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ORIGINAL SCIENTIFIC REPORT

Predicting Conversion from Laparoscopic to Open Cholecystectomy: A Single Institution Retrospective Study

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Abstract

Background Laparoscopic cholecystectomy (LC) is the standard surgical treatment for benign gallbladder disease. Nevertheless, conversion to open cholecystectomy (OC) is needed in some cases. The aim of this study is to calculate our institutional conversion rate and to identify the variables that are implicated in increasing the risk of conversion (LC–OC).

Materials and methods We carried out a retrospective study of all cases of LC performed at the American University of Beirut Medical Center between 2000 and 2015. Each (LC–OC) case was randomly matched to a laparoscopically completed case by the same consultant within the same year of practice, as the LC–OC case, in a 1:5 ratio. Forty-eight parameters were compared between the two study groups.

Results Forty-eight out of 4668 LC were converted to OC over the 15-year study period; the conversion rate in our study was 1.03%. The variables that were found to be most predictive of conversion were male gender, advanced age, prior history of laparotomy, especially in the setting of prior gunshot wound, a history of restrictive or constrictive lung disease and anemia (Hb < 9 g/dl). The most common intraoperative reasons for conversion were perceived difficult anatomy or obscured view secondary to severe adhesions or significant inflammation. Patients who were in the LC–OC arm had a longer length of hospital stay.

Conclusion Advance age, male gender, significant comorbidities and history of prior laparotomies have a high risk of conversion. Patients with these risk factors should be counseled for the possibility of conversion to open surgery preoperatively. Further research is needed to determine whether these high risks patients should be operated on by surgeons with more extensive experience in minimal invasive surgery.

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Introduction

Laparoscopic cholecystectomy (LC) has become the gold standard treatment for benign gall bladder disease since it was first introduced by Mouret in 1987 [1]. LC has gradually replaced open surgical treatment to become one of the most common surgical procedure performed worldwide [2, 3]. The advantages of LC demonstrably outweigh the open technique and are associated with a significantly shorter hospital stay, a quicker convalescence, less postoperative pain and better cosmetic outcomes [4–8]. However, there are no significant differences related to the incidence of bile duct injuries and overall mortality [5].

Cholecystectomies that cannot be completed laparoscopically necessitate conversion to open surgery. This has been attributed to a number of reasons including, but not limited to, technical difficulty related to unclear anatomy [9] or extensive adhesions [10, 11]. Other factors reported to increase the risk of conversion include male gender, emergency admission, old age, morbid obesity, liver cirrhosis, portal hypertension, previous upper abdominal surgery and chronic gallbladder disease [10–12]. Moreover, the skills and the experience of the surgeon have been shown to be an independent risk factor for conversion [13–16]. There is a wide variation in the rate of conversion to OC reported in the literature; however, the accepted rate ranges from 2 to 15% [10, 17, 18]. Predicting the risk of conversion with a degree of confidence should help the surgeon to plan the operation and consent patients accordingly.

Several prediction models for conversion have been reported; however, none have been widely integrated into clinical practice because of perceptions regarding shortcomings in methodological approaches and the heterogeneity and impracticality of the models [8, 19–24]. The objective of our study is to determine independent risk factors for conversion from LC to OC (LC–OC). A secondary aim is to compare clinical outcomes between patients in the LC arm compared to those in the LC–OC arm.

Materials and methods

Study design

Between the years 2000 and 2015, all adult patients above the age of 18 who underwent LC for benign gall bladder disease, performed at the American University of Beirut Medical Center (AUBMC), were retrospectively reviewed. Patient charts were accessed through the AUBMC Health Information System (HIS), which is an in-house electronic medical record database that was established in 2007; the data of patients admitted from the years 2000 till 2008 were collected from their paper charts. Institutional review board (IRB) approval was obtained, and consent was waived based on de-identification of patients.

