is another technology with expanding adoption within the acute setting, demonstrating a 37-fold increased use for cholecystectomies from 2010 to 2019 [21]. Support and research for robotic-assisted surgery has been controversial. A narrative review of robotic versus laparoscopic cholecystectomy for benign gallbladder disease demonstrated no difference in length of stay, surgical site admissions, or re-admissions, however did report longer operating times [22]. A retrospective study by Gangemi, et al. reported significantly lower conversion rates for robotic-assisted cholecystectomies compared to laparoscopic cholecystectomies when paired by demographic data. This suggests the ability of robotic-assisted surgery to decrease the impact of demographic risk factors such as age and sex on conversion rates [6].

There are several limitations to this study. First, the OSHPD administrative database was used to obtain data and thus our data may contain inaccurate or incomplete patient diagnoses or procedure coding. It is also unable to capture specific patient clinical comorbidities and data that may contribute to the higher OC and CONV rates seen in our male and age ≥ 40 cohorts. Second, we were unable to determine the severity of acute cholecystitis with the ICD-10 codes available from 2016 until 2018. Modifier codes which provide details of the extent of disease such as K82.A1 and K82.A2 for gangrene and perforation of the gallbladder, respectively, in the setting of cholecystitis were not available until 2019 [23]. We did ultimately have 8 patients with these modifier codes (K82.A1 or K82.A2). We suspect this is from retroactive application of the codes to the dataset once the codes became available. Lastly, federal hospitals are not included within the OSHPD database and thus Veterans Affairs hospitals which have predominantly older, male patients, were excluded.

Despite these limitations, our data is unique in that it focuses not only on patient factors, but also geographic and hospital factors which impact surgical approach, specifically in the acute cholecystitis population. We understand that surgical decision-making is often affected by factors beyond patient characteristics. Consistent with previous data, we demonstrated that older age and male sex are associated with higher odds of both primary open cholecystectomy or conversion to open cholecystectomy. Regarding external factors impacting patient care, in our acute cholecystectomy population, surgical approach was affected by teaching hospital and safety-net hospital status as well as low cholecystectomy volume. If a patient presented to the emergency department at these hospitals they were more likely to undergo either a primary open cholecystectomy or conversion to open cholecystectomy.

Future research should assess the management strategy of cholecystectomy for high-risk patients (older patients and male sex) in the setting of biliary colic or symptomatic cholelithiasis, the decision-making processes and hospital staffing at teaching and safety-net hospitals, as well as the adoption of newer technologies, such as AI guidance and robot-assistance.

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Declarations

Disclosures Tess C Huy, MD, Rivfka Shenoy, MD, Mark Girgis, MD, James S Tomlinson, MD, PhD, and Marcia M Russell, MD have no conflicts of interest or financial ties to disclose.

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