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ORIGINAL ARTICLE

Laparoscopic bile duct injuries: timing of surgical repair does not influence success rate. A multivariate analysis of factors influencing surgical outcomes

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Abstract

Background: Many factors contribute to the success of biliary reconstructions following laparoscopic bile duct injury. We previously reported that control of intra-abdominal infection, complete preoperative cholangiography, surgical technique and surgical experience affected the results. There is no consensus, however, on whether the timing of the operation is important.

Methods: We examined factors influencing the success of the *first* repair of 307 major bile duct injuries following laparoscopic cholecystectomy. Factors were assessed for cases initially repaired either by the *primary* surgeon or a *biliary* specialist. Bivariate and multivariate analyses were used to determine the significance of comparisons.

Results: A total of 137 injuries were initially repaired by a biliary surgeon and 163 injuries were initially repaired by the primary surgeon; seven were managed non-surgically. Repairs by primary surgeons were performed earlier than those by biliary surgeons (11 vs. 59 days; $P < 0.0001$). Bivariate analysis of the entire cohort suggested that later repairs might have been more successful than earlier ones (17 vs. 50 days; $P = 0.003$). Multivariate analysis, however, showed that the timing of the repair was unimportant ($P = 0.572$). Instead, success correlated with: eradication of intra-abdominal infection ($P = 0.0001$); complete preoperative cholangiography ($P = 0.002$); use of correct surgical technique ($P = 0.0001$), and repair by a biliary surgeon ($P = 0.0001$). Separate multivariate analyses of outcomes for primary and biliary surgeons revealed that timing was unrelated to success in either case.

Conclusions: The success of biliary reconstruction for iatrogenic bile duct injuries depended on complete eradication of abdominal infection, complete cholangiography, use of correct surgical technique, and repair by an experienced biliary surgeon. If these objectives were achieved, the repair could be performed at any point with the expectation of an excellent outcome. We see no reason to delay the repair for some arbitrary period.

Keywords

laparoscopy, bile duct injury, biliary structure, surgical repair, biliary reconstruction

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Introduction

Although it is associated with less overall morbidity, laparoscopic cholecystectomy has a higher rate of major bile duct injury than does open cholecystectomy (0.3–0.7% of cases vs. 0.1–0.2% of cases).[1,2] Although practising surgeons in the USA have now progressed beyond the initial learning curve associated with this technique, bile duct injuries still occur at a relatively constant rate.[3,4] Our group and others have described the mechanism of injury, guidelines for prevention, clinical findings, and factors influencing the success of treatment.[3–33] Although prevention would be ideal,[4,5,9] the best way to limit morbidity is through early recognition and appropriate treatment. Many aspects of the management of a case influence its outcomes. We found that the success of the initial repair was the most important variable influencing the length of illness, and that factors influencing success included: the

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level of experience of the surgeon performing the repair; the preoperative eradication of intra-abdominal infection, and complete preoperative imaging.[6] Others have claimed, however, that the timing of the repair has an effect.[13–16] The current study examines this question.

Materials and methods

We analysed 307 cases of major bile duct injury following laparoscopic cholecystectomy that were referred for evaluation and/or treatment. Of these, 137 injuries were initially repaired by a *biliary surgeon* and 163 injuries were initially repaired by the *primary surgeon*; seven were managed non-surgically.

The patient's clinical presentation was recorded. Three groups were defined based on the level of inflammatory manifestations at the time of injury recognition:

1 operative recognition;
2 none/systemic inflammatory response syndrome (SIRS): no inflammatory manifestations or SIRS manifestations: (fever [≥38 °C]; leucocytosis [white blood cells ≥11 k/cm^2]; respiratory rate ≥20/min; heart rate ≥90/min), and/or
3 complicated: cases with cholangitis (Charcot's triad), peritonitis, sepsis (hypotension, shock, organ dysfunction) or abdominal abscess.