As reported in the literature [16, 19, 20], the surgeon's experience is an important factor in determining the rate of conversion [13–15]. Determining the disease and morbidity related risk factors for conversion necessitated limiting the confounding effect attributed to the surgeon's experience. This was controlled by selecting cases performed by surgeons with at least 5 years of experience at a consultant level and by matching every converted case to five randomly selected laparoscopically completed cases, by the same surgeon within the same year of the LC–OC case. Although most references recommend a 1:4 matching ratio, we have opted to consider a 1:5 ratio to further increase the sample size and compensate for the loss of power due to the small number of conversions. Increasing the ratio of non-exposed to exposed patients will increase the precision by increasing the sample size [25].

Patients who had a hepatobiliary malignancy, had their cholecystectomy as part of another procedure or could not tolerate pneumoperitoneum were excluded from the study.

LCs were performed with the standard 4-port technique, and cystic arteries and ducts were triply clipped using 10 mm or 5 mm endoclips and divided. Intraoperative cholangiogram (IOC) was performed based on surgeon preference and the patient-specific indications. The open technique was performed with the standard right subcostal Kocher incision and the gallbladder removed in the anterograde manner. All surgeries were performed by the consultant surgeon or by a senior resident with the assistance of the consultant surgeon.

Study variables

A retrospective analysis of 48 variables was performed including demographics, clinical findings, imaging results, laboratory analyses, intraoperative findings and postoperative admission status and length of hospital stay.

Demographic variables included age, gender, body mass index (BMI), the American Society of Anesthesiology (ASA) class, functional status, smoking, history of prior abdominal surgery and concomitant systemic disease (cardiac, renal, respiratory, oncological etc.). The cutoff

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values for alkaline phosphatase, alanine transaminase, aspartate transaminase, γ-glutamyl transferase, amylase and lipase were chosen to be double the normal values and set at 250, 130, 100, 100, 200 and 120 IU/l, respectively. The cutoff value for total and direct bilirubin was 2 and 0.6 mg/dl, respectively. Hemoglobin level was categorized into three groups with levels more than 12 g/dl, level between 9 and 12 mg/dl and less than 9 mg/dl. A cutoff level of 1.5 was chosen for international normalized ratio (INR), while a 1.5-fold increase above normal was chosen for creatinine level. Preoperative variables included admission status (emergency inpatient or patient already in the intensive care or medical ward), admission diagnosis (cholelithiasis, cholecystitis, gallstone pancreatitis and cholangitis), septic state, ultrasound findings (gall bladder wall thickness, presence of impacted stone, pericholecystic fluid) and endoscopic findings (endoscopic ultrasound (EUS) and/or Endoscopic Retrograde Cholangiopancreatography (ERCP)), if done preoperatively.

Operative variables included operative time, intraoperative cause of conversion as mentioned by the surgeon in the operative report including anatomical difficulty, extensive bleeding and common bile duct (CBD) stone/exploration.

Postoperative variables included postoperative admission status (regular floor versus the intensive care unit), 30-day mortality and postoperative complications.

Statistical analyses

Data were entered into the Statistical Package for Social Sciences (SPSS, version 24), which was used for data cleaning, management and analyses. Categorical variables were summarized as numbers and percentages, whereas continuous variables were expressed as means and standard deviations. Laboratory values were analyzed using cutoff values that have been validated in previous studies [26]. The association between the conversion group and other categorical variables was determined by using the Chi-square test, whereas Student's t test was used for the association with continuous variables. Multivariate analysis was carried out to adjust for potentially confounding variables. More specifically, the stepwise logistic regression analysis was used to examine the association between the conversion and the different predictors. Results were presented by the odds ratio (OR) and 95% confidence interval (CI). p value < 0.05 was used to indicate statistical significance.

Results

A total of 4668 LC cases were retrieved. A total of 48 cases of LC–OC were identified; however, 2 cases were omitted due to the inability to access their respective charts. Each of the remaining 46 cases was randomly matched to a LC case performed by the same consultant within the same year of practice in a 1:5 ratio. The conversion rate at our institution was calculated as 1.03%.

