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Acute cholecystitis, obesity, and steatohepatitis constitute the lethal triad for bile duct injury (BDI) during laparoscopic cholecystectomy

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Abstract

Objective The most feared complication during laparoscopic cholecystectomy remains a bile duct injury (BDI). Accurately risk-stratifying patients for a BDI remains difficult and imprecise. This study evaluated if the lethal triad of acute cholecystitis, obesity, and steatohepatitis is a prognostic measure for BDI.

Methods A retrospective review of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) registry was performed. All laparoscopic cholecystectomy cases within the main NSQIP database for 2012–2019 were queried. Two study cohorts were constructed. One with the lethal triad of acute cholecystitis, BMI ≥ 30, and steatohepatitis. The other cohort did not have the full triad present. Multivariate analysis was performed via logistic regression modeling with calculation of odds ratios (OR) to identify independent factors for BDI. An uncontrolled and controlled propensity score match analysis was performed.

Results A total of 387,501 cases were analyzed. 36,887 cases contained the lethal triad, the remaining 350,614 cases did not have the full triad. 860 BDIs were identified resulting in an overall incidence rate 0.22%. There were 541 BDIs within the lethal triad group with 319 BDIs in the other cohort and an incidence rate of 1.49% vs 0.09% ($P < 0.001$). Multivariate analysis identified the lethal triad as an independent risk factor for a BDI by over 15-fold (OR 16.35, 95%CI 14.28–18.78, $P < 0.0001$) on the uncontrolled analysis. For the controlled propensity score match there were 29,803 equivalent pairs identified between the cohorts. The BDI incidence rate remained significantly higher with lethal triad cases at 1.65% vs 0.04% ($P < 0.001$). The lethal triad was an even more significant independent risk factor for BDI on the controlled analysis (OR 40.13, 95%CI 7.05–356.59, $P < 0.0001$).

Conclusions The lethal triad of acute cholecystitis, obesity, and steatohepatitis significantly increases the risk of a BDI. This prognostic measure can help better counsel patients and potentially alter management.

Keywords Cholecystectomy · Bile duct injury · Cholecystitis · Lethal triad · Obesity · Steatohepatitis

Laparoscopic cholecystectomy remains one the most common general surgery procedures performed annually in the United States as well as worldwide [1]. The most feared complication during a laparoscopic cholecystectomy is a bile duct injury (BDI). This major complication has been the surgical consternation with the procedure since the onset with the historic concern being that BDIs were more prevalent with the laparoscopic approach compared to the previous open standard [2, 3]. Now with the majority of operating surgeons possessing advanced laparoscopic surgical experience the BDI rate associated with laparoscopic cholecystectomies is equivocal to the pinnacle low-incidence rate established with the open approach [4, 5]. While the current BDI rate with laparoscopic cholecystectomy is statistically low, approximately 0.2%, it remains a dreaded complication with severe morbidity [4, 6–8]. Despite being one of the most frequently performed operations with a tremendous amount of surgical teaching and education dedicated to making BDIs a "never event" with laparoscopic cholecystectomies there

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is relatively limited literature identifying those individuals at highest risk for BDI [9–11].

Our study objective was to identify a high-risk patient population for BDIs. Based on the surgical experience of the authors, a lethal triad for BDIs in those undergoing laparoscopic cholecystectomy was proposed. This triad is defined by the presence of acute cholecystitis, obesity, and underlying steatohepatitis. Utilizing the *American College of Surgeons* (ACS) *National Surgical Quality Improvement Program* (NSQIP) registry, the risk of BDI in patients with the lethal triad was assessed and compared to the general population.

Methods

A retrospective review of the ACS NSQIP registry was performed. NSQIP systematically records hundreds of preoperative, perioperative, and postoperative variables collected from nearly 700 international participant hospitals by trained registrars [12]. The NSQIP registry has been validated for high-quality academic surgical research [12, 13]. The main institution is a participant member of the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) and is authorized by the ACS to scientifically research and publish NSQIP data and thus separate IRB review was not required.

