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Risk Factors and Predictive Models for Conversion of Laparoscopic Cholecystectomy to Open Surgery, and Surgical Quality Outcome Measures

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Additional information is available at the end of the chapter

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Abstract

Background: Laparoscopic cholecystectomy is the preferred surgical operation for symptomatic gallstone disease. Conversion of laparoscopic cholecystectomy to open surgery is used to prevent intra-abdominal organ injury, for open common bile duct exploration and to repair intra-abdominal organ injury.

Objective: The objective of this chapter is to review risk factors and predictive models for conversion of laparoscopic cholecystectomy to open surgery, and surgical quality outcome measures.

Methods: A narrative literature review using Pubmed, Medline, Cochrane library databases and Google search engine is described.

Results: From the literature review, patient- and surgeon-related risk factors and predictive models for conversion of laparoscopic cholecystectomy to open surgery were identified. Patient-dependent risk factors included preoperative and intraoperative variables. Current conversion of laparoscopic cholecystectomy to open surgery predictive models use only patient-dependent risk factors and were not tested on an independent sample of patients. Surgical quality outcome measures incorporate an association between conversion and intra-abdominal organ injury that demonstrates that conversion was used as an emergency strategy to repair injuries rather than a safety measure.

Conclusion: Conversion of laparoscopic cholecystectomy to open surgery risk stratification based on patient- and surgeon-dependent variables may allow a better management of the patient to keep conversion at low rates and to maintain benefits of minimally invasive surgery.

1. Introduction

The prevalence of cholelithiasis in an adult Western population is between 15 and 20% [1, 2]. In the United States, an estimated 11.8 million people aged between 20 and 74 years have gallbladder (GB) stones [3]. Yearly approximately 1–2% of patients with silent gallstones develop symptoms and require treatment (**Figure 1**) [4–6]. Acute cholecystitis (AC) accounts for 20% of patients presented to hospital with right upper quadrant pain, which in patients with significant co-morbidities and in the elderly is associated with 2–3% mortality [5, 7, 8]. In the United States, in 2009, cholecystitis was the underlying cause of death in 2009 patients and a contributing cause of death in 3295 patients accounting for a mortality crude rate of 0.7 per 100,000 patients [9]. In the same country, GB disease is one of the most common inpatient diagnosis that accounts for more than 260,000 hospital admissions and annual health care provider expenditure exceeding $3.03 billion [9].
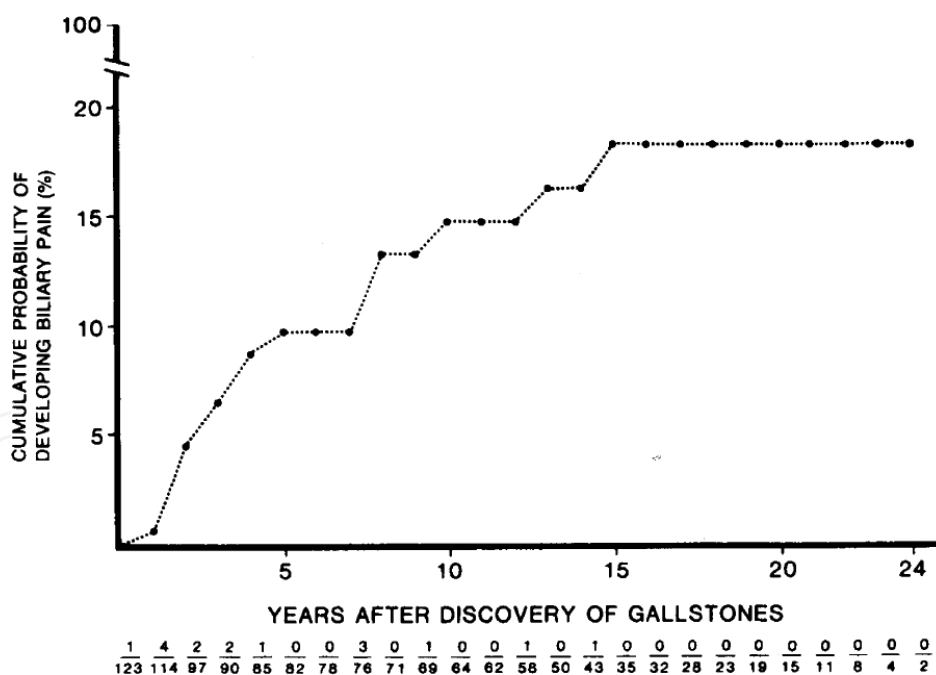

Figure 1. Life-table analysis of the outcome of silent gallstone disease. The fractions along the abscissa show the number of people developing biliary pain over the number at risk (adapted from Gracie and Ransohoff [4]).

Laparoscopic cholecystectomy (LC) is considered as the "gold standard" surgical technique for treatment of GB disease [10]. Conversion of LC to open surgery (CTO) is used to prevent intra-abdominal organ injury (IOI), for common bile duct (CBD) exploration and to repair IOI.

The aim of this chapter is to review risk factors and predictive models for CTO, and surgical quality outcome measures.

2. Laparoscopic cholecystectomy

LC is the minimally invasive surgical operation that was introduced in clinical practice by Erich Muehe of Boeblingen, Germany, in 1985 [11]. LC can be performed with the conventional four-port or three-port technique.

Compared to the conventional open cholecystectomy (OC), LC has decreased post-operative pain, decreased respiratory function dysfunction, reduced post-operative ileus, earlier oral fluid and food intake, better cosmesis, reduced patient's hospital stay, fastened post-operative recovery and lowered morbidity and mortality [12–14].

A meta-analysis comparing LC with the small-incision OC (the length of incision of less than 8 cm) demonstrated that both techniques had similar rates of mortality; intraoperative, minor and severe post-operative complications (without bile duct injuries, BDI); BDI; total complications; and post-operative convalescence [15]. A subgroup analysis of high-quality trials showed a shorter operative time for the small-incision OC than LC (weighted mean difference, random effects 16.4 min, 95% CI: 8.9–23.8 min) [15]. Compared with the small-incision OC, the self-reported quality of life up to 30 days after LC is higher; 2326 (95% CI: 2187–2391) and 2411 (95% CI: 2334–2502), respectively, $P = 0.03$ [16].

Main disadvantages of LC compared to the conventional OC and small-incision OC are a lack of a three-dimensional view, narrow field of laparoscopic vision, inconvenience with liver retraction, insufficient tactile sensations due to manipulation with long laparoscopic instruments and difficulties with instruments placement and manoeuvring [17–19].

Another significant limitation of LC is an increased risk of IOI, including bile duct injury (BDI) [20, 21]. In the United States, approximately 750,000 LCs are performed annually [22]. With the incidence of major BDI during LC fluctuating between 0.4 and 2%, it is expected that 3000 to 15,000 patients will suffer from iatrogenic BDI [21, 23, 24]. Major BDI is associated with significant morbidity, mortality and socioeconomic burden [21].

2.1. Indications for conversion of LC to open surgery

The primary indication for CTO is to prevent IOI. CTO can also be used for CBD exploration, to repair cholecysto-intestinal fistula and to perform an extended OC in patients with gall-bladder cancer. In addition, CTO is performed to control haemorrhage and repair single or multiple IOI [25, 26].