The majority (80%) of patients who underwent intraoperative conversion were males ($p < 0.0001$) (Table 1). The average age group of patients in the LC–OC was higher than the patients in the LC group (68.35 ± 13.74 vs. 47.72 ± 16.96, $p < 0.0001$), respectively. The LC–OC had a higher rate of comorbidities (Table 1). Furthermore, the LC–OC group had a higher ASA class (ASA3 45.7 vs. 11.8% $p < 0.0001$) than the control group.

Twenty-two out of the 46 patients in the LC–OC group had a prior laparotomy, 48% as opposed to 19.5% in the LC group ($p < 0.04$). All of the patients who had prior laparotomy for gunshot wound (4 out of 4; 100%) and presented for benign gallbladder disease at a later stage needed conversion to OC. This translated to doubling the risk of conversion in this subcategory of patients over those who had a prior explorative laparotomy for other causes.

Seventy-eight percent of the LC–OC group were either patients on the medical ward, in the intensive care unit, or presented through the emergency department while 50% of the LC group had similar admission characteristics and the other 50% were admitted on an elective basis ($p < 0.0001$). There was no difference between the two groups in regard to BMI or smoking history (Table 1).

Patients who had complicated cholecystitis on preoperative imaging (US/CT scan) (e.g. early phlegmon formation or perforated gallbladder) had a higher risk of conversion ($p < 0.0001$). Conversely, ultrasound findings of uncomplicated cholecystitis (wall thickness, pericholecystic fluid, impacted stone) were not found to be variables associated with conversion to open cholecystectomy (Table 1).

The variables shown in Table 1 presented as bivariate analysis were integrated into multivariate analysis as independent variables (Table 2). The variables found to influence the rate of conversion were male gender (OR 0.09, 95% CI 0.03–0.25), age (OR 2.15, 95% CI 1.62–2.85), prior history of abdominal surgery especially GSW (OR 4.66, 95% CI 1.78–12.17), pulmonary disease (OR 6.03, 95% CI 1.21–29.97) and patients with Hemoglobin level less than 9 g/dl (OR 36.57, 95% CI 3.16–423.72).

Indications for conversion included extensive adhesions ($n = 15$, 32.6%), significant inflammation ($n = 17$,