The NSQIP database was analyzed from 2012 to 2019. Procedural identification was performed via Common Procedural Terminology (CPT) codes 47,562 and 47,563 which correlated with operations performed with and without intraoperative cholangiography (IOC) respectively. BDIs were identified via International Classification of Disease (ICD) codes within the postoperative diagnosis fields, reoperative diagnosis fields, or readmission diagnosis fields within NSQIP. The time period in which the NSQIP datasets was analyzed involved the transition from ICD-9 to ICD-10 coding, therefore, any ICD code associated with a BDI was selected. ICD-9 terminology has several codes that could be considered a BDI to include 576.3, 576.4, 576.0, 868.02, 995, 997.4, 997.49, 998.13, 998.2, 998.51, 998.59, 998.89. ICD-10 terminology is more specific for a BDI and has a standalone category of S36.13. Baseline demographics for the entire study included age, sex, race, functional status, American Society of Anesthesia (ASA) class, medical comorbidities, smoking history, and admission/operative characteristics.

Two study cohorts were constructed: a lethal triad group and a non-lethal triad group. The lethal triad cohort was defined by the inclusion of all the following criteria: acute cholecystitis, clinical obesity, and underlying steatohepatitis. The presence of cholecystitis was determined by ICD-9 or -10 codes within the postoperative diagnosis field. Patients with clinical obesity were identified by a body mass index (BMI) equal to or greater than 30 which is consistent with class I obesity as defined by the National Institute of Health (NIH) and World Health Organization (WHO). Determination of underlying steatohepatitis was obtained via hepatic steatosis index (HIS) scoring with a threshold score of ≥ 36, which has a positive predictive value of 92.4% [14, 15]. To prevent confounding, cirrhotic patients were excluded from analysis. Acting as control cases, the non-lethal triad cohort had up to two of the lethal triad criteria present.

The primary study analysis involved an unadjusted multivariate analysis for factors associated with a BDI utilizing the lethal triad criteria in addition to other known or suspected risk factors for BDI. In order to better control for an equivalent comparison between the cohorts, propensity score matching was performed. Propensity score testing variables included all the baseline demographics used in the main unadjusted analysis. Following identification of properly matched cases between the cohorts, an adjusted multivariate analysis was performed in a similar fashion to the main analysis.

Statistical analysis

For comparison of characteristics between the cohorts, categorical variables were evaluated using Pearson's Chi-square testing and quantitative variables were evaluated using Fisher's exact testing. Propensity-score matching was performed as previously described. Multivariate analysis was performed via multiple linear regression in a stepwise fashion. Odds ratios (OR) were reported based on multivariate analysis. All reported P values in this study were considered statistically significant based on $P < 0.05$. All statistical analysis were processed using the International Business Machines (IBM) Statistical Package for Social Sciences version 28.0.0 analytical software (IBM Inc. Armonk, New York).

Results

A total of 387,501 laparoscopic cholecystectomy cases were present within the selected NSQIP datasets. For the study cohorts, there were 36,887 cases within the lethal triad group and 350,614 cases in the control group. The baseline demographics for the cohorts are provided in Table 1. The overall study population was primarily Caucasian females in their mid-to-late 40 s who were completely independent with mild medical comorbidities undergoing an outpatient cholecystectomy without cholangiography. The study cohorts had several statically significant differences in baseline demographics to include age, sex, race, functional status, ASA class, medical comorbidities, procedure

Table 1 Overall study demographics

	Lethal triad Cohort (N = 36,887 cases)	Non-lethal triad Cohort (N = 350,614 cases)	P value
Age†	46.9 years old (± 16.6)	49.4 years old (± 17.2)	0.001
Sex†	Male, 26.4%	Male, 30.4%	0.001
	Female, 73.6%	Female, 69.6%	
Race†	Caucasian, 66.3%	Caucasian, 70.8%	< 0.0001
	Hispanic, 15.4%	Hispanic, 16.3%	
	African-American, 15.4%	African-American, 8.0%	
	Asian, 1.3%	Asian, 3.5%	
	Pacific-Islander, 0.7%	Pacific-Islander, 0.4%	
	American-Indian, 0.9%	American-Indian, 0.9%	
Functional status†	Independent, 97.3%	Independent, 98.0%	0.001
	Partially dependent, 1.7%	Partially dependent, 0.9%	
	Completely dependent, 1.0%	Completely dependent, 1.1%	
ASA class†	ASA-1, 3.6%	ASA-1, 11.7%	< 0.0001
	ASA-2, 45.8%	ASA-2, 58.2%	
	ASA-3, 46.2%	ASA-3, 27.9%	
	ASA-4, 4.2%	ASA-4, 2.1%	
	ASA-5, 0.01%	ASA-5, 0.01%	
Cardiovascular disease†	39.9%	32.9%	0.001
Pulmonary disease†	3.3%	2.6%	0.001
Renal disease†	0.9%	0.5%	0.001
Diabetic†	18.9%	12.0%	0.001
Smoker	17.0%	17.2%	0.175
Cholecystectomy procedure†	Cholecystectomy alone, 74.3%	Cholecystectomy alone, 77.9%	0.001
	Cholecystectomy with IOC, 25.7%	Cholecystectomy with IOC, 22.1%	
Disposition status†	Outpatient, 0.5%	Outpatient, 69%	< 0.0001
	Inpatient, 99.%	Inpatient, 31%	
Operative time†	83 min (± 47)	64 min (± 38)	< 0.0001