Compared to LC, CTO is associated with an increased morbidity and mortality. A clinical audit of 7242 LCs for AC performed in the United States between 2005 and 2011 showed that compared to the LC group, patients who underwent CTO had higher rates of surgical site infection (1.8 versus 9.2%, $P < 0.0001$), operations for complications (1.4 versus 3.4%, $P = 0.001$),

serious morbidity (3.8 versus 14.9%, $P < 0.0001$), overall morbidity (6.0 versus 21.8%, $P < 0.0001$) and mortality (0.5 versus 2.3%, $P < 0.0001$) [18]. In addition, the CTO group of patients had a longer mean operation time (122.1 ± 51.0 min versus 80.0 ± 42.6 min, $P < 0.0001$) as well as the length of hospital stay (8.6 ± 13.0 days versus 3.4 ± 6.7 days, $P < 0.0001$) than LC patients [18].

2.2. Risk factors for conversion of LC to open surgery

As high rate of CTO and IOI can diminish clinical benefits and cost-effectiveness of LC, identification of preoperative and intraoperative patient-dependent and surgeon-related risk factors for CTO can be used for development of risk stratification models and refinement of the management. This will keep CTO at low rates and maintain benefits of minimally invasive GB surgery.

2.2.1. Preoperative patient-related risk factors

Preoperative patient-related risk factors for CTO have been extensively investigated and identified. In previous studies, the advanced age has been shown to be a risk factor for CTO [25, 27, 28]. In a meta-analysis, Yang et al. demonstrated that age >65 years is associated with a twofold increase in CTO rate (odds ratio (OR) = 1.8; 95% confidence interval (CI): 1.4–2.5; $P < 0.0001$) (**Table 1**) [29]. These findings can be explained by a higher proportion of severe AC, GB cancer, choledocholithiasis and previous abdominal operations among the older patients compared to their younger counterparts [28, 30].

Preoperative patient-related risk factors for CTO	OR	95% CI	*P* value	References
Advanced age (>65 years)	1.8	1.4–2.5	<0.0001	[29]
Male	2.8	1.1–6.6	0.037	[32]
Clinical diagnosis of AC	8	6.1–10.5	<0.00005	[35]
Duration of AC >72 h	3.1	1.2–7.7	0.0072	[37]
Repeated attacks of AC, ≥2	7.9	1.5–76.8	<0.0052	[41]
Diabetes mellitus	2.5	1.3–4.4	0.003	[43]
Obesity, BMI >30 kg/m^2	7.6	4.1–14	<0.001	[52]
Previous upper abdominal surgery	20.4	2.4–927.4	0.0007	[50]
Post-ERC/ES, ≥16 weeks	3	1.2–7.4	0.009	[57]
WCC ≥ 11 × 10^9/L	4	2.5–6.1	<0.00005	[25]
Elevated CRP, 10 mg/L	1.05	1.01–1.09	0.014	[37]
Elevated total bilirubin	6.5	4.1–10.2	<0.00005	[64]
Alkaline phosphatase (>135 U/L)	7	3.6–14	<0.00001	[52]
Gallbladder wall thickness, mm	2	1.7–2.3	<0.00005	[52]
Pericholecystic fluid on US	26	5.0–166.1	<0.00005	[41]
ASA score >2	2.5	1.3–4.6	0.004	[66]

Abbreviations: CTO, conversion of laparoscopic cholecystectomy to open surgery; OR, odds ratio; CI, confidence interval; AC, acute cholecystitis; BMI, body mass index; ERC/ES, endoscopic retrograde cholangiography with endoscopic sphincterotomy; WCC, white cell count; CRP, C-reactive protein; U, units; L, litre; ASA, American Society of Anaesthesiologist; US, trans-abdominal ultrasound.

Table 1. Preoperative patient-related risk factors for conversion of laparoscopic cholecystectomy to open surgery.

A. Local signs of inflammation, etc.:

(1) Murphy's sign, (2) RUQ mass/pain/tenderness

B. Systemic signs of inflammation, etc.:

(1) Fever, (2) raised WCC, (3) elevated CRP

C. Imaging findings: imaging findings characteristic of acute cholecystitis

(1) Trans-abdominal ultrasound findings:

Positive sonographic Murphy sign (ultrasound transducer elicited tenderness on gentle pressure over the gallbladder

Thickened gallbladder wall (>4 mm, provided there is no congestive heart failure, chronic liver disease and ascites)

Marked distension of the gallbladder (long axis diameter >80 mm, short axis diameter >40 mm)

Gallstone impacted in Hartman's pouch; biliary sludge, pericholecystic fluid collection

Sonolucent halo in the gallbladder wall

(2) CT findings:

Gallbladder distension

Gallbladder subserosal oedema

Gallbladder wall thickening

Pericholecystic stranding, fluid collection

(3) Magnetic resonance imaging findings:

Cystic duct stone

Intraluminal sludge

Pericholecystic high signal

Gallbladder distension

Gallbladder wall thickening, abnormal signal intensity and oedematous stratification

(4) Tc-HIDA scan findings:

Non-visualized gallbladder within 1 h

"Rim sign" (increased pericholecystic hepatic radioactivity)

Suspected diagnosis: One item in A + one item in B

Definite diagnosis: One item in A + one item in B + C

Note: acute hepatitis, other acute abdominal diseases, and chronic cholecystitis should be excluded.
Abbreviations: RUQ, right upper abdominal quadrant; CRP, C-reactive protein; WCC, white cell count; US, ultrasound;
MRI, magnetic resonance imaging; CT, computed tomography; Tc-HIDA scan, 99mTc-hepatic iminodiacetic acid
cholescintigraphy.

Table 2. The 2013 Tokyo guidelines diagnostic criteria for acute cholecystitis (modified from Yokoe et al. [34]).

Male gender is a well-recognized risk factor for difficult LC and CTO [18, 25, 28, 29]. Males
have more prominent adhesions between the GB and the omentum and surrounding internal
organs, have a higher proportion of severe forms of AC on histological examination of the GB,

have a higher CTO rate and require a longer operation time [31]. Two-stage LC male patients have a three times higher rate of CTO (OR = 2.8; 95% CI: 1.1–6.6, P = 0.037) than females [32]. This might be due to men's reluctance to seek medical and surgical help, and their late hospital presentations after several repeated attacks of AC [31].

Patients with the clinical diagnosis of AC and higher severity grades of AC carry more chances of CTO [25, 33, 34]. Diagnostic criteria for AC are presented in **Table 2** [34]. AC patients have eight times higher risk of CTO than patients with uncomplicated gallstone disease (OR = 8.01; 95% CI: 6.1–10.5; P < 0.00005) [35]. Severity grades of AC, as defined by the 2013 Tokyo Guidelines, are associated with an increased rate of CTO [36, 37]. The 2013 Tokyo Guidelines for severity grades of AC are shown in **Table 3** [34]. Severe AC makes LC technically more difficult, because AC is accompanied by extensive adhesions around GB and weakness of the GB wall, which preclude its retraction with laparoscopic forceps and cause GB perforation and spillage of infected bile and gallstones into the peritoneal cavity [32].

Grade I (mild) acute cholecystitis

Does not meet the criteria of "grade III" or "grade II" acute cholecystitis. Grade I can also be defined as acute cholecystitis in a healthy patient with no organ dysfunction and mild inflammatory changes in the gallbladder, making cholecystectomy a safe and low-risk operative procedure

Moderate (grade II) acute cholecystitis

Grade II (moderate) acute cholecystitis

Associated with any one of the following conditions:

1. Elevated white cell count (>18,000/mm^3)

2. Palpable tender mass in the right upper quadrant

3. Duration of complaints > 72 h

4. Marked local inflammation (gangrenous cholecystitis, pericholecystic abscess, hepatic abscess, biliary peritonitis, emphysematous cholecystitis)

Grade III (severe) acute cholecystitis

Associated with dysfunction of any one of the following organs/systems:

1. Cardiovascular dysfunction (hypotension requiring treatment with dopamine ≥5 mcg/kg/min, or any dose of norepinephrine)

2. Neurological dysfunction (decreased level of consciousness)

3. Respiratory dysfunction (PaO$_2$/FiO$_2$ ratio <300)

4. Renal dysfunction (oliguria, creatinine >2.0 mg/dL)

5. Hepatic dysfunction (PT-INR >1.5)

6. Haematological dysfunction (platelet count <100,000/mm^3)

Table 3. The 2013 Tokyo guidelines severity grading for acute cholecystitis (adapted from Yokoe et al. [34]).

