



An analysis of early postoperative complications following biliary reconstruction of major bile duct injuries using the Modified Accordion and Anatomic, Timing Of and Mechanism classifications



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ABSTRACT

Background: Few studies have reported patient outcome after surgical repair of bile duct injury using a standardized, validated classification system. This is the first analysis to investigate the correlation between the Anatomic, Timing Of and Mechanism classification of bile duct injury and severity of postoperative complications classified using the Modified Accordion Grading System.

Methods: Patients undergoing index hepaticojejunostomy repair of bile duct injury in laparoscopic cholecystectomy at a tertiary referral center from 1993–2018 were included. Patient demographics, geographic distance from referral center, time to referral, Anatomic, Timing Of and Mechanism classification and highest Modified Accordion Grade complication were retrieved from a prospective database. The primary outcome was determined using correlation statistics to assess the relationship between level of injury and severity of postoperative complication.

Results: One hundred and twenty-eight patients were included. There was no correlation between level of injury and severity of postoperative complication ($r_s(128) = -0.113, P = .203$). Seventy (54.7%) patients had an injury less than 2 cm from the hepatic duct bifurcation and 52% of patients developed a postoperative complication, most mild to moderate in severity. Geographic distance resulted in substantial delays in referral ($P < .001$) but did not affect complication rate ($P = .523$).

Conclusion: In this prospective analysis the short-term complication rate was higher than previous retrospective reports, but the distribution of the severity of complications and spectrum of injury type were similar. There was no correlation between severity of injury and postoperative complications. Geographic distance from referral center resulted in substantial differences in referral delay but had no statistically significant effect on outcome.

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INTRODUCTION

LAPAROSCOPIC CHOLECYSTECTOMY (LC) is the preferred method of treatment of symptomatic gallstones and offers several advantages over open cholecystectomy, including less postoperative pain, fewer wound infections, shorter hospital stay, earlier return to normal activities and improved cosmetic results [1–3]. A dreaded complication of LC is bile duct injury (BDI), reported to occur in 0.4% of operations, a figure twice as high as that recorded for open cholecystectomy [4–5]. A population-based study reported a BDI rate of 1.5%, suggesting an underestimation of injury rates in the published literature [6]. While minor injuries with duct continuity may be treated successfully with

endoscopic stenting alone, major injuries with duct division may require complex and technically demanding biliary reconstructive surgery best undertaken by a surgical team with expertise and established credentials [7–9].

A variety of BDI classification systems have been proposed, each with different strengths and weaknesses. Strasberg et al. adapted the Bismuth classification, which is now widely used for injuries occurring in LC [10–12]. However, the Strasberg–Bismuth classification does not include concomitant vascular injury, suggested to be a predictor of poor postoperative outcome [13]. The most detailed classification system is the Anatomic, Timing Of injury and Mechanism (ATOM) classification which includes information on the anatomic level and extent of the injury, associated vascular injury, timing of detection, and mechanism of injury [14]. For anatomic classification of the level of injury six subtypes are defined. Time of detection is classified as either early or late, with further subdivision into early intraoperative or immediate postoperative. Mechanism of injury is classified as either mechanical or energy driven [14].

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Several studies have investigated the relationship between severity of injury and postoperative outcomes using different classification systems with conflicting results. In some, an injury above the hepatic duct bifurcation was a predictor of poor outcome [15–16]. In others, no correlation between severity of injury and long-term outcome was found [17–18]. We analyzed the correlation between the severity of injury according to the ATOM classification and the risk of postoperative complications as assessed by the Modified Accordion Grading System (MAGS) in a large cohort of patients after biliary reconstruction of major BDI at a tertiary referral center [14,19].

MATERIALS AND METHODS

Since the introduction of LC, all patients with a LC-BDI referred to Groote Schuur Hospital or the University of Cape Town Private Academic Hospital were prospectively entered into an ethics approved registry. Patients who had an operative repair of a LC-BDI between January 1993 and January 2018 were reviewed. The primary outcome was correlation between type of BDI and severity of post-operative complications. Secondary outcomes included potential confounders effecting post-repair outcomes such as geographic distance from referral center and time to diagnosis, referral and repair. Patient characteristics, preoperative data, operative details and postoperative outcomes were retrieved from the database. Patients who had undergone an attempted repair prior to referral were excluded. The geographical distances from referral hospital to treatment facility were documented as <100 km, 100–500 km, or >500 km. Time to referral was calculated as days from LC to admission to the tertiary center. Research ethics board approval for the analysis was obtained from the Faculty of Health Sciences Ethics and Research Committee (HREC 248/2018).