†Statistically significant

type, and disposition status. There were 860 BDIs identified within the study population which resulted in an overall BDI incidence rate of 0.22%. The characteristics of the BDI and non-BDI cases are presented in Table 2. The characteristics of the patient population that suffered BDIs was very similar to the overall study population with a Caucasian female in their late 40 s who was completely independent with mild systemic disease undergoing an outpatient cholecystectomy without cholangiography.

The results of the unadjusted multivariate analysis of the entire study population are provided in Table 3. Several independent factors were associated with BDI on that multivariate analysis. The lethal triad was the most significant risk factor for a BDI with an OR of 16.35 (95%CI 14.23–18.78, $P < 0.0001$). A BDI occurred in 1.49% of the lethal triad cases compared to 0.09% in the control group ($P < 0.001$). The acute cholecystitis and obesity components of the lethal triad were also independent risk factors for a BDI with ORs of 1.22 (95%CI 1.06–1.40, $P = 0.004$) and 2.31 (95%CI 2.02–2.64, $P = 0.001$), respectively. The steatohepatitis component of the lethal triad did not reach significance on the unadjusted analysis (OR 0.94, 95%CI 0.82–1.07, $P = 0.063$). The other independent risk factors for a BDI on the unadjusted analysis were smoking (OR 1.48, 95%CI 1.26–1.73, $P = 0.001$) and inpatient surgery (OR 1.22, 95%CI 1.06–1.40, $P = 0.004$). Non-Caucasian race was the one factor independently associated with a decreased rate of a BDI (OR 0.67, 95%CI 0.93–1.24, $P = 0.001$).

On propensity score matching 29,803 equivocally matched pairs between the lethal triad and control groups were selected resulting in a total of 59,606 cases for the adjusted analysis. The characteristics of the propensity matched cases are presented in Table 4. Similar to the main unadjusted analysis, the cases in the propensity score match were primarily Caucasian females in their late 40 s who were completely independent with mild systemic disease who underwent a cholecystectomy without IOC. The only difference in the adjusted analysis was nearly

Table 2 BDI characteristics

	BDI cases (*N* = 860)	Non-BDI cases (*N* = 386,641)	*P* value
Age	49.6 years old (± 16.4)	49.2 years old (± 17.2)	0.453
Sex	Male, 31.5%	Male, 30.0%	0.352
	Female, 68.5%	Female, 70.0%	
Race†	Caucasian, 75.9%	Caucasian, 70.4%	0.001
	Hispanic, 14.0%	Hispanic, 16.2%	
	African-American, 5.6%	African-American, 8.7%	
	Asian, 2.3%	Asian, 3.3%	
	Pacific-Islander, 0.1%	Pacific-Islander, 0.1%	
	American-Indian, 2.1%	American-Indian, 0.9%	
Functional status	Independent, 97.4%	Independent, 98.0%	0.285
	Partially dependent, 1.6%	Partially dependent, 1.0%	
	Completely dependent, 1.0%	Completely dependent, 1.0%	
ASA class	ASA-1, 10.0%	ASA-1, 11.0%	0.566
	ASA-2, 55.7%	ASA-2, 57.0%	
	ASA-3, 31.2%	ASA-3, 29.6%	
	ASA-4, 2.9%	ASA-4, 2.3%	
	ASA-5, 0.01%	ASA-5, 0.01%	
Cardiovascular disease†	36.9%	33.7%	0.042
Pulmonary disease†	5.0%	2.6%	0.001
Renal disease	0.6%	0.6%	1.00
Diabetic†	18.9%	12.0%	0.001
Smoker†	23.5%	17.2%	0.001
Cholecystectomy procedure	Cholecystectomy alone, 76.3%	Cholecystectomy alone, 77.6%	0.369
	Cholecystectomy with IOC, 23.7%	Cholecystectomy with IOC, 22.4%	
Disposition status†	Outpatient, 57.8%	Outpatient, 62.5%	0.005
	Inpatient, 42.2.%	Inpatient, 37.5%	
Operative time†	73 min (± 49)	65 min (± 39)	0.001