The bile duct injuries were classified using the Stewart–Way classification (Table 1). Class I injuries (5% of cases) involved an incision in the common bile duct with no loss of duct. These injuries occurred when the common bile duct was mistaken for the cystic duct and the mistake was recognized during the initial operation (usually in operative cholangiograms), or when an incision in the cystic duct for a cholangiogram catheter was unintentionally extended into the common bile duct. Class II injuries (24% of cases) consisted of lateral damage to the hepatic duct with a resultant stenosis and/or fistula. These injuries resulted from unintended application of clips or cautery to the bile duct, usually during attempts to control bleeding in the triangle of Calot. Class III injuries, the most common (61% of cases), involved transection and excision of a variable length of the duct, which always included the cystic duct–common duct junction. Class III injuries resulted from an error of perception whereby the common bile duct was misidentified as the cystic duct. The surgeon transected the common duct (deliberately, thinking it was the cystic duct) early in the dissection and transected the common hepatic duct unknowingly later as the gall bladder was separated from the liver bed. Class III injuries were subdivided based on the proximal extent of the injury as follows: in class IIIa injuries, a remnant of the common bile duct or common hepatic duct remained; in class IIIb injuries, the proximal transaction was at the bifurcation at the common hepatic duct; in class IIIc injuries, the bifurcation of the common hepatic duct had been excised, and in class IIId injuries, the proximal line of resection was above the first bifurcation of the lobar ducts (into segmental ducts). Class IV injuries (10% of cases) involved damage (transection or injury) of the right hepatic duct (or a right segmental duct), often combined with injury to the right hepatic artery. Class IV injuries were caused by misidentifying the right hepatic duct (or right posterior segmental duct) as the cystic duct and the right hepatic artery as the cystic artery, or from lateral injury to the right hepatic duct during dissection in Calot's triangle.

Only factors contributing to the success of the *first repair* were analysed. Many (51%) patients in this cohort required more than one surgical procedure to achieve a successful result, but as the timing of repair relates best to the initial surgical procedure, only initial repairs were analysed in this study.

We examined the influence of the following factors on the success of surgical reconstruction: clinical presentation group; control of intra-abdominal infection; complete preoperative cholangiography; use of correct surgical technique; surgical experience; associated right hepatic artery injury; level of injury (or Stewart–Way class), and timing of surgical repair.[6] Criteria used as evidence of right hepatic artery injury included: ligation or clipping cited during the initial cholecystectomy or a subsequent operation; identification of right hepatic artery ligation during a biliary repair or videotape review; hepatic angiography demonstrating right hepatic artery injury, and non-enhancement of the right hepatic lobe during the arterial phase of a contrast computed tomography (CT) scan.

The correct method for performing a hepaticojejunostomy was considered to comprise a single layer, end-to-side anastomosis of healthy bile duct (non-viable ductal tissue removed) to the

Table 1 Distribution of injuries and level at the time of injury

	Total	Level				Right hepatic artery injury (%)
		A CBD/CHD	B Bifurcation	C Above bifurcation	D Segmental ducts	
Class I, *n* (%)	16 (5%)	16 (100%)				0
Class II, *n* (%)	72 (24%)	63 (88%)	8 (11%)	1 (1%)	0	11 (15%)
Class III, *n* (%)	187 (61%)	115 (61%)	36 (19%)	26 (14%)	10 (5%)	58 (31%)
Class IV, *n* (%)	32 (10%)			19 (69%)	13 (41%)	19 (60%)
Total, *n* (%)	307 (100%)	194 (63%)	44 (14%)	46 (15%)	23 (7%)	88 (29%)

CBD, common bile duct; CHD, common hepatic duct

Table 2 Outcomes by Stewart–Way injury class and surgeon

	Primary surgeons				Biliary surgeons			
	Total	Success	Success with IR dil	Fail/refer	Total	Success	Success with IR dil	Success with second repair
Class I, *n* (%)	14	6 (43%)	0	8 (57%)	1	1 (100%)	0	0
Class II, *n* (%)	33	4 (12%)	1 (3%)	28 (85%)	34	34 (100%)	0	0
Class III, *n* (%)	107	12 (11%)	10 (9%)	85 (79%)	79	70 (89%)	4 (5%)	5 (6%)
Class IV, *n* (%)	9	0	1 (11%)	8 (89%)	21	19 (90%)	1 (5%)	2 (9%)
Totals, *n* (%)	163	22 (13%)	12 (7%)	129 (79%)	137	124 (91%)	5 (4%)	7 (5%)