Patients had a standard evaluation, including investigations to accurately define the biliary and vascular anatomy, the level and extent of the injury and the presence of fluid collections. In a step-up approach, multiphase contrast-enhanced computed tomography (CE-CT) and/or magnetic resonance imaging (MRI), with magnetic resonance cholangiopancreatography (MRCP), were performed, followed by percutaneous transhepatic cholangiography (PTC) and endoscopic retrograde cholangiography (ERC) when deemed indicated. PTC was routinely followed by placement of a percutaneous biliary drain to facilitate intraoperative identification of the injury site and provide drainage of an obstructed biliary system or sub-hepatic collections. For separated right and left hepatic ducts bilateral drains were placed. The BDI was classified according to the ATOM classification [14]. Patients with biliary peritonitis, sepsis or organ failure had ultrasound guided percutaneous drainage of abdominal collections and definitive surgical repair was delayed and performed only after resolution of sepsis, restoration of organ function and optimization of the general condition. Timing of repair was classified as immediate (during same anesthesia as LC), urgent (within 72 hours of LC), early (>72 hours, ≤14 days), intermediate (>14, ≤90 days), and late (>90 days). A standard operative technique was used for bile duct reconstruction, the technical details of which have been published previously [20]. Postoperative surgical and nonsurgical complications were classified using the MAGS [19].

Statistical analysis. Baseline characteristics are presented using medians and ranges for continuous variables. Categorical variables are expressed as total numbers and percentages. Fisher exact, Kruskal-Wallis, and Median tests were used when appropriate. The Spearman rank-order correlation coefficient (r_s) for nonparametric data was used to assess the association between severity of injury and postoperative complications. SPSS Statistics for MacIntosh, Version 25.0 (IBM Corp, Armonk, NY) was used for statistical analysis.

RESULTS

Patient characteristics. One hundred twenty-eight patients were included in the study of whom the demographic and clinical characteristics

are summarized in Table 1. The median age of the cohort was 45 (18–80) years. Most patients were female. Nine patients had a LC performed at our center, with the remaining 119 referred from other hospitals. Median time from LC to diagnosis was 4 (0–156) days and median time to referral was 11 (range 0–258) days. Sixty-eight patients (53.1%) underwent LC at a geographically distant (>100 km) center. Patients referred from less than 100 km away had a median time to referral of 3.5 (0–89) days compared to those referred from 100 to 500 km away with a median referral of 9.5 (0–105) days. Patients who traveled more than 500 km had a median referral of 25.5 (3–258) days. The difference in days to referral between geographic distance categories was statistically significant ($P < .001$). The most common presenting feature after BDI was bile leak, followed by jaundice, sepsis, and cholangitis (Table 1).

Preoperative investigations. Preoperative investigations are summarized in Table 1. Seventy-six percent of patients had a PTC with biliary drain placement. Sixty-eight (53.1%) patients underwent ERC, most of which were performed in the pre-MRCP era and mostly in patients undergoing an intermediate or delayed repair. Cross-sectional imaging included CE-CT in 48 (37.5%) patients and MRI/MRCP in 55 (43.0%) patients.

Assessment of injuries. The BDIs, classified by the ATOM classification, are summarized in Table 2. Most patients presented with major bile duct (MBD) level 2 (54.7%) or level 3 injuries (18.8%). Sixty-two patients (48.4%) had complete occlusions, 26 (20.3%) partial occlusions and 97 (75.8%) had a complete division of the main bile duct, 82 of which (64.1%) included excision of variable lengths of duct. Fourteen patients (10.9%) had a vasculobiliary injury (VBI), the majority of which involved the right hepatic artery. In only 36 patients (28.1%) was the injury detected intra-operatively. In 46 patients (35.9%) the BDI was identified within seven days, and in the remaining 46, more than 7 days postoperatively. Mechanical injury was the most common mechanism of BDI ($n = 106$, 82.8%).

Table 1

Demographic, clinical characteristics, and preoperative investigations for patients who underwent HJ repair of bile duct injury in LC at a single tertiary referral center from January 1993 to January 2018