Table 1 Preoperative risk factors for conversion to open cholecystectomy

	LC $N = 230$	LC–OC $N = 46$	p value	OR (95% CI)
Demographics				
Gender			<0.0001	
Male (%)	95 (41.3)	37 (80.4)		Reference
Female (%)	135 (58.7)	9 (19.6)		0.17 (0.08–0.37)
Age (years)	47.72 ± 16.96	68.35 ± 13.74	<0.0001	1.08 (1.05–1.10)
BMI (kg/m^2)	29.70 ± 6.10	30.29 ± 6.56	0.64	1.01 (0.95–1.08)
Smoking	86 (43.9)	27 (58.7)	0.07	1.82 (0.95–3.49)
Functional status				
Independent	227 (98.7)	41 (89.1)	0.004	Reference
Dependent[a]	3 (1.3)	5 (10.9)		9.23 (2.12–40.11)
Duration symptoms (days)			<0.0001	NA
<30	132 (76.3)	44 (100.0)		
≥30	41 (23.7)	0 (0.0)		
Clinical				
ASA class				
1	102 (44.5)	0 (0.0)	<0.0001	Reference
2	100 (43.7)	24 (52.2)		NA
3	27 (11.8)	21 (45.7)		NA
4	0 (0.0)	1 (2.2)		NA
Admission status				
Elective	114 (49.6)	10 (21.7)	0.001	Reference
Inpatient/emergency	116 (50.4)	36 (78.3)		3.54 (1.68–7.47)
History abdominal surgery	43 (19.5)	18 (39.1)	0.004	2.65 (1.34–5.22)
Trauma gunshot	0 (0.0)	4 (8.7)	0.001	NA
Medical comorbidities				
Hypertension	71 (30.9)	35 (76.1)	<0.0001	7.12 (3.42–14.83)
Dyslipidemia	48 (20.9)	26 (56.5)	<0.0001	4.93 (2.54–9.58)
Renal disease[c]	13 (5.7)	12 (26.1)	<0.0001	5.89 (2.48–13.98)
Cardiac disease[d]	27 (11.7)	19 (41.3)	<0.0001	5.29 (2.60–10.77)
Neurological disease[e]	5 (2.2)	5 (10.9)	0.01	5.49 (1.52–19.81)
Liver disease[f]	1 (0.4)	0 (0.0)	1.00	NA
Lung disease[g]	4 (1.7)	10 (21.7)	<0.0001	15.69 (4.67–52.72)
Diabetes mellitus	33 (14.3)	16 (34.8)	0.001	3.18 (1.56–6.48)
Malignancy	6 (2.6)	7 (15.2)	0.002	6.70 (2.14–21.00)
Bleeding disorder	5 (2.2)	6 (13.0)	0.004	6.75 (1.97–23.17)
Drug steroids intake	2 (0.9)	3 (6.5)	0.03	7.95 (1.29–49.02)
Sepsis	37 (16.1)	20 (43.5)	<0.0001	4.01 (2.03–7.93)
Radiological finding				
Cholelithiasis/cholecystitis	198 (86.1)	19 (41.3)	<0.0001	Reference
CBD stone	26 (11.3)	12 (26.1)		4.81 (2.10–11.03)
Complicated[b]	6 (2.6)	15 (32.6)		26.05 (9.05–75.00)
ERCP/EUS	37 (16.1)	12 (26.1)	0.11	1.84 (0.87–3.88)
Wall thickness (>4 mm)	56 (40.9)	20 (50.0)	0.3	1.45 (0.71–2.93)
Pericholecystic fluid	33 (23.7)	12 (30.0)	0.42	1.38 (0.63–3.01)
Impacted stone	24 (17.1)	4 (10.0)	0.27	0.54 (0.17–1.65)
Gall bladder distension	87 (62.1)	24 (60.0)	0.81	0.91 (0.44–1.87)

Table 1 continued

	LC $N = 230$	LC–OC $N = 46$	p value	OR (95% CI)
Laboratory				
Alkaline phosphatase (IU/l)			<0.0001	
<250	190 (96.9)	35 (81.4)		Reference
≥250	6 (3.1)	8 (18.6)		7.24 (2.40–22.14)
Alanine transaminase (IU/l)			0.97	
<130	162 (83.5)	36 (83.7)		Reference
≥130	32 (16.5)	7 (16.3)		0.98 (0.40–2.41)
Aspartate transaminase (IU/l)			0.34	
<100	156 (83.0)	33 (76.7)		Reference
≥100	32 (17.0)	10 (23.3)		1.48 (0.66–3.30)
γ-Glutamyl transferase (IU/l)			0.01	
<100	155 (76.0)	25 (55.6)		Reference
≥100	49 (24.0)	20 (44.4)		2.53 (1.29–4.94)
Bilirubin total (mg/dl)			0.01	
<2	162 (93.1)	35 (79.5)		Reference
≥2	12 (6.9)	9 (20.5)		3.47 (1.36–8.87)
White blood count (cu.mm)			0.06	
<4000	7 (3.2)	1 (2.2)		0.68 (0.08–5.68)
4000–11,000	157 (70.7)	25 (54.3)		Reference
>11,000	58 (26.1)	20 (43.5)		2.17 (1.13–4.19)
Polymorphonuclear (%)	67 ± 12	75 ± 10	<0.0001	1.79 (1.35–2.37)
Hemoglobin (g/dl)			0.004	
<9	3 (1.3)	4 (8.7)		6.98 (1.51–32.35)
9–12	41 (18.4)	13 (28.3)		1.75 (0.85–3.61)
>12	179 (80.3)	29 (63.0)		Reference
Hematocrit (%)	39 ± 4.8	36 ± 6.7	0.004	0.90 (0.85–0.96)
Platelets (cu.mm)	255 ± 74	255 ± 103	0.97	1.00 (0.96–1.04)
International normalized ratio			0.16	
<1.5	51 (92.7)	23 (82.1)		Reference
≥1.5	4 (7.3)	5 (17.9)		2.77 (0.68–11.28)
Bilirubin direct			<0.0001	
<0.5 mg/dl	149 (85.6)	27 (61.4)		Reference
≥0.5 mg/dl	25 (14.4)	17 (38.6)		3.75 (1.79–7.87)
Amylase (U/l)			1.00	
<200	86 (93.5)	22 (95.7)		Reference
≥200	6 (6.5)	1 (4.3)		0.65 (0.07–5.70)
Lipase (U/l)			0.19	
<120	85 (86.7)	28 (96.6)		Reference
≥120	13 (13.3)	1 (3.4)		0.23 (0.03–1.87)
BUN (mg/dl)			0.33	
<50	205 (99.5)	45 (97.8)		Reference
≥50	1 (0.5)	1 (2.2)		4.56 (0.28–74.21)
Cr (mg/dl)			0.02	
<1.8	208 (98.6)	42 (91.3)		Reference
≥1.8	3 (1.4)	4 (8.7)		6.60 (1.42–30.59)