The longer the duration of untreated AC, the greater is the risk for CTO [27]. Asai et al. showed that 12 of 29 (41.4%) patients in the CTO group and 36 of 196 (18.4%) patients in LC group had symptoms of AC for longer than 72 h ($P = 0.0004$) [37]. Therefore, untreated AC lasting more than 2 days increases the risk for CTO by three times (OR 3.1; 95% CI: 1.2–7.7; $P = 0.0072$).

Repeated attacks of AC are associated with difficult LC and CTO [38–40]. When compared to AC patients with less than two previous episodes, patients with at least two past attacks of AC have an eightfold increase in the difficulty of LC (OR = 7.9; 95% CI: 3.4–18.2; $P < 0.00005$) and the rate of CTO (OR = 7.9; 95% CI: 1.5–76.8; $P = 0.0052$) [41]. Compared to patients with one previous attack of AC, having at least three attacks of AC escalates LC difficulty by a factor of 28 (OR = 28.3; 95% CI: 7.4–127.6; $P < 0.00005$) and increases the rate of CTO a 14-fold (OR = 14.1; 95% CI: 2.1–153.2; $P = 0.0021$) [41].

Diabetes mellitus (DM) has been consistently shown to be associated with CTO [18, 25, 42]. Diabetics undergoing LC have a 2.5 times higher risk for CTO than nondiabetic patients (OR = 2.5; 95% CI: 1.3–4.4, $P = 0.003$) [43]. This might be because diabetic patients have a threefold greater risk for the development of AC than non-diabetics (OR 2.7; 95% CI: 1.8–4.2; $P < 0.00005$) [44]. Also, diabetics, especially if they are on insulin, have an 85% increased risk of preoperative GB perforation (adjusted OR = 1.85; 95% CI: 1.38–2.48; $P < 0.001$) [45]. Poor glycaemic control and presence of diabetic microagiopathy and autonomic neuropathy, as well as frequent bactibilia, are important conditions that predispose diabetics to advanced forms of AC and infective complications [40, 46–49].

Obesity (body mass index (BMI) > 30 kg/m^2) is not only a risk factor for CTO but also associated with major BDI [18, 28, 50, 51]. Obese patients undergoing LC have an eightfold higher risk of CTO than non-obese patients (OR = 7.6; 95% CI: 4.1–14; $P < 0.001$) [52]. Compared to the non-obese patients, class I and class II–III obese patients have a two- and threefold increase in the risk of CTO (OR = 1.8; 95% CI: 1.1–2.8; $P = 0.0105$) and (OR = 2.7; 95% CI: 1.5–4.6; $P = 0.0006$), respectively [53].

Previous surgery above the umbilicus is a risk factor for CTO [52, 54]. In Lee's study, 7 (17%) of 41 patients from the CTO group and 1 (1%) of 100 patients from the LC group had a history of previous upper abdominal surgery [50]. This estimates the risk for CTO for patients with the past history of upper abdominal surgery 20 times higher than for those without previous surgery above the umbilicus (OR = 20.4, 95% CI: 2.4–927.4; $P = 0.0007$).

The risk of CTO is also higher in patients following endoscopic retrograde cholangiography with sphincterotomy (ERC/ES) for CBD stone clearance [54–56]. A two-stage LC after 15 weeks following ERC/ES increases the rate of CTO three times (RR = 2.7, 95% CI: 1.4–5.5, $P = 0.004$) and major BDI 10-fold (RR = 10.2, 95% CI: 1.1–95.7, $P = 0.043$) [57]. Boerma et al. compared the two-stage LC conducted within 6 weeks after ERC with that performed after 6 weeks and found that the latter was more technically demanding and associated with a threefold increase in the CTO rate (RR = 2.7, 95% CI: 1.3–3.4, $P = 0.01$) [58]. An association between preoperative ERC/ES and difficult LC can be explained by bactibilia-related inflammation of bile ducts with desmoplastic changes around the Calot's triangle and shrinking of the GB [59, 60].

Thickened gallbladder wall on ultrasound (US) of the upper abdomen is associated with CTO [25, 28]. The risk of CTO doubles with every millimetre increase in gallbladder wall thickness (OR = 2; 95% CI: 1.7–2.3; $P < 0.001$) [52]. Patients with GB wall thickness >5 mm on trans-abdominal US have a 16 times higher risk of CTO than those with GB wall thickness 3–5 mm (OR = 16.3; 95% CI: 8.1–33.3; $P < 0.00005$) [35]. GB wall thickness >4 mm on US is not only a radiological marker for AC but also associated with greater operational difficulty [40, 61].

The presence of pericholecystic fluid on imaging of the abdomen increases the risk of CTO by 26 times (OR = 26; 95% CI: 5.0–166.1; $P < 0.00005$) [41]. This radiological sign has the sensitivity of 70% in predicting CTO, the specificity of 92%, the positive predictive value of 33% and the negative predictive value of 98% [41].

An elevated white cell count (WCC) is a predictor of CTO [28]. Compared to the LC group, the CTO group had a higher proportion of patients with leucocytosis, defined as WCC ≥ 11 × 10^9/L, 161 (12.7%) of 1265 patients versus 41 (36.6%) of 112 patients, respectively, $P < 0.001$ [25]. This estimates a fourfold higher risk of CTO among patients with WCC ≥ 11 × 10^9/L (OR = 4.0; 95% CI: 2.5–6.1) compared with leucopenic and patients with normal WCC (WCC ≤ 11 × 10^9/L), $P < 0.00005$. In another study, Nidoni et al. showed that the sensitivity of WCC ≥ 11 ×10^9/L in predicting CTO is 80%, the specificity 83.5%, the positive and negative predictive values 22.2 and 98.6%, respectively [41].

Histopathology of acute cholecystitis	WCC cut-off (95% CI)	CRP cut-off (95% CI)	AUC of WCC (95% CI)	AUC of CRP (95% CI)	P value
Overall AC	9.15 (8.7–9.6)	30.5 (10.2–50.8)	0.83 (0.79–0.87)	0.94 (0.92–0.97)	<0.00005
Mild AC	9.01 (8.7–9.32)	26.5 (13.6–39.4)	0.79 (0.74–0.84)	0.93 (0.9–0.95)	<0.00005
Moderate-severe AC	11.05 (10.22–11.88)	67 (61.9–72.1)	0.92 (0.88–0.97)	0.99 (0.97–1.0)	0.0093
Acute on chronic cholecystitis	9.15 (8.81–9.49)	26.5 (15.72–37.28)	0.72 (0.65–0.79)	0.87 (0.82–0.92)	0.0004
Acute edematous cholecystitis	9.05 (8.29–9.81)	30.5 (3.34–51.68)	0.78 (0.69–0.87)	0.93 (0.87–0.99)	0.0001
Acute necrotizing cholecystitis	9.05 (6.97–11.12)	57.5 (34.74–80.26)	0.89 (0.83–0.95)	0.97 (0.94–1.0)	0.0149
Acute suppurative cholecystitis	9.15 (7.96–10.34)	92 (76.43–111.57)	0.82 (0.67–0.97)	1.0 (1.0–1.0)	0.0189
Acute gangrenous cholecystitis	11.65 (10.63–12.67)	67 (61.78–72.22)	0.93 (0.89–0.98)	0.99 (0.97–1.0)	0.0375
Pericholecystic abscess/ gallbladder perforation	9.15 (7.82–10.48)	86 (66.28–105.72)	0.89 (0.76–1.0)	1.0 (1.0–1.0)	0.0852

Abbreviations: CRP, C-reactive protein; WCC, white cell count; AC, acute cholecystitis; AUC, the area under receiver operating characteristic curve.