†Statistically significant

all cases were inpatient procedures. The results from the adjusted multivariate analysis are provided in Table 5. Again, the lethal triad was the strongest risk factor for a BDI in the adjusted analysis with an OR of 40.13 (95%CI 7.05–356.59, $P < 0.0001$). The BDI incidence rate in the lethal triad group was 1.65% compared to 0.04% in the control group ($P < 0.001$) and provided in Table 6. All of the individual components of the lethal triad were independent risk factors for a BDI within the adjusted analysis with ORs of 1.56 (95%CI 1.46–1.67, $P = 0.001$), 1.74 (95%CI 1.45–2.09, $P = 0.006$), and 1.002 (95%CI 1.001–1.072, $P = 0.039$) for acute cholecystitis, obesity, and steatohepatitis respectively. Again, smoking (OR 1.29, 95%CI 1.04–1.61, $P = 0.034$) and inpatient surgery (OR 1.56, 95%CI 1.46–1.67, $P = 0.001$) were independent risk factors on the adjusted analysis with non-Caucasian race (OR 0.59, 95%CI 0.49–0.71, $P = 0.004$) being the only factor associated with a decreased BDI risk. Female sex (OR 1.32, 95%CI 1.09–1.58, $P = 0.011$) and morbid obesity (OR 1.23, 95%CI 1.01–1.49, $P = 0.002$) were found to be new independent risk factors for BDI in the adjusted analysis.

Discussion

BDI is one of the most feared complications during laparoscopic cholecystectomy and, though rare, when it does occur, the negative health impact on the patient is significant. Not only is it associated with longer hospital stays, increased pain, and potential need for reintervention, it has also been shown to carry a sixfold increase in all-cause mortality as well as a 126% increase in payments per patient [16, 17]. Multiple interventions have been implemented in an effort to reduce the risk of BDI. Standard requirements for achieving the critical view of safety prior to transection of the cystic duct is the prime example of an intraoperative intervention created to prevent inadvertent BDI, in

Table 3 Unadjusted multivariate analysis BDI

	Odds ratio	95%CI	*P* value
Acute cholecystitis[†]	1.219	1.064–1.396	0.004
BMI ≥ 30[†]	2.305	2.015–2.637	0.001
Steatohepatitis	0.938	0.820–1.072	0.063
Lethal triad[†]	16.345	14.227–18.778	< 0.0001
Sex	1.071	0.927–1.237	0.341
Race[†]	0.672	0.581–0.776	0.001
Age	1.001	0.998–1.005	0.811
Functional status	1.272	0.832–1.943	0.062
ASA class	1.109	0.963–1.277	0.343
Morbid obesity[a]	0.910	0.736–1.124	0.204
Diabetic	0.951	0.774–1.167	0.357
Smoker[†]	1.477	1.262–1.730	0.001
Disposition status[†]	1.219	1.064–1.396	0.004
IOC performed	1.074	0.918–1.257	0.492
Pre-Op WBC	1.000	0.998–1.001	0.474
Pre-Op AST/ALT	0.999	0.998–1.001	0.283
Pre-Op alk phos	1.000	0.999–1.001	0.331
Pre-Op bilirubin	0.998	0.997–1.001	0.623
Pre-Op albumin	0.999	0.998–1.001	0.233