Characteristics	n = 128 (%)
Demographics	
Median age (y) (range)	45 (18–80)
Gender (male:female)	23:105 (18.0:82.0) (82.0)
LC at referring hospital	119 (93.0)
LC at tertiary referral center	9 (7.0)
LC hospital location	
<100 km from referral center	60 (46.9)
100–500 km from referral center	20 (15.6)
>500 km from referral center	48 (37.5)
Clinical presentation	
Median days to diagnosis (range)	4 (0–156)
Median days to referral (range)	11 (0–258)
Median days to referral, <100 km from center	3.5 (0–89)*
Median days to referral, 100–500 km from center	9.5 (0–105)*
Median days to referral, >500 km from center	25.5 (3–258)*
Bile leak	87 (68.0)
Jaundice	48 (37.5)
Cholangitis	10 (7.8)
Sepsis	14 (10.9)
Abnormal liver function tests	99 (77.3)
Preoperative investigations	
Ultrasound	24 (18.8)
CE-CT	48 (37.5)
MRI/MRCP	55 (43.0)
ERC	68 (53.1)
PTC	98 (76.6)

* Kruskal-Wallis H test and Median test showed a statistically significant difference in days to referral by geographic distance category from tertiary referral center [H(2) = 45.768, $P < .001$ with a mean rank delay in referral of 43.09, 63.68 and 91.60 respectively; $\chi^2(2) = 29.576$, $P < .001$].

Table 2

ATOM classification of bile duct injuries in patients who underwent hepaticojejunostomy repair at a single tertiary referral center from January 1993 to January 2018

ATOM classification	n = 128 (%)
MBD 1	14 (10.9)
MBD 2	70 (54.7)
MBD 3	24 (18.8)
MBD 4	14 (10.9)
MBD 5	6 (4.7)
Anatomic characteristics	
Complete occlusion	62 (48.4)
Partial occlusion	26 (20.3)
Complete division	97 (75.8)
Partial division	8 (6.3)
Loss of substance	82 (64.1)
VBI present	14 (10.9)*
Right hepatic artery	11 (8.6)^
Left hepatic artery	1 (0.8)
Common hepatic artery	2 (1.6)^
Timing of detection	
Early, intraoperative	36 (28.1)
Early postoperative (≤7 d)	46 (35.9)
Late postoperative (>7 d)	46 (35.9)
Mechanism of injury	
Mechanical	106 (82.8)
Energy device	1 (0.8)
Unknown	21 (16.4)

* No VBIs identified between 1993 and 2008.

^ One patient with a right hepatic artery and two patients with common hepatic artery injuries had primary repairs of the injured artery.

Surgical repair. The median time from injury to repair was 22 (0–586) days. Eight patients (6.3%) were repaired immediately, 11 (8.6%) urgently, 34 (26.6%) early, 50 (39.1%) during the intermediate period, and 25 (19.5%) were repaired late (Table 3). Five of the eight immediate repairs were performed by a hepatobiliary surgeon who traveled from the referral center to the local hospital where the LC was being performed. Of the patients who had a VBI, three had primary repairs of the injured artery (two common hepatic and one right hepatic) (Table 2).

Complications. Median length of follow-up was 12.9 (0.2–226) months. Postoperative complications are listed by the MAGS in Table 4. Sixty-five patients (50.8%) had at least one complication following hepaticojejunostomy (HJ), most of which were moderate (grade 2), with wound infection occurring in 28 (21.9%) patients. Bile leaks were mostly mild (grade 1), but severe in 2 patients, one requiring a PTC (grade 3) and the other re-laparotomy (grade 4). Of the patients who developed a bile leak, four had preoperatively placed biliary catheters used in the HJ reconstruction. The other severe complications included 3 patients with intra-abdominal infections and one patient with an enterocutaneous fistula, managed successfully with percutaneous drainage (grade 3), 1 patient with bowel obstruction requiring re-laparotomy

Table 3

Timing of HJ repair for bile duct injury in LC classified as immediate, urgent, early, delayed, and late categories for patients treated at a tertiary referral center from January 1993 to January 2018

Timing of repair	n = 128 (%)
Median days from injury to repair (range)	22 (0–586)
Timing category	
Immediate (same anesthesia as LC)	8 (6.3)*
Urgent (≤72 h)	11 (8.6)
Early (>72 h, ≤14 d)	34 (26.6)
Intermediate (>14 d, ≤90 d)	50 (39.1)
Late (>90 d)	25 (19.5)

* Three patients underwent LC at the referral center and a hepatobiliary surgeon was consulted intraoperatively for an immediate repair.

(grade 4), and 2 with systemic sepsis associated with single organ failure (grade 4). One patient developed an upper gastrointestinal bleed requiring gastroscopy (grade 3), and 2 patients had prolonged ICU stays for multiorgan failure (grade 5). Two patients developed intrahepatic abscesses that were successfully managed with percutaneous drainage (grade 3). The delay in referral from geographically distant hospitals did not translate into a statistically significant difference in complication rate ($P = .412$).