Table 4. Cut-off values and areas under receiver operating characteristic curve of CRP and WCC in acute cholecystitis (adapted from Beliaev et al. [63]).

An elevated C-reactive protein (CRP) level also predicts CTO [62]. Every 10 mg/L increase in CRP concentration, the rate of CTO increases by 5% (OR = 1.05; 95% CI: 1.01–1.09; $P = 0.014$) [37]. The cut-off point of CRP > 115 mg/L predicts CTO with the sensitivity of 79% and

specificity of 57%. CRP as a predictor of CTO has the area under receiver operating characteristic curve (AUC) of 67% [37]. An association between CTO and CRP concentration can be explained by severity of AC. The cut-off point of CRP concentration increases with more advanced histological forms of AC and its severity grades (**Table 4**) [63].

Deranged liver function tests predict CTO [28, 64]. Patients with elevated concentrations of total bilirubin and alkaline phosphatase (>135 U/L) have seven times higher risk of CTO, OR = 6.5 (95% CI: 4.1–10.2; $P < 0.00005$) and OR = 7.0 (95% CI: 3.6–14; $P < 0.00001$), respectively [25, 52]. Elevated levels of total bilirubin and alkaline phosphatase are both independently associated with choledocholithiasis [65]. Open CBD exploration is one of the reasons for CTO.

An increasing ASA score has been shown in multiple studies to be an independent risk factor for CTO [25, 27, 28, 52, 62, 66]. Patients with ASA score of 3 have 2.5 times odds of CTO (OR = 2.5; 95% CI: 1.3–4.6) than those with ASA score of 1 ($P = 0.004$) [66].

2.2.2. Intraoperative patient-related risk factors

To prevent IOI during LC, when the surgeon encounters dense intra-abdominal adhesions, extensive inflammatory changes around the gallbladder, haemorrhage, inability to grasp and retract a friable gallbladder with forceps, CTO is advised [67].

Severe intra-abdominal adhesions make laparoscopic dissection very difficult and are associated with a fivefold increase in CTO risk (OR = 5.2; 95% CI: 1.9–14.4; $P = 0.002$) [32]. Some authors report their institutional policy of avoidance of difficult dissections during LC and making a decision of CTO if there is a lack of dissection progress for 15–30 min [27].
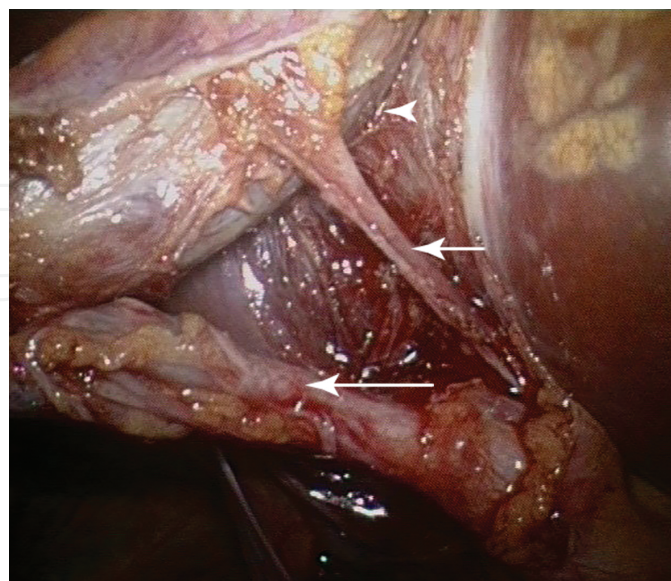

Figure 2. Critical view of safety. The arrowhead shows detachment of the lowest part of the gallbladder from the gallbladder bed, the smaller arrow depicts the cystic artery and the larger arrow points at the cystic duct.

Intense inflammatory infiltrate in the Calot's triangle makes identification of the cystic duct and cystic artery very challenging predisposing patients to iatrogenic BDI and uncontrollable bleeding [32, 35]. To prevent BDI, CTO is directed when one of three fundamentals of the critical view of safety cannot be ascertained [30, 68]. These essentials include the clearance of the Calot's triangle from adipose and fibrous tissue, detachment of the lowest part of the gallbladder from the GB bed and identification of the cystic duct and cystic artery going into the gallbladder (**Figure 2**) [69]. Alternatively, when the surgeon encounters severe inflammatory or desmoplastic reaction in the Calot's triangle laparoscopic subtotal cholecystectomy can be performed [70–72].

Unclear biliary anatomy is another reason for CTO [20]. Instead, intraoperative cholangiography (IOC) can be used to prevent misidentification of the cystic duct and prevent BDI [73, 74]. Failure of the contrast to opacify the common hepatic duct and the right and left hepatic ducts would signal the surgeon that the CBD, not the cystic duct, has been cannulated [74]. The use of IOC is associated with a 62% reduction in CTO rate (OR = 0.38, 95% CI: 0.17–0.94; P = 0.04) [75]. If IOC does not facilitate unmistakeable biliary ducts recognition, then CTO is indicated [74].

Intraoperative patient-related risk factors for CTO
Adhesions caused by previous upper abdominal operations
Adhesions in the upper abdomen caused by severe pericholecystic tissue inflammation
Enlarged fatty liver (steatohepatitis) restricting access and inability to elevate gallbladder to dissect Calot's triangle
Intra-hepatic gallbladder
Necrotic gallbladder wall
Thickened sclerotic gallbladder wall/porcelain gallbladder
Gallbladder perforation with biliary peritonitis
Large gallbladder stone impacted in Hartman's pouch/Mirizzi syndrome
Fibrosis of tissue in Calot's triangle
Severe inflammation in Calot's triangle
Uncontrollable bleeding from cystic artery, hepatic artery, gallbladder bed
Cholecysto-intestinal fistula
Unclear biliary anatomy
Choledocholithiasis requiring open CBD exploration
Suspicion of gallbladder cancer
Intra-abdominal organs injury
Intolerance of intraperitoneal carbon dioxide insufflation

Abbreviations: CTO, conversion of laparoscopic cholecystectomy to open surgery; CBD, common bile duct.

Table 5. Intraoperative patient-related risk factors that may require conversion of laparoscopic cholecystectomy to open surgery.

CTO is performed when open CBD exploration and stone clearance is required provided CBD stones cannot be removed laparoscopically or post-operatively by ERC/ES [20, 76, 77]. Furthermore, CTO is advised for an open repair of intraoperatively diagnosed IOI [20, 25]. Infrequently, CTO is necessary when the patient is not able to tolerate 12 mm Hg intraperitoneal carbon dioxide insufflation pressure and develops premature ventricular beats and bradycardia with hypotension [20].

Intraoperative patient-related risk factors that may require conversion of laparoscopic cholecystectomy to open surgery are presented in **Table 5**.

2.2.3. Surgeon-related risk factors

Surgeon's knowledge, laparoscopic fellowship training, operative experience and skills in laparoscopic surgery play an important role in timely recognition of the need for CTO and are important predictors for CTO [49, 74, 75, 78]. Surgical registrars (postgraduate year 4–5) have a twofold higher rate of CTO (OR = 1.7; 95% CI: 1.1–2.5; P = 0.0067) than surgical consultants [25]. Compared to general surgical registrars without fellowship training, completion of the surgical fellowship program is associated with 92% reduction in the rate of CTO (OR = 0.08; 95% CI: 0.02–0.32, P < 0.0001) [79].