[†]Statistically significant

[a]Morbid obesity defined as BMI ≥ 40

addition to being a critical education component in surgical training of safe cholecystectomy [18]. Additional surgical adjuncts including intraoperative cholangiography, via standard cholangiogram or emerging techniques such as ICG fluorescence, or intraoperative ultrasound (IOUS) have been proposed as measures to limit BDI but have not conclusively proven to limit BDI occurances [4, 19]. Intraoperative "time outs" with peer assessment to confirm the critical view of safety has been achieved as well as artificial intelligence augmentation to ensure achieving the critical view of safety have also been recommended to minimize BDIs [20–22]. If preoperative patient characteristics indicating increased risk for BDI can be established, this may lead to alterations in practice patterns with further reduction in incidences of BDI. However, there is currently a limited paucity of literature that identifies high-risk patients for BDI. It was the objective of this study to propose a high-risk patient population for BDI based on the surgical experience of the authors. In our collective history the combination of cholecystitis, obesity, and steatohepatitis presented a significant impediment to effectively achieving a critical view of safety and increased the risk for BDI. Utilizing the NSQIP registry we attempted to confirm our clinical suspicion that there was a "lethal triad" for BDI during laparoscopic cholecystectomy with large volume data.

Previous studies have attempted to identify patient characteristics that are associated with higher rates of BDI and although results are largely dated and vary across studies, there are some clear trends. Bjorn et al. identified acute cholecystitis as an independent risk factor for BDI with increasing risk corresponding to increasing levels of inflammation as defined by the Tokyo classification [23]. That study however reported that BMI was not an independent risk factor though this may be due to a smaller sample size and inadequate power [23]. Hasan et al. reported a significantly larger study which was able to identify preoperative obesity as a significant risk factor though the exact underlying mechanism was unclear and may relate to overall longer operative times associated with obesity or unclear anatomy associated with increased intraabdominal fat [24]. Fullum et al. further identified male sex, age > 60 and surgery performed in an academic setting as independent risk factors [25]. However, these have been contradicted in other studies such as by Nuzzo et al., Moossa et al., and Yang et al [26–28]. All of which identify some overlapping preoperative risk factors but without consistent trends. The only consistently proven increased risk factor for BDI with laparoscopic cholecystectomy is the presence of cholecystitis [29–31]. Yet, the clinical utility of that knowledge is limited considering the ubiquity of cholecystitis in patients undergoing cholecystectomy. Therefore, more specific stratification of high-risk BDI patients is greatly desired within the surgical community.

Within this study, the lethal triad of acute cholecystitis, obesity, and hepatic steatosis was identified as the most significant patient-related factors leading to an increased risk for BDI. That lethal triad was associated with an over 15-fold increase in the rate of BDI on the unadjusted analysis and 40-fold increase on the adjusted analysis. These characteristics are important especially for the US population due to their sheer prevalence. Within the US, rates of obesity have continually increased since the late 1990s [32]. Today, roughly 70% of the population is overweight and 40% of the US population is obese [32]. Additionally, 27% of the population has hepatic steatosis and, annually, over 200,000 Americans are diagnosed with acute cholecystitis [20, 21]. Therefore, the number of patients presenting with the constellation of characteristics that we have coined the "lethal triad" is likely to continue increasing and preoperative recognition is essential. Through operative experience of the included authors the presence of inflammation, increased intra-abdominal fat, reduced domain, and a large steatohepatic liver all contribute to a significantly more difficult operation and decreased ability to achieve the critical view of safety. In addition to anecdotal increased BDIs in that specific patient population, it was not surprising that increased rates of BDIs in the lethal triad was also supported by the NSQIP analysis results.

The lethal triad can serve as a prognostic indicator for patients at higher-than-average risk for BDI and guide preoperative risk counseling, risk reduction measures, and