IR dil, stricture dilatation by interventional radiology

intestine, using fine absorbable suture material (4–0, 5–0 or 6–0, depending on duct size). A Roux-en-Y hepaticojejunostomy was deemed necessary for anastomoses above the level of the cystic duct (common hepatic duct or higher). Anastomosis to the duodenum was considered appropriate for injuries located in the common bile duct (choledochoduodenostomy), but not for those at the level of the hepatic duct (hepaticoduodenostomy). Stents were not considered to be essential. A direct closure of the common duct was considered appropriate in class I injuries, but not in injuries of other classes. A T-tube was considered unnecessary and undesirable, but using a T-tube was not counted as an error. Repairing a class II injury around a T-tube, end-to-end bile duct anastomosis in class II or III injuries, and right hepatic duct to common hepatic duct anastomosis in class IV injuries were considered inappropriate. The preferred operations were Roux-en-Y hepaticojejunostomy in class II and III injuries, and right hepaticojejunostomy in class IV injuries.

Statistical analysis

Statistical analysis was performed using analysis of variance or Student's *t*-test for interval parametric data, the chi-squared test for variables on a nominal scale (rates and proportions), and Pearson and Spearman correlations for bivariate analysis of interval and nominal variables. Multiple regression analysis was performed using SPSS (SPSS, Inc., Chicago, IL, USA), which was also used for the other statistical calculations.

Bivariate analysis of factors contributing to success was performed for each variable analysed. Factors that correlated with surgical outcome on bivariate analysis ($P < 0.1$) were included in the multivariate analysis.

Results

The study population included 234 women and 73 men, with an average age of 46 years (range 18–86 years). The preoperative diagnosis was chronic cholecystitis in 201 (65%), acute cholecystitis in 96 (31%), gallstone pancreatitis in seven (2%), biliary dyskinesia in one and cholangitis in one. In one patient the bile duct injury occurred during a laparoscopic fundoplication for gastro-oesophageal reflux disease. According to the Stewart–Way classification of injury, injuries were distributed as follows: class I, 5%; class II, 24%; class III, 61%, and class IV, 10% (Table 1). A total of 79 (26%) injuries were identified during the index operation. The remaining 74% were diagnosed postoperatively, with recognition occurring at a mean of 20 days (median 8 days, range 1–151 days). The first operative repair was performed by the primary surgeon in 163 cases and by a specialist biliary surgeon in 137 cases; seven cases did not undergo repair surgery. For cases referred to a biliary surgeon, the average time from injury to referral was 31 days (range 1–386 days).

The success of the initial repair as a function of injury class is shown in Table 2. Overall, rates for primary success and success with post-repair interventional radiology (IR) dilatation were 21% for primary surgeons and 95% for biliary surgeons. Among cases treated by a biliary surgeon, one patient died of a myocardial infarction in the postoperative period (mortality rate 0.7%). The median follow-up of cases repaired by a biliary surgeon was 40 months.

Clinical presentation, preoperative evaluation and preparation

A total of 79 (26%) injuries were recognized during the index operation and the rest were recognized postoperatively at a mean of 20 days (range 1–151 days). Among cases recognized in the postoperative period, 65% presented with none/SIRS and 35% with a complicated clinical presentation (cholangitis, peritonitis, sepsis or abscess). Cases with a complicated clinical presentation underwent a longer period of preoperative preparation for control of abdominal inflammation than those recognized at the index operation or those with none/SIRS (Fig. 1). However, this varied by treating surgeon (Fig. 1): the period of preoperative preparation for these complicated cases was longer among patients cared for by biliary surgeons than for those under the care of primary surgeons (33 vs. 4 days, biliary vs. primary surgeons; $P < 0.0001$, *t*-test). The overall level of preoperative preparation also differed by treating surgeon (see below).

Among the 163 cases initially repaired by the primary surgeon, 60 cases were recognized and repaired at the index laparoscopic cholecystectomy; 23 cases did not have a biliary fistula as part of the injury (eight were class II injuries and 15 were class III injuries in which the common hepatic duct was clipped); six cases had a