Importantly, there is statistically significant inverse correlation between surgeons' LC volume and the rate of CTO (P = 0.03) [80]. The surgeons with more than 5 years of experience in independent practice, who performed at least 100 LC or more than 75 cases annually are considered to be experts, and the surgeons with personal records of less than 100 LC as the first surgeons to be non-experts [81, 82]. In addition, surgeon's specialization influences the incidence of CTO. The expertise of upper gastrointestinal (UGI) surgeons is recognized to be the standard in LC against which the other surgeons' capability can be measured. Compared to the UGI surgeons, non-UGI surgeons have a two times higher incidence of CTO (OR = 2.1; 95% CI: 1.1–3.7; P = 0.0122) [80].

2.3. Predictive models for conversion of LC to open surgery

Few predictive models have been developed to help the surgeon make an early CTO decision. Lipman et al. found that variables such as male gender, WCC ≥ 11 × 10^9/L, low albumin, pericholecystic fluid on US, the presence of diabetes mellitus and elevated total bilirubin independently predict CTO. These risk factors were included into the model which has the AUC of 83%. The authors showed that if none of these risk factors were present, the risk of conversion is 2%, but when six risk factors were present, the risk of conversion escalated to 90% [25].

Kama et al. presented a CTO risk scoring model consisting of a constant (-20) and six variables with their coefficients, age ≥60 years (coefficient of 5), male gender (11), previous upper abdominal surgery (8), abdominal tenderness (9), thickness of gallbladder wall >4 mm on US (13) and the clinical diagnosis of AC (15) [83]. The final risk score for CTO (RSCLO) is the sum of the constant and coefficients of the risk factors that are present in an individual patient. The

RSCLO can take a value between −20 and 41. An operation with RSCLO exceeding −3 is considered difficult [84].

Goonawardena et al. proposed a CTO prediction model that is constructed on five independent variables, previous upper abdominal surgery, obesity (BMI > 30 kg/m^2) and the presence of choledocholithiasis, impacted stone at the Hartmann's pouch and GB wall thickening on the trans-abdominal US [52].

Sugrue et al. developed an intraoperative 10-point scoring system for an assessment of the difficulty in LC [85]. A score of <2 indicates mild degree difficulty, 2–4 moderate, 5–7 severe and 8–10 the extreme difficulty of LC [85].

These predictive models have limitations. They have not been tested on an independent sample. Therefore, their real-life predictive ability is unknown. In addition, these models excluded surgeon-related risk factors. Thus, it is difficult to tailor management of high-risk for CTO patients according to an available hepato-biliary expertise.

3. Outcomes and quality indicators in laparoscopic cholecystectomy

Time to operation theatre (*TTO*) is the period between hospital admission and the start of operation. TTO is correlated with the length of the index hospital admission and associated with an increased expenditure for health care provider. Fry et al. showed that the length of preoperative hospitalization exceeding 3 days (96 h) incurs an added cost of 2011 US$ 7584 [86].

The CTO rate is the proportion of cases of LC converted to open surgery to the total number of intended LC. Mueller et al. consider CTO as a quality variable, because CTO is associated with a worse outcome [87]. Other authors do not regard CTO as a complication, but rather as a "sign of experience" or "mature judgment" to prevent IOI [20, 28]. We classify all CTO into three groups: (1) the safety CTO when conversion is performed to prevent IOI; (2) conversion of LC to extended surgery is implemented for an open CBD exploration, for closure of cholecysto-intestinal fistula, or for an extended OC in case of GB cancer; and (3) the emergency CTO is performed to stop bleeding or repair IOI detected intraoperatively. In this view, safety CTO and extended surgery CTO are not complications, but carefully thought-out surgical strategies.

Laparoscopic BDI rate is the proportion of injury to bile ducts that occurred during LC to the total number of LCs. Commonly, BDIs are specified according to the Strasberg's classification [88].

IOI rate is the proportion of iatrogenic injury to one or more intra-abdominal organs, including the liver, bile ducts, small and large bowel, stomach, spleen, pancreas, mesentery and vascular injury accompanied with extensive haemorrhage to the total number of cholecystectomies.

An association between CTO and IOI is a surgical quality indicator that shows that CTO is used predominantly as an emergency surgical strategy to control haemorrhage and repair IOI diagnosed intraoperatively [89].

Procedures or operations performed for treatment of complications are procedures performed for complications during the index hospital admission and readmissions.

Severity of post-operative complications can be graded using the Dindo-Clavien classification [90]. This classification does not specify the hospital admission during which they developed. We suggest using the Dindo-Clavien classification to grade post-operative complications that arose during the index hospital admission.

The length of stay (*LOS*) is the duration of the index hospital admission.

Readmission within 30 or 90 days from the index hospital discharge is the readmission to any acute care hospital with a condition that could be considered an outcome of the procedure or operation [86]. To define readmissions period, some authors use a 30-day period after the index hospital admission discharge, the others a 90-day period [86, 91, 92]. We think that the 90-day post-index hospital stay readmission period is more meaningful, because it is more likely to capture an adverse event due to a retained CBD stone rather than a 30-day period.

The post-operative length of stay (LOS) below 2 days (72 *h*) *with no hospital readmission* is an indicator of an uncomplicated cholecystectomy [93].

The prolonged post-operative LOS exceeding 3 days (96 *h*) is an indicator of protracted admission after LC.

The total length of hospital stay includes the length of the index hospital admission and duration of readmissions within 90-day post-index hospital stay discharge.

Thirty-day or 90-day postdischarge death is the death that occurs within 30 days or 90 days from either the index hospital admission or hospital readmission discharge.

Patient-reported outcome measures including generic (the Short Form 36 (SF-36) Health Survey, Nottingham Health Profile), preference-based (European Quality of Life Question-naire, EQ-5D) and condition-specific instruments (Otago Gallstones Condition-Specific Questionnaire, Gastrointestinal Quality of Life Index, Abdominal Surgery Impact Scale and Gallstone Impact Checklist) as well as economic evaluations (cost–minimization analysis, cost–consequence analysis, cost–effectiveness analysis, cost–utility analysis and cost–benefit analysis) can also be used as outcome measures.

4. Conclusion

LC is the treatment of choice for symptomatic GB disease, which in some patients requires CTO. CTO risk stratification based on patient- and surgeon-dependent variables may allow a better patient's management to keep CTO at low rates and maintain benefits of minimally invasive GB surgery. The absence of an association between CTO and IOI is an important surgical safety indicator that demonstrates that CTO is used as a safety strategy rather than an emergency measure to repair iatrogenic IOI and control haemorrhage.

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References

[1] Glambek I, Kvaale G, Arnesjo B, Soreide O. Prevalence of gallstones in a Norwegian population. Scand J Gastroenterol. [Research Support, Non-U.S. Gov't]. 1987 Nov;22(9): 1089–94.

[2] Muhrbeck O, Ahlberg J. Prevalence of gallstone disease in a Swedish population. Scand J Gastroenterol. [Research Support, Non-U.S. Gov't]. 1995 Nov;30(11):1125–8.

[3] Everhart JE, Khare M, Hill M, Maurer KR. Prevalence and ethnic differences in gallbladder disease in the United States. Gastroenterology. 1999 Sep;117(3):632–9.

[4] Gracie WA, Ransohoff DF. The natural history of silent gallstones: the innocent gallstone is not a myth. N Engl J Med. 1982 Sep 23;307(13):798–800.