Table 4 Propensity score match results

	Lethal triad Cohort (N=29,803 cases)	Non-lethal triad Cohort (N=29,803 cases)
Age	48.5 years old (±16.8)	48.2 years old (±18.7)
Sex	Male, 29.8%	Male, 28.5%
	Female, 70.2%	Female, 71.5%
Race	Caucasian, 66.0%	Caucasian, 65.8%
	Hispanic, 16.3%	Hispanic, 19.1%
	African-American, 14.7%	African-American, 9.6.0%
	Asian, 1.3%	Asian, 4.3%
	Pacific-Islander, 0.7%	Pacific-Islander, 0.4%
	American-Indian, 1.0%	American-Indian, 0.8%
Functional status	Independent, 97.3%	Independent, 97.4%
	Partially dependent, 1.7%	Partially dependent, 1.6%
	Completely dependent, 1.0%	Completely dependent, 1.0%
ASA class	ASA-1, 4.2%	ASA-1, 12.6%
	ASA-2, 54.0%	ASA-2, 46.2%
	ASA-3, 37.5%	ASA-3, 36.7%
	ASA-4, 4.1%	ASA-4, 4.1.1%
	ASA-5, 0.01%	ASA-5, 0.01%
Cardiovascular disease	37.8%	36.7%
Pulmonary disease	3.4%	3.2%
Renal disease	1.1%	1.0%
Diabetic	18.2%	17.4%
Smoker	17.1%	16.5%
Cholecystectomy procedure	Cholecystectomy alone, 74.0%	Cholecystectomy alone, 75.3%
	Cholecystectomy with IOC, 26.0%	Cholecystectomy with IOC, 24.7%
Disposition status	Outpatient, 0.6%	Outpatient, 0.6%
	Inpatient, 99.4%	Inpatient, 99.4%
Operative time	80 min (±41)	79 min (±44)

intraoperative planning. These patients should be counseled on the risk for BDI and the possible need for conversion to open cholecystectomy, subtotal cholecystectomy, or subsequent bile duct repair. They should also be counseled that, given their increased risk, intraoperative cholangiogram may be required to define the anatomy. Though not always possible, especially in the setting of urgent or emergent cholecystectomy, risk reduction measures such as weight loss can be recommended before a patient undergoes elective cholecystectomy. Finally, for those patients undergoing cholecystectomy for acute cholecystitis where risk reduction is not possible, the operating surgeon may elect for routine cholangiogram in all patients with the lethal triad.

Our study has a few limitations. The first of which involves the retrospective nature of the analysis, therefore, no definitive causations between the lethal triad and BDI can be derived from the results rather only a strong association between the lethal triad and BDI is demonstrated. Next, this study involved a large international database where there was a large volume of analyzable cases, however, the quality of the queried data is less than ideal for optimal clinical application. All retrospective studies of large international multi-institutional registries are inherently subject to potential bias due to incorrect, miscoded, or missing patient or procedural information [22]. Since BDI cases were only able to be identified by accurate ICD codes it is likely not all BDIs that occurred were able to be identified within the constraints of the NSQIP registry. Furthermore, while the NSQIP registry has been well-validated for academic surgical research the decreased granularity of the extracted variables from participant centers does not allow for evaluation of more clinically pertinent second and third-order data [12, 13]. That construct of the NSQIP database made it impossible to determine the severity of BDIs identified. Study results were unable to differentiate between minor BDIs, such as cystic duct stump leaks, versus major BDIs that required hepatobiliary reconstruction. Considering the inherent limitations of NSQIP analyses and the retrospective nature of the study the authors still submit the results hold merit for identifying a specific group of patients at increased risk for BDI.

Table 5 Adjusted multivariate analysis BDI

	Odds Ratio	95%CI	*P* value
Acute cholecystitis[†]	1.559	1.459–1.665	0.001
BMI ≥ 30[†]	1.741	1.449–2.093	0.006
Steatohepatitis[†]	1.002	1.001–1.072	0.039
Lethal triad[†]	40.127	7.047–356.59	< 0.0001
Sex[†]	1.315	1.092–1.583	0.011
Race[†]	0.587	0.487–0.707	0.004
Age	1.003	0.998–1.012	0.090
Functional status	1.067	0.626–1.819	0.288
ASA class	0.880	0.733–1.055	0.071
Morbid obesity[†,a]	1.227	1.012–1.487	0.002
Diabetic	0.971	0.741–1.272	0.501
Smoker[†]	1.293	1.039–1.610	0.034
Disposition status[†]	1.559	1.459–1.665	0.001
IOC performed	0.986	0.804–1.209	0.708
Pre-Op WBC	0.989	0.981–1.001	0.134
Pre-Op AST/ALT	0.998	0.997–1.001	0.055
Pre-Op alk phos	1.001	0.999–1.002	0.865
Pre-Op bilirubin	0.990	0.979–1.002	0.142
Pre-Op albumin	0.999	0.993–1.002	0.357