Table 1 continued

	LC $N = 230$	LC–OC $N = 46$	p value	OR (95% CI)
Glomerular filtration rate (ml/min/1.73 m^2)				
<60	12 (6.0)	12 (26.1)	0.0001	Reference
≥60	188 (94.0)	34 (73.9)		0.18 (0.07–0.44)

Bivariate analysis: numerical values are expressed as mean ± standard deviation and categorical variables are expressed as numbers (%)

[a]Dependent refers to patients who are living in nursing home facilities

[b]Complicated gallbladder refers to gangrenous, porcelain, perforated gallbladder on preoperative imaging

[c]Renal disease refers to patients with chronic renal disease and those who presented with kidney injury

[d]Cardiac disease includes patients with a known history of heart failure, arrhythmia or coronary artery disease

[e]Neurological disease included patients with a history of patients with stroke or transient ischemic attack

[f]Liver disease: refers to patients with a chronic history of cirrhosis (Child–Pugh class A, B or C.)

[g]Lung disease: patient with active pneumonia at presentation, or obstructive/restrictive lung disease

36.9%), intraoperative need for CBD exploration ($n = 7$, 15.2%) and extensive bleeding ($n = 3$, 6.5%). Intraoperative blood loss was found to be significantly higher in the patients who underwent conversion as the majority of patients who underwent laparoscopic cholecystectomy had an intraoperative blood loss less than 25 cc.

Patients who underwent conversion had a longer operative time than those who proceeded successfully with LC (2.98 ± 0.92 vs. 1.15 ± 0.6 h, $p < 0.0001$). Further, 19.8% of the LC–OC group was admitted to the ICU postoperatively as opposed to 1.9% in the LC group. The LC–OC group was also more likely to have a drain placed (38 (82.6%) vs. 25 (10.9%) $p < 0.0001$).

LC–OC group had an increased overall perioperative morbidity compared to the LC group. They tended to have a longer duration of hospital stay (9.85 ± 7.13 days vs. 2 ± 4 days $p < 0.0001$). These patients tended to be at a higher risk of postoperative pre-renal azotemia despite a similar preoperative kidney function status. Pre-renal acute kidney injury developed in 5 patients of the conversion group (10.9%) versus 3 patients in the LC group (1.3%) ($p < 0.004$). There was no difference in the rates of postoperative bile leak, urinary tract infections or pneumonia. Surgical site infections developed in 4.3% of patient in the LC–OC group versus none in the LC group (Table 3). However, on multivariate logistic regression, the only morbidity that was shown to reach statistical significance in the LC–OC over the LC group was postoperative hospital length of stay. There was no significant difference in regard to surgical site infection rate or the incidence of acute kidney injury postoperatively (Table 4).