[5] Halldestam I, Enell EL, Kullman E, Borch K. Development of symptoms and complications in individuals with asymptomatic gallstones. Br J Surg. 2004 Jun;91(6):734–8.

[6] Friedman GD. Natural history of asymptomatic and symptomatic gallstones. Am J Surg. [Research Support, U.S. Gov't, P.H.S.Review]. 1993 Apr;165(4):399–404.

[7] Papadakis M, Ambe PC, Zirngibl H. Critically ill patients with acute cholecystitis are at increased risk for extensive gallbladder inflammation. World J Emerg Surg. 2015;10:59.

[8] Haltmeier T, Benjamin E, Inaba K, Lam L, Demetriades D. Early versus delayed same-admission laparoscopic cholecystectomy for acute cholecystitis in elderly patients with comorbidities. J Trauma Acute Care Surg. 2015 Apr;78(4):801–7.

[9] Peery AF, Dellon ES, Lund J, Crockett SD, McGowan CE, Bulsiewicz WJ, et al. Burden of gastrointestinal disease in the United States: 2012 update. Gastroenterology. [Research Support, N.I.H., Extramural Research Support, Non-U.S. Gov't]. 2012 Nov; 143(5):1179–87 e1–3.

[10] Agresta F, Campanile FC, Vettoretto N, Silecchia G, Bergamini C, Maida P, et al. Laparoscopic cholecystectomy: consensus conference-based guidelines. Langenbecks Arch Surg. [Review]. 2015 May;400(4):429–53.

[11] Reynolds W, Jr. The first laparoscopic cholecystectomy. Jsls. [Biography Historical Article Portraits]. 2001 Jan–Mar;5(1):89–94.

[12] Csikesz N, Ricciardi R, Tseng JF, Shah SA. Current status of surgical management of acute cholecystitis in the United States. World J Surg. [Comparative Study Multicenter Study Research Support, Non-U.S. Gov't]. 2008 Oct;32(10):2230–6.

[13] Keus F, de Jong JA, Gooszen HG, van Laarhoven CJ. Laparoscopic versus open cholecystectomy for patients with symptomatic cholecystolithiasis. Cochrane Database Syst Rev. [Meta-Analysis Research Support, Non-U.S. Gov't Review]. 2006(4):CD006231.

[14] Bablekos GD, Michaelides SA, Analitis A, Charalabopoulos KA. Effects of laparoscopic cholecystectomy on lung function: a systematic review. World J Gastroenterol. [Meta-Analysis Review]. 2014 Dec 14;20(46):17603–17.

[15] Keus F, Gooszen HG, Van Laarhoven CJ. Systematic review: open, small-incision or laparoscopic cholecystectomy for symptomatic cholecystolithiasis. Aliment Pharmacol Ther. [Review]. 2009 Feb 15;29(4):359–78.

[16] Rosenmuller MH, Thoren Ornberg M, Myrnas T, Lundberg O, Nilsson E, Haapamaki MM. Expertise-based randomized clinical trial of laparoscopic versus small-incision open cholecystectomy. Br J Surg. [Comparative Study Randomized Controlled Trial Research Support, Non-U.S. Gov't]. 2013 Jun;100(7):886–94.

[17] Lo CM, Fan ST, Liu CL, Lai EC, Wong J. Early decision for conversion of laparoscopic to open cholecystectomy for treatment of acute cholecystitis. Am J Surg. 1997 Jun;173(6): 513–7.

[18] Sippey M, Grzybowski M, Manwaring ML, Kasten KR, Chapman WH, Pofahl WE, et al. Acute cholecystitis: risk factors for conversion to an open procedure. J Surg Res. 2015 Dec;199(2):357–61.

[19] Neugebauer E, Troidl H, Kum CK, Eypasch E, Miserez M, Paul A. The E.A.E.S. Consensus Development Conferences on laparoscopic cholecystectomy, appendectomy, and hernia repair. Consensus statements – September 1994. The Educational Committee of the European Association for Endoscopic Surgery. Surg Endosc. [Consensus Development Conference Research Support, Non-U.S. Gov't Review]. 1995 May;9(5):550–63.

[20] Nagle A., J. S. Laparoscopic Cholecystectomy and Choledocholithotomy. In: Blumgart LH, editor. Surgery of the Liver, Biliary Tract, and Pancreas. 4th ed. Philadelphia: Saunders Elsevier; 2007. p. 506–27.

[21] Cannon RM, Brock G, Buell JF. A novel classification system to address financial impact and referral decisions for bile duct injury in laparoscopic cholecystectomy. HPB Surg. 2011;2011:371245.

[22] Vollmer CM, Jr., Callery MP. Biliary injury following laparoscopic cholecystectomy: why still a problem? Gastroenterology. [Comment]. 2007 Sep;133(3):1039–41.

[23] Nijssen MA, Schreinemakers JM, Meyer Z, van der Schelling GP, Crolla RM, Rijken AM. Complications after laparoscopic cholecystectomy: a video evaluation study of whether the critical view of safety was reached. World J Surg. 2015 Jul;39(7):1798–803.

[24] Strasberg SM. Biliary injury in laparoscopic surgery: part 1. Processes used in determination of standard of care in misidentification injuries. Journal of the American College of Surgeons. [Review]. 2005 Oct;201(4):598–603.

[25] Lipman JM, Claridge JA, Haridas M, Martin MD, Yao DC, Grimes KL, et al. Preoperative findings predict conversion from laparoscopic to open cholecystectomy. Surgery. 2007 Oct;142(4):556–63; discussion 63–5.

[26] Pitt SC, Jin LX, Hall BL, Strasberg SM, Pitt HA. Incidental gallbladder cancer at cholecystectomy: when should the surgeon be suspicious? Ann Surg. 2014 Jul;260(1): 128–33.

[27] Schafer M, Krahenbuhl L, Buchler MW. Predictive factors for the type of surgery in acute cholecystitis. Am J Surg. 2001 Sep;182(3):291–7.

[28] Rosen M, Brody F, Ponsky J. Predictive factors for conversion of laparoscopic cholecystectomy. Am J Surg. 2002 Sep;184(3):254–8.

[29] Yang TF, Guo L, Wang Q. Evaluation of preoperative risk factor for converting laparoscopic to open cholecystectomy: a meta-analysis. Hepato-gastroenterology. [Meta-Analysis Review]. 2014 Jun;61(132):958–65.

[30] Licciardello A, Arena M, Nicosia A, Di Stefano B, Cali G, Arena G, et al. Preoperative risk factors for conversion from laparoscopic to open cholecystectomy. Eur Rev Med Pharmacol Sci. 2014 Dec;18(2 Suppl):60–8.

[31] Akcakaya A., Okan I., Bas G., Sahin G., Sachin M. Does the difficulty of laparoscopic cholecystectomy differ between genders? Indian J Surg. 2015;77 (Suppl 2):S452–6.

[32] Donkervoort SC, van Ruler O, Dijksman LM, van Geloven AA, Pierik EG. Identification of risk factors for an unfavorable laparoscopic cholecystectomy course after endoscopic retrograde cholangiography in the treatment of choledocholithiasis. Surg Endosc. 2010 Apr;24(4):798–804.

[33] Simopoulos C, Botaitis S, Karayiannakis AJ, Tripsianis G, Pitiakoudis M, Polychronidis A. The contribution of acute cholecystitis, obesity, and previous abdominal surgery on the outcome of laparoscopic cholecystectomy. Am Surg. 2007 Apr;73(4):371–6.

[34] Yokoe M, Takada T, Strasberg SM, Solomkin JS, Mayumi T, Gomi H, et al. TG13 diagnostic criteria and severity grading of acute cholecystitis (with videos). J Hepato-biliary Pancreat Sci. [Practice Guideline]. 2013 Jan;20(1):35–46.