There were 2 deaths at 90 days in this series (1.6%). A 73-year-old man with multiple comorbidities had a portal vein injury during LC, which resulted in conversion to laparotomy for control of bleeding. After an urgent transfer to our center he underwent HJ repair on post-LC day 1 during which a right hepatic artery injury was identified. A relook laparotomy was performed on day 6 for a bile collection. He developed intractable sepsis and died 65 days after HJ repair of multiorgan failure. The second patient was a 50-year-old man who underwent immediate HJ repair at the time of LC and was discharged on post-repair day 5 with no complications. He represented on postrepair day 48 with septic shock. At emergency laparotomy, the anastomosis was intact and patent, but a large liver abscess was found and drained. Postoperatively he remained unstable and died 24 hours later from overwhelming sepsis.

Correlation between severity of injury (ATOM) and complications (MAGS). The association between severity of BDI and postoperative complications is shown in the Figure. Most patients with postoperative complications had MBD 2 injuries, and the greatest proportion of complications occurred in the moderate category (MAGS grade 2). However, when the number of patients in each ATOM injury level were correlated to the number and severity of MAGS complications there was no statistically significant relationship [$r_s(128) = -0.113, P = .203$].

DISCUSSION

This is the first study that correlates postoperative complications following bile duct reconstruction for LC-BDI according to the MAGS with type of BDI as assessed by the ATOM classification. Approximately half of the patients undergoing a HJ repair of LC-BDI had one or more complications, most of which were mild to moderate in severity. Interestingly, there was no significant relationship between the type of injury and the severity of postoperative complications. Importantly, this paper also assessed potential confounders effecting patient outcome after surgical repair in a developing country including the influence of geographical distance between referral and treating facility on the delay in referral and intervention, and eventual outcome.

From its inception, the database included detailed documentation of complications that allowed accurate assignment of events to the MAGS grades. This may explain the higher rate of complications in this study compared to other published series, including studies from other high middle-income countries that reported complication rates around 30% [21–25]. Similar to previously published reports, the distribution of the severity of complications in this study is comparable to those previously published [16,23–24]. The majority of patients were referred from geographically distant centers, often associated with referral delays, which could potentially have influenced the complication rate. However, our data show that there was no significant increase in complications in this group. The application of a standard protocol with the systematic management of injuries at our center could have minimized the possible negative impact of distance and referral delay.

The use of PTC with biliary catheter placement has been reported to increase the risk of postoperative complications [26]. Preoperative PTCs in this study were more frequently used than in previous reports, which may have contributed to the higher rate of observed complications [22]. Although there is ongoing debate as to whether VBI influences outcome, a number of studies have documented the negative impact of VBI on the postoperative course [27–28]. In this study, the prevalence of VBI was similar to previously published studies [18,29]. Notably, however, no VBIs were identified pre-operatively in patients treated in the early

Table 4

Postoperative complications by the MAGS in patients who underwent hepaticojejunostomy repair of bile duct injury in LC at a single tertiary referral center from January 1993 to January 2018

	MAGS				
	Mild	Moderate	Severe		
	1	2	3	4	5
Surgical complications	n (%)	n (%)	n (%)	n (%)	n (%)
Biliary					
Bile leak	5 (3.9)	-	1 (0.8)	1 (0.8)	-
Liver abscess	-	-	2 (1.6)	-	-
Intra-abdominal infection	-	1 (0.8)	3 (2.3)	-	-
Small bowel obstruction	-	-	-	1 (0.8)	-
Postoperative ileus	-	1 (0.8)	-	-	-
Enterocutaneous fistula	-	-	1 (0.8)	-	-
Wound					
Dehiscence	1 (0.8)	-	-	-	-
Seroma	1 (0.8)	-	-	-	-
Infection	3 (2.3)	28 (21.9)	-	-	-
Nonsurgical complications					
Acute kidney injury	-	1 (0.8)	-	-	-
Upper gastrointestinal bleed	-	-	1 (0.8)	-	-
Delirium	-	2 (1.6)	-	-	-
Nonsurgical infection	-	7 (5.5)	-	-	-
Systemic sepsis	-	1 (0.8)	-	2 (1.6)	-
Multi-organ failure	-	-	-	-	2 (1.6)
Total	10 (7.8)	41 (32.0)	8 (6.3)	4 (3.1)	2 (1.6)
90-d Mortality	2 (1.6)				
Total complications by referral distance					
<100 km from referral center, n = 60	34 (56.7)				P = .412*
100–500 km from referral center, n = 20	10 (50.0)				
>500 km from referral center, n = 48	21 (43.5)				

* The Fisher exact test was used for this analysis.

period when there was limited access to and poorer quality of cross sectional imaging. It is therefore possible the incidence of VBI in the study is under-reported and does not reflect the true impact of VBI on postoperative complications.