Table 2 Stepwise multivariate logistic regression of independent factors for conversion

Conversion (reference: no)		
Variables	OR (95% CI)	p value
Gender	0.09 (0.03–0.25)	<0.0001
Age	2.15 (1.62–2.85)	<0.0001
History abdominal surgery	4.66 (1.78–12.17)	0.002
Pulmonary disease	6.03 (1.21–29.97)	0.03
Hemoglobin < 9 g/dl	36.57 (3.16–423.72)	0.004

Gender (reference: female), age (increase by 10 units), history of abdominal surgery, pulmonary disease, hemoglobin, blood urea nitrogen, creatinine, GFR

Discussion

The role of LC in the management of benign gallbladder disease has been well established; however, some cases will need to be converted to open surgery. The need to convert should not be seen as a failure, rather an attempt to avoid complications and ensure patient safety. Recently, the conversion rate has decreased because of the experience gained by minimally invasive surgical training [23]; still the rate in the reported literature ranges from 3 to 24% [10, 18, 27]. The reasons behind this variability include patient selection, surgeon's experience and operative factors. Our rate of conversion is 1.03%. To the best of our knowledge, this is one of the lowest conversion rates in the English medical literature to date [9, 10, 18, 27]. The rate of conversion of all the surgeons at our institution was roughly similar ranging between 0 and 4% over a fifteen-year period (data not included). Coffin et al. [24] reported that the conversion rate of surgeons with minimal invasive surgical training (MIST) was statistically lower than surgeons with no formal training in minimally invasive surgery for the different risk factors studied. Similarly, Abelson et al. [28] reported a conversion rate of 1.7% for surgeon with MIST. The low rate of conversion in our study allows us to suggest that the reasons for conversion are linked to the disease of the gallbladder or morbidity of the patients rather than the skills of the surgeon.

The main reasons for conversion in our study were related to an unclear anatomy at the Calot's triangle secondary to severe inflammation or dense adhesions. The other most common reasons were the need for CBD exploration and intraoperative bleeding. These four reasons for conversion are consistent with other studies [8, 20, 21]. Several factors have been identified by multiple studies to be associated with the risk of conversion. These risks include age, male gender, emergency operation, impacted stone and certain comorbidities. Identifying independent factors that predict conversion from LC to OC is an important question that has several implications related to our practice, cost utility and clinical outcome [29]. Our study has identified several risk factors for conversion on bivariate analysis; however, multivariate stepwise regression analysis identified only five variables to have a significant association with conversion. Most studies have found that age and male gender are independent risk factors, and our analysis showed similar results.

Table 4 Stepwise multivariate logistic regression model for "outcomes" of LC–OC group

Conversion (reference: no)		
Variables	OR (95% CI)	*p* value
Postoperative length stay (days)	1.17 (1.06–1.29)	0.002
Drain	21.04 (7.80–56.77)	<0.0001

In a retrospective study of 5164 patients for whom LC was attempted, Genc et al. [27] found that the conversion rates in female and male patients were 2.25 and 5.65%, respectively ($p < 0.001$). Their study concluded that male gender was the only statistically significant risk factor for conversion. Male gender has been reported as a risk factor for conversion in several studies, and this association may be related to the increased severity of gallstone disease in men [30, 31]. Our study has shown that 27 of 37 male patients (73%) had their surgery converted to LC for either severe adhesion or severe inflammation at the Calot's triangle as opposed to 5 of 9 females (55%). The age reported in the literature as a risk factor for conversion varies from 50 to 65 with a twofold to fourfold higher conversion rate in these patients [7, 8, 15, 24]. The average age of patients in the LC–OC group in our study was 69 years. Likely reasons can be related to the fact the elderly patients have a higher incidence of complicated cholecystitis and comorbid conditions [32].