[35] Cwik G, Skoczylas T, Wyroslak-Najs J, Wallner G. The value of percutaneous ultra-sound in predicting conversion from laparoscopic to open cholecystectomy due to acute cholecystitis. Surg Endosc. [Comparative Study]. 2013 Jul;27(7):2561–8.

[36] Paul Wright G, Stilwell K, Johnson J, Hefty MT, Chung MH. Predicting length of stay and conversion to open cholecystectomy for acute cholecystitis using the 2013 Tokyo Guidelines in a US population. J Hepatobiliary Pancreat Sci. 2015 Nov;22(11):795–801.

[37] Asai K, Watanabe M, Kusachi S, Matsukiyo H, Saito T, Kodama H, et al. Risk factors for conversion of laparoscopic cholecystectomy to open surgery associated with the severity characteristics according to the Tokyo guidelines. Surg Today. 2014 Dec;44(12): 2300–4.

[38] Lal P, Agarwal PN, Malik VK, Chakravarti AL. A difficult laparoscopic cholecystecto-my that requires conversion to open procedure can be predicted by preoperative ultrasonography. Jsls. 2002 Jan–Mar;6(1):59–63.

[39] Gupta N, Ranjan G, Arora MP, Goswami B, Chaudhary P, Kapur A, et al. Validation of a scoring system to predict difficult laparoscopic cholecystectomy. Int J Surg. 2013;11(9):1002–6.

[40] Stanisic V, Milicevic M, Kocev N, Stojanovic M, Vlaovic D, Babic I, et al. Prediction of difficulties in laparoscopic cholecystectomy on the base of routinely available param-eters in a smaller regional hospital. Eur Rev Med Pharmacol Sci. 2014;18(8):1204–11.

[41] Nidoni R, Udachan TV, Sasnur P, Baloorkar R, Sindgikar V, Narasangi B. Predicting difficult laparoscopic cholecystectomy based on clinicoradiological assessment. J Clin Diagn Res. 2015 Dec;9(12):PC09–12.

[42] Bedirli A, Sozuer EM, Yuksel O, Yilmaz Z. Laparoscopic cholecystectomy for sympto-matic gallstones in diabetic patients. J Laparoendosc Adv Surg Tech A. 2001 Oct;11(5): 281–4.

[43] Paajanen H, Suuronen S, Nordstrom P, Miettinen P, Niskanen L. Laparoscopic versus open cholecystectomy in diabetic patients and postoperative outcome. Surg Endosc. [Evaluation Studies]. 2011 Mar;25(3):764–70.

[44] Cho JY, Han HS, Yoon YS, Ahn KS. Risk factors for acute cholecystitis and a complicated clinical course in patients with symptomatic cholelithiasis. Arch Surg. 2010 Apr;145(4): 329–33; discussion 33.

[45] Karamanos E, Sivrikoz E, Beale E, Chan L, Inaba K, Demetriades D. Effect of diabetes on outcomes in patients undergoing emergent cholecystectomy for acute cholecystitis. World J Surg. [Evaluation Studies]. 2013 Oct;37(10):2257–64.

[46] Hickman MS, Schwesinger WH, Page CP. Acute cholecystitis in the diabetic. A case-control study of outcome. Arch Surg. [Comparative Study]. 1988 Apr;123(4):409–11.

[47] Walsh DB, Eckhauser FE, Ramsburgh SR, Burney RB. Risk associated with diabetes mellitus in patients undergoing gallbladder surgery. Surgery. 1982 Mar;91(3):254–7.

[48] Shpitz B, Sigal A, Kaufman Z, Dinbar A. Acute cholecystitis in diabetic patients. Am Surg. [Comparative Study]. 1995 Nov;61(11):964–7.

[49] Ibrahim S, Hean TK, Ho LS, Ravintharan T, Chye TN, Chee CH. Risk factors for conversion to open surgery in patients undergoing laparoscopic cholecystectomy. World J Surg. 2006 Sep;30(9):1698–704.

[50] Lee NW, Collins J, Britt R, Britt LD. Evaluation of preoperative risk factors for converting laparoscopic to open cholecystectomy. Am Surg. 2012 Aug;78(8):831–3.

[51] Aziz H, Pandit V, Joseph B, Jie T, Ong E. Age and obesity are independent predictors of bile duct injuries in patients undergoing laparoscopic cholecystectomy. World J Surg. 2015 Jul;39(7):1804–8.

[52] Goonawardena J, Gunnarsson R, de Costa A. Predicting conversion from laparoscopic to open cholecystectomy presented as a probability nomogram based on preoperative patient risk factors. Am J Surg. 2015 Sep;210(3):492–500.

[53] Paajanen H, Kakela P, Suuronen S, Paajanen J, Juvonen P, Pihlajamaki J. Impact of obesity and associated diseases on outcome after laparoscopic cholecystectomy. Surg Laparosc Endosc Percutan Tech. 2012 Dec;22(6):509–13.

[54] Costantini R, Caldaralo F, Palmieri C, Napolitano L, Aceto L, Cellini C, et al. Risk factors for conversion of laparoscopic cholecystectomy. Ann Ital Chir. 2012 May–Jun;83(3): 245–52.

[55] Ahn KS, Kim YH, Kang KJ, Kim TS, Cho KB, Kim ES. Impact of preoperative ERCP on laparoscopic cholecystectomy: a case-controlled study with propensity score matching. World J Surg. [Research Support, Non-U.S. Gov't]. 2015 Sep;39(9):2235–42.

[56] Kwon YH, Cho CM, Jung MK, Kim SG, Yoon YK. Risk factors of open converted cholecystectomy for cholelithiasis after endoscopic removal of choledocholithiasis. Dig Dis Sci. 2015 Feb;60(2):550–6.

[57] Beliaev AM, Booth M. Late two-stage laparoscopic cholecystectomy is associated with an increased risk of major bile duct injury. ANZ J Surg. 2016 Jan;86(1–2):63–8.

[58] Boerma D, Rauws EA, Keulemans YC, Janssen IM, Bolwerk CJ, Timmer R, et al. Wait-and-see policy or laparoscopic cholecystectomy after endoscopic sphincterotomy for bile-duct stones: a randomised trial. Lancet. [Clinical Trial Multicenter Study Randomized Controlled Trial Research Support, Non-U.S. Gov't]. 2002 Sep 7;360(9335):761–5.

[59] Maseda E, Maggi G, Gomez-Gil R, Ruiz G, Madero R, Garcia-Perea A, et al. Prevalence of and risk factors for biliary carriage of bacteria showing worrisome and unexpected resistance traits. J Clin Microbiol. 2013 Feb;51(2):518–21.

[60] Reinders JS, Kortram K, Vlaminckx B, van Ramshorst B, Gouma DJ, Boerma D. Incidence of bactobilia increases over time after endoscopic sphincterotomy. Dig Surg. [Multicenter Study Randomized Controlled Trial]. 2011;28(4):288–92.

[61] Hirota M, Takada T, Kawarada Y, Nimura Y, Miura F, Hirata K, et al. Diagnostic criteria and severity assessment of acute cholecystitis: Tokyo Guidelines. J Hepatobiliary Pancreat Surg. [Practice Guideline Research Support, Non-U.S. Gov't]. 2007;14(1):78–82.

[62] Wevers KP, van Westreenen HL, Patijn GA. Laparoscopic cholecystectomy in acute cholecystitis: C-reactive protein level combined with age predicts conversion. Surg Laparosc Endosc Percutan Tech. [Comparative Study]. 2013 Apr;23(2):163–6.