In our analysis, the level of injury had no influence on postoperative complications. In the literature, there is a paucity of reports where a systematic and validated classification system was used to assess postoperative complications following BDI. In the single analysis to date that used the MAGS, and included open and laparoscopic injuries, the level of injury as assessed by the Strasberg-Bismuth classification was not an independent predictor of postoperative complications [24]. Similarly, Booi et al using the Clavien-Dindo classification found that for

complications greater than grade 3, level of injury was not independently associated with postoperative outcome [17]. In both studies, the distribution of injury severity was similar to the distribution in this study. Conversely, in a series of 138 patients from India, injury at or above the bifurcation was a significant predictor of postoperative complications. However, postoperative complications were not recorded using a validated classification system and most BDIs occurred during open cholecystectomies [13].

The timing of BDI repair has been extensively discussed, but an internationally recognized classification system for timing of repair has not materialized. In this study a new category of urgent repair (≤ 72 hours after LC) was used to identify those patients who were treated with the intention of an immediate repair, but in whom delays in transfer, the necessity of a preoperative workup and delays in operating room availability precluded repair under the same anesthesia as LC. Further discussion of this classification, which could be particularly useful in resource-challenged environments, is beyond the scope of this article, but warrants further studies to determine the relevance of this refinement.

There are several limitations of this study that must be considered. The study is subject to the biases and shortcomings of observational retrospective reviews of prospectively collected data. Patients were referred to a tertiary facility, which could have resulted in selective referral of more severe injuries. The reported cohort is therefore unlikely to be a representative sample of the total population of patients with LC-BDIs. In addition, this cohort is from a developing country, and thus, findings related to geographic distances and times to referral and repair are less applicable to patients undergoing LC-BDI repair in a developed country. However, they were hypothesized to be potential confounders effecting postoperative complications within the cohort and for that reason were included in the analysis. There was a broad range in length of follow-up in our study, with a median length just over 1 year, despite difficulties due to distant referrals. It is possible that patients who were not followed up resulted in underreporting of long term complications. The duration of this study, although in many

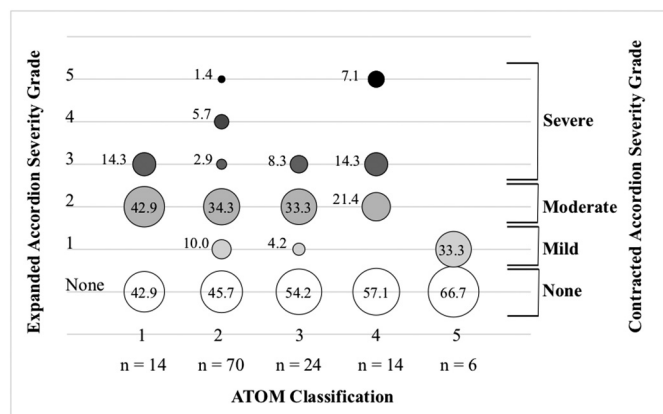


Figure. Postoperative complications defined using the MAGS stratified by ATOM Classification grouping expressed as percentages. The postoperative complications are defined using the expanded (left) and contracted (right) MAGS definitions. The size of each bubble represents the percentage of patients in each category. There was no significant correlation between level of injury and severity of postoperative complication using the Spearman rank-order correlation coefficient [$r_s(128) = -0.113, P = .203$].

ways is a strength, is also a limitation as technology and availability of technology, including CE-CT, MRI, and interventional radiology, changed significantly in South Africa over the last 3 decades.

Furthermore, some potentially relevant aspects have not been analyzed. The well-documented negative impact of attempts at bile duct repair outside specialist centers was not investigated. Exclusion of these patients was deliberate to avoid confounding factors as this analysis specifically addresses the association between the severity of acute injuries and complications of patients primarily repaired at a specialist center. This patient category, however, warrants further evaluation that will be addressed in a future analysis.

In conclusion, although the overall short-term complication rate in this study was higher than previously reported, the distribution of the severity of complications and injury types were similar to previously published studies with no correlation found between severity of injury and postoperative complications. Future studies should include in-depth analysis of the relationship between distance from referral center and its impact on delays in diagnosis, referral and repair, and patient outcomes. The concept of an urgent repair timing category should also be explored.

Author contribution

All authors have contributed substantially to the conception, data acquisition and analysis, drafting and critical revision of this work, and have given their final approval of this version for publication.

Conflict of interest

The authors have no conflicts of interest to declare.

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