[†]Statistically significant

[a]Morbid obesity defined as BMI ≥ 40

Table 6 BDI incidence for adjusted multivariate analysis

	Lethal triad	Control	*P* value
BDI rate[†]	1.65%	0.04%	< 0.001

[†]Statistically significant

Conclusion

Acute cholecystitis, obesity, and steatohepatitis constitute the "lethal triad" for BDI during laparoscopic cholecystectomy. This study found a strong statistically significant association between the triad and that most dreaded complication with a laparoscopic cholecystectomy. Identification of patients with that prognostic measure could lead to improved patient risk counseling and alteration of intraoperative techniques to limit BDI occurrence. We propose this lethal triad be considered when managing patients undergoing laparoscopic cholecystectomy.

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Declarations

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References

1. Kapoor T, Wrenn SM, Callas PW, Abu-Jaish W (2018) Cost analysis and supply utilization of laparoscopic cholecystectomy. Minim Invasive Surg 2018:1–5. https://doi.org/10.1155/2018/7838103
2. Vollmer CM, Callery MP (2007) Biliary injury following laparoscopic cholecystectomy: why still a problem? Gastroenterology 133(3):1039–1041. https://doi.org/10.1053/j.gastro.2007.07.041
3. Savader SJ, Lillemoe KD, Prescott CA et al (1997) Laparoscopic cholecystectomy-related bile duct injuries. Ann Surg 225(3):268–273. https://doi.org/10.1097/00000658-199703000-00005
4. Mangieri CW, Hendren BP, Strode MA, Bandera BC, Faler BJ (2019) Bile duct injuries (BDI) in the advanced laparoscopic cholecystectomy era. Surg Endosc 33(3):724–730. https://doi.org/10.1007/s00464-018-6333-7
5. Terho P, Sallinen V, Lampela H, Harju J, Koskenvuo L, Mentula P (2021) The critical view of safety and bile duct injuries in laparoscopic cholecystectomy: a photo evaluation study on 1532 patients. HPB 23(12):1824–1829. https://doi.org/10.1016/j.hpb.2021.04.017
6. Barrett M, Asbun HJ, Chien HL, Brunt LM, Telem DA (2018) Bile duct injury and morbidity following cholecystectomy: a need for improvement. Surg Endosc 32(4):1683–1688. https://doi.org/10.1007/s00464-017-5847-8
7. Halbert C, Altieri MS, Yang J et al (2016) Long-term outcomes of patients with common bile duct injury following laparoscopic cholecystectomy. Surg Endosc 30(10):4294–4299. https://doi.org/10.1007/s00464-016-4745-9
8. Flum DR (2003) Bile duct injury during cholecystectomy and survival in medicare beneficiaries. JAMA 290(16):2168. https://doi.org/10.1001/jama.290.16.2168
9. Rosser JC (2007) The impact of video games on training surgeons in the 21st century. Arch Surg 142(2):181. https://doi.org/10.1001/archsurg.142.2.181
10. Kneebone R (2003) Simulation in surgical training: educational issues and practical implications. Med Educ 37(3):267–277. https://doi.org/10.1046/j.1365-2923.2003.01440.x
11. Pucher PH, Brunt LM, Fanelli RD, Asbun HJ, Aggarwal R (2015) SAGES expert Delphi consensus: critical factors for safe surgical practice in laparoscopic cholecystectomy. Surg Endosc 29(11):3074–3085. https://doi.org/10.1007/s00464-015-4079-z
12. Khuri SF (2005) The NSQIP: a new frontier in surgery. Surgery 138(5):837–843. https://doi.org/10.1016/j.surg.2005.08.016
13. Shiloach M, Frencher SK, Steeger JE et al (2010) Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. J Am Coll Surg 210(1):6–16. https://doi.org/10.1016/j.jamcollsurg.2009.09.031
14. Lee JH, Kim D, Kim HJ et al (2010) Hepatic steatosis index: a simple screening tool reflecting nonalcoholic fatty liver disease. Dig Liver Dis 42(7):503–508. https://doi.org/10.1016/j.dld.2009.08.002
15. Long MT, Pedley A, Colantonio LD et al (2016) Development and validation of the Framingham steatosis index to identify persons with hepatic steatosis. Clin Gastroenterol Hepatol 14(8):1172-1180.e2. https://doi.org/10.1016/j.cgh.2016.03.034
16. Barrett M, Asbun HJ, Chien H-L, Brunt LM, Telem DA (2018) Bile duct injury and morbidity following cholecystectomy: a need