[63] Beliaev AM, Marshall RJ, Booth M. C-reactive protein has a better discriminative power than white cell count in the diagnosis of acute cholecystitis. J Surg Res. 2015 Sep;198(1):66–72.

[64] Tayeb M, Raza SA, Khan MR, Azami R. Conversion from laparoscopic to open cholecystectomy: multivariate analysis of preoperative risk factors. J Postgrad Med. 2005 Jan–Mar;51(1):17–20; discussion 1–2.

[65] Pejovic T, Stojadinovic MM. Scoring system development and validation for prediction choledocholithiasis before open cholecystectomy. Srp Arh Celok Lek. [Research Support, Non-U.S. Gov't]. 2015 Nov–Dec;143(11–12):681–7.

[66] Kanakala V, Borowski DW, Pellen MG, Dronamraju SS, Woodcock SA, Seymour K, et al. Risk factors in laparoscopic cholecystectomy: a multivariate analysis. Int J Surg. 2011;9(4):318–23.

[67] Yamashita Y, Takada T, Strasberg SM, Pitt HA, Gouma DJ, Garden OJ, et al. TG13 surgical management of acute cholecystitis. J Hepatobiliary Pancreat Sci. [Practice Guideline]. 2013 Jan;20(1):89–96.

[68] Booij KA, de Reuver PR, Nijsse B, Busch OR, van Gulik TM, Gouma DJ. Insufficient safety measures reported in operation notes of complicated laparoscopic cholecystectomies. Surgery. [Evaluation Studies]. 2014 Mar;155(3):384–9.

[69] Strasberg SM, Brunt LM. Rationale and use of the critical view of safety in laparoscopic cholecystectomy. J Am Coll Surg. 2010 Jul;211(1):132–8.

[70] Shingu Y, Komatsu S, Norimizu S, Taguchi Y, Sakamoto E. Laparoscopic subtotal cholecystectomy for severe cholecystitis. Surg Endosc. 2016 Feb;30(2):526–31.

[71] Kaplan D, Inaba K, Chouliaras K, Low GM, Benjamin E, Lam L, et al. Subtotal chole-cystectomy and open total cholecystectomy: alternatives in complicated cholecystitis. Am Surg. [Comparative Study Evaluation Studies]. 2014 Oct;80(10):953–5.

[72] Sinha I, Smith ML, Safranek P, Dehn T, Booth M. Laparoscopic subtotal cholecystecto-my without cystic duct ligation. Br J Surg. 2007 Dec;94(12):1527–9.

[73] Strasberg SM, Eagon CJ, Drebin JA. The "hidden cystic duct" syndrome and the infundibular technique of laparoscopic cholecystectomy – the danger of the false infundibulum. J Am Coll Surg. 2000 Dec;191(6):661–7.

[74] Strasberg SM. Biliary injury in laparoscopic surgery: part 2. Changing the culture of cholecystectomy. J Am Coll Surg. [Review]. 2005 Oct;201(4):604–11.

[75] Abelson JS, Afaneh C, Rich BS, Dakin G, Zarnegar R, Fahey TJ, 3rd, et al. Advanced laparoscopic fellowship training decreases conversion rates during laparoscopic cholecystectomy for acute biliary diseases: a retrospective cohort study. Int J Surg. 2015 Jan;13:221–6.

[76] Blumgart LH. Stones in the Common Bile Duct – Clinical Features and Open Surgical Approaches and Techniques. In: Blumgart LH, editor. Surgery of the Liver, Biliary Tract, and Pancreas. 4th ed. Philadelphia: Saunders Elsevier; 2007. p. 528–47.

[77] Koc B, Adas G, Karahan S. Use of laparoscopic common bile duct exploration for failed endoscopic bile duct stone extractions. Minerva Chir. 2014 Aug;69(4):209–15.

[78] Alponat A, Kum CK, Koh BC, Rajnakova A, Goh PM. Predictive factors for conversion of laparoscopic cholecystectomy. World J Surg. 1997 Jul–Aug;21(6):629–33.

[79] Afaneh C, Abelson J, Rich BS, Dakin G, Zarnegar R, Barie PS, et al. Obesity does not increase morbidity of laparoscopic cholecystectomy. J Surg Res. 2014 Aug;190(2):491–7.

[80] Andrews S. Does concentration of surgical expertise improve outcomes for laparo-scopic cholecystectomy? 9 year audit cycle. Surgeon. 2013 Dec;11(6):309–12.

[81] Giger UF, Michel JM, Opitz I, Th Inderbitzin D, Kocher T, Krahenbuhl L. Risk factors for perioperative complications in patients undergoing laparoscopic cholecystectomy: analysis of 22,953 consecutive cases from the Swiss Association of Laparoscopic and Thoracoscopic Surgery database. J Am Coll Surg. 2006 Nov;203(5):723–8.

[82] Madani A, Watanabe Y, Feldman LS, Vassiliou MC, Barkun JS, Fried GM, et al. Expert intraoperative judgment and decision-making: defining the cognitive competencies for safe laparoscopic cholecystectomy. J Am Coll Surg. [Research Support, Non-U.S. Gov't]. 2015 Nov;221(5):931–40 e8.

[83] Kama NA, Kologlu M, Doganay M, Reis E, Atli M, Dolapci M. A risk score for conver-sion from laparoscopic to open cholecystectomy. Am J Surg. 2001 Jun;181(6):520–5.

[84] Kologlu M, Tutuncu T, Yuksek YN, Gozalan U, Daglar G, Kama NA. Using a risk score for conversion from laparoscopic to open cholecystectomy in resident training. Surgery. [Validation Studies]. 2004 Mar;135(3):282–7.

[85] Sugrue M, Sahebally SM, Ansaloni L, Zielinski MD. Grading operative findings at laparoscopic cholecystectomy – a new scoring system. World J Emerg Surg. 2015;10:14.

[86] Fry DE, Pine M, Locke D, Pine G. Composite measurement of outcomes in medicare inpatient laparoscopic cholecystectomy. J Am Coll Surg. [Evaluation Studies Research Support, Non-U.S. Gov't]. 2015 Jul;221(1):102–9.

[87] Muller BP, Holzinger F, Leepin H, Klaiber C. Laparoscopic cholecystectomy: quality of care and benchmarking. Results of a single-institution specialized in laparoscopy compared with those of a nationwide study in Switzerland. Surg Endosc. [Comparative Study Validation Studies]. 2003 Feb;17(2):300–5.

[88] Strasberg SM, Hertl M, Soper NJ. An analysis of the problem of biliary injury during laparoscopic cholecystectomy. J Am Coll Surg. [Review]. 1995 Jan;180(1):101–25.

[89] Beliaev AM, Booth M. An association between conversion of laparoscopic cholecystectomy to open surgery and intra-abdominal organ injury. ANZ J Surg. 2016; doi: 10.1111/ans.13539.

[90] Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. [Comparative Study Evaluation Studies Validation Studies]. 2004 Aug;240(2):205–13.

[91] Fry DE, Pine M, Pine G. Ninety-day postdischarge outcomes of inpatient elective laparoscopic cholecystectomy. Surgery. [Evaluation Studies]. 2014 Oct;156(4):931–6.

[92] Rana G, Bhullar JS, Subhas G, Kolachalam RB, Mittal VK. Thirty-day readmissions after inpatient laparoscopic cholecystectomy: factors and outcomes. Am J Surg. 2016 Mar; 211(3):626–30.

[93] Harboe KM, Bardram L. The quality of cholecystectomy in Denmark: outcome and risk factors for 20,307 patients from the national database. Surg Endosc. 2011 May;25(5): 1630–41.