Table 3 Postoperative outcome of the LC as compared to the LC–OC group

	LC $N = 230$	LC-OC $N = 46$	*p* value	OR (95% CI)
Complications				
Urinary tract infection	0 (0.0)	1 (2.2)	0.17	NA
Pneumonia	4 (1.7)	1 (2.2)	1.00	1.26 (0.14–11.50)
Surgical site infection	0 (0.0)	2 (4.3)	0.03	NA
Bile leak	1 (0.4)	0 (0.0)	1.00	NA
Acute kidney injury (AKI)	3 (1.3)	5 (10.9)	0.004	9.23 (2.12–40.11)
Respiratory failure	0 (0.0)	2 (4.3)	0.03	NA
Postoperative common bile duct stone	3 (1.3)	0 (0.0)	1.00	NA
Outcomes				
Operative time (h)	1.15 ± 0.60	2.98 ± 0.92	<0.0001	13.55 (6.62–27.74)
Drain insertion	25 (10.9)	38 (82.6)	<0.0001	38.95 (16.35–92.80)
Postoperative admission				
Regular floor	226 (98.3)	37 (80.4)	<0.0001	Reference
Intensive care unit	4 (1.7)	9 (19.6)		13.74 (4.02–46.92)
Postoperative length stay (days)	2.00 ± 4.06	9.85 ± 7.13	<0.0001	1.42 (1.27–1.59)
Mortality	0 (0.0)	1 (2.2)	0.17	NA

Bivariate analysis (numerical values are expressed as mean ± standard deviation, categorical variables are expressed as numbers (%)

Medical comorbidities have been found to be a risk factor for conversion from laparoscopic to open surgery in different operations. In a review of more than three hundred thousand patients who had laparoscopic colorectal resection, Moghadamyeghaneh et al. [33] found that chronic pulmonary disease is an independent risk factor for conversion. Similarly, Sippey et al. [34] identified 7242 patients who underwent LC using the American College of Surgeon' National Surgical Quality Improvement Program (ACS-NSQIP). The conversion rate in this patient population was 6%. Medical comorbidities were found to be a risk factor for conversion, while patient with pulmonary comorbidity had an OR of 2.18 for conversion ($p < 0.001$). Similarly, our study showed several comorbidities to be risk factors; however, only pulmonary disease was statistically increasing the risk of conversion from LC to LC–OC. The preoperative comorbidity of a patient was found to be essential in the decision to proceed with an open cholecystectomy instead of LC [7]; however, it is not clear how such comorbidities can play a role in the decision to convert from LC–OC.

Prior history of abdominal operations is not a contraindication for LC; however, previous abdominal surgery has been found to be associated with an increase risk of conversion in several published studies [7, 9, 14, 21]. The increase in the conversion rate is related to the extent of adhesions and the need for adhesiolysis. In a series of 2693 LC, Ercan et al. [13] reported a conversion rate of 4.08%. Among patients whose operations were converted, 37% had a history of previous abdominal surgery. In our study, 22 out of the 46 patients (48%) had a prior history of laparotomy. Four patients out of the 46 had a previous gunshot wound to the abdomen and underwent abdominal exploration with variable organ resection. We found out that this subcategory of patients had the highest risk of conversion.

Our multivariate analysis has also shown that hemoglobin level less than 9 g/dl is a risk factor for conversion. It is unclear why anemia increases the odds for conversion despite the fact that it has been documented as a risk in previous studies [7]. Anemia is known to be present in chronic diseases. It is possible that anemia is a confounding variable for other factors that might have been detected with a larger sample size study.

The most common reported cause of intraoperative conversion was significant inflammation and fibrosis surrounding the Calot's triangle precluding safe dissection [9, 35]. Patients who have evidence of a complicated diagnosis on preoperative imaging such as a perforated or gangrenous gallbladder had a higher risk of conversion. Tosun et al. [36] identified various preoperative ultrasound findings such as gall bladder wall thickness, absence of fluid or sludge in the gall bladder, stones in common bile duct, air in the intrahepatic bile duct or dilated common bile duct to be significantly correlated with risk of conversion to open surgery. Similarly, our study has demonstrated that complicated pathology of the gallbladder on ultrasound is a significant risk factor for conversion to open surgery in the bivariate but not on multivariate analysis. The study by Tosun et al. included only patients who were admitted on an elective basis and excluded certain morbidities that we believe should have been included in the analysis of risk factors for conversion. Furthermore, all the cases in the study by Tosun et al. were performed by one surgeon, questioning the generalizability of the study.