for improvement. Surg Endosc 32:1683–1688. https://doi.org/10.1007/s00464-017-5847-8
17. Sinha S, Hofman D, Stoker DL et al (2012) Epidemiological study of provision of cholecystectomy in England from 2000 to 2009: retrospective analysis of hospital episode statistics. Surg Endosc. https://doi.org/10.1007/s00464-012-2415-0
18. Yamashita Y, Kimura T, Matsumoto S (2010) A safe laparoscopic cholecystectomy depends upon the establishment of a critical view of safety. Surg Today 40(6):507–513. https://doi.org/10.1007/s00595-009-4218-z
19. Quaresima S et al (2020) Routine near infra-red indocyanine green fluorescent cholangiography versus intraoperative cholangiography during laparoscopic cholecystectomy: a case-matched comparison. Surg Endosc 34:1959–1967.
20. Choi YS, Beltran TA, Calder SA, Padilla CR, Berry-Cabán CS, Salyer KR (2022) Prevalence of hepatic steatosis and fibrosis in the United States. Metab Syndr Relat Disord 20(3):141–147. https://doi.org/10.1089/MET.2021.0111
21. Gallaher JR, Charles A (2022) Acute cholecystitis: a review. JAMA 327(10):965–975. https://doi.org/10.1001/JAMA.2022.2350
22. Hu WH, Cajas-Monson LC, Eisenstein S, Parry L, Cosman B, Ramamoorthy S (2015) Preoperative malnutrition assessments as predictors of postoperative mortality and morbidity in colorectal cancer: an analysis of ACS-NSQIP. Nutr J 14(1):91. https://doi.org/10.1186/s12937-015-0081-5
23. Törnqvist B, Waage A, Zheng Z, Ye W, Nilsson M (2016) Severity of acute cholecystitis and risk of iatrogenic bile duct injury during cholecystectomy, a population-based case–control study. World J Surg 40(5):1060–1067. https://doi.org/10.1007/s00268-015-3365-1
24. Aziz H, Pandit V, Bellal J, Jie T, Ong E (2015) Age and obesity are independent predictors of bile duct injuries in patients undergoing laparoscopic cholecystectomy. World J Surg 39:1804–1808. https://doi.org/10.1007/s00268-015-3010-z
25. Fullum TM, Downing SR, Ortega G et al (2013) Is laparoscopy a risk factor for bile duct injury during cholecystectomy? JSLS. https://doi.org/10.4293/108680813X13654754535638
26. Yang S, Hu S, Gu X, Zhang X (2022) Analysis of risk factors for bile duct injury in laparoscopic cholecystectomy in China: a systematic review and meta-analysis. Medicine 101(37):e30365. https://doi.org/10.1097/MD.0000000000030365
27. Nuzzo G (2005) Bile duct injury during laparoscopic cholecystectomy. Arch Surg 140(10):986. https://doi.org/10.1001/archsurg.140.10.986
28. Moossa AR (1990) Iatrogenic injury to the bile duct. Arch Surg 125(8):1028. https://doi.org/10.1001/archsurg.1990.01410200092014
29. Söderlund C, Frozanpor F, Linder S (2005) Bile duct injuries at laparoscopic cholecystectomy: a single-institution prospective study. Acute cholecystitis indicates an increased risk. World J Surg 29(8):987–993
30. Borzellino G et al (2008) Laparoscopic cholecystectomy for severe acute cholecystitis. A meta-analysis of results. Surg Endosc 22(1):8–15
31. Nuzzo G et al (2005) Bile duct injury during laparoscopic cholecystectomy: results of an Italian national survey on 56 591 cholecystectomies. Arch Surg 140(10):986–992
32. Wang Y, Beydoun MA, Min J, Xue H, Kaminsky LA, Cheskin LJ (2020) Has the prevalence of overweight, obesity and central obesity levelled off in the United States? Trends, patterns, disparities, and future projections for the obesity epidemic. Int J Epidemiol 49:810–823. https://doi.org/10.1093/ije/dyz273