Numerous studies have attempted to develop a risk score for conversion from LC–OC [8, 21, 22, 31, 37]. Theses risk scores have not been used in the clinical practice because they have been derived from either retrospective studies, studies with a small sample size or the lack of validation in prospective trials. Sutcliffe et al. [38] reported a validated risk score derived from a prospective UK database of 8820 patients. The reported score was derived from 6 variables and predicted a 7.1% versus a 1.2% risk of conversion for high risk as opposed to low risk patients, respectively. However, their risk score did not take into account patient-related factors such as previous surgery and comorbidities that were found to be significant risks in our analysis. The decision to convert varies between surgeons and is related to experience and perceived procedural difficulty. The fact that there is the "surgeon" variable, which is hard to quantify in a study, leads to a significant limitation in any score that will be developed. Accordingly, we believe that having the objective of identifying the independent factors that might affect conversion is valuable and applicable in different settings, irrespective of the surgeon's experience.

The rate of postoperative complication between LC and LC–OC varies in the literature. Kaafarani et al. [7] reported a higher rate of complications such as wound infection, wound dehiscence, deep venous thrombosis, while Ashfaq et al. [35] did not find any difference in terms of wound infection, postoperative hemorrhage, subhepatic collection or bile leak; however, a difference in the length of hospital stay was noted. Similarly, our study revealed that patients who underwent conversion had had a higher overall morbidity but only hospital length of stay was noted to be significant on multivariate analysis.

There are several limitations to the study. First, this is a retrospective study based on chart review. Several disease-related factors such as complicated cholecystitis and its severity have been documented to increase the risk of conversion. We made every effort to confirm the diagnosis by matching the diagnostic data with the surgeon's note and the histopathology results. However, we recognize that the retrospective nature of our study limits our ability to correctly classify the preoperative diagnosis with certainty, thus introducing a potential inaccuracy in our analysis of risk factors for conversion. Analyzing a random sample of successful laparoscopic cholecystectomies rather than the entire population is another limitation by itself. Unfortunately, a large number of these records (prior to year 2007) were paper based and not electronic. Reviewing such a large number of paper records is particularly time-consuming and inefficient. Nevertheless, we believe that a 1:5 matching ratio is representative sample of the entire population [25]. The reasons for conversion were retrieved from the surgeon operative note. This represents another limitation because there is an inherent heterogeneity in the surgeons' decision to convert. Finally, this is a single academic center study limiting the generalizability of our results.

We consider that one of the strengths of our study derives from the large numbers of patients included. In addition, we assessed a comprehensive list of preoperative variables which replicates the clinical picture of the vast majority of patients presenting for cholecystectomy and increases the generalizability of our results. Our conversion rate of 1% is one of the lowest conversion rates reported in the medical literature today. It reflects the practice of 17 surgeons who had a roughly consistent conversion rate over a 15-year period. This may imply that LC–OC patients had their operation converted because of factors other than the surgeons' skills [15] that if these patients were anywhere else they would have had a similar chance of conversion regardless of the surgeon's experience.

Conclusion

LC is the surgical procedure of choice for benign gallbladder disease; however, LC will need to be converted to OC in a minority of patients. Our results are consistent with previous studies that showed that male gender, advanced age, significant past medical history especially pulmonary disease and previous laparotomy are the major risk factors for conversion. The morbidity and the cost of conversion to OC have been well documented in the literature. An accurate prediction of what constitutes "high risk" enables appropriate counseling of patients. Further research is needed to determine whether these high risks patients should be operated by surgeons with more extensive training and experience in minimal invasive surgery.

Author's contribution MS contributed to the integral part in data collection, analysis, writing and editing of paper. EM helped with data collection and analysis. HT helped with lead biostatistician, data analysis and revised the manuscript. JF contributed to revision of the manuscript. FW helped with revision of the manuscript. BN contributed to revision and editing the manuscript. SY contributed to the conceptualization of the study and critical revision. HA is the principal investigator and contributed to the conceptualization of the study. Integral part in data collection, data analysis and critical revision of the manuscript. All authors read and approved the final manuscript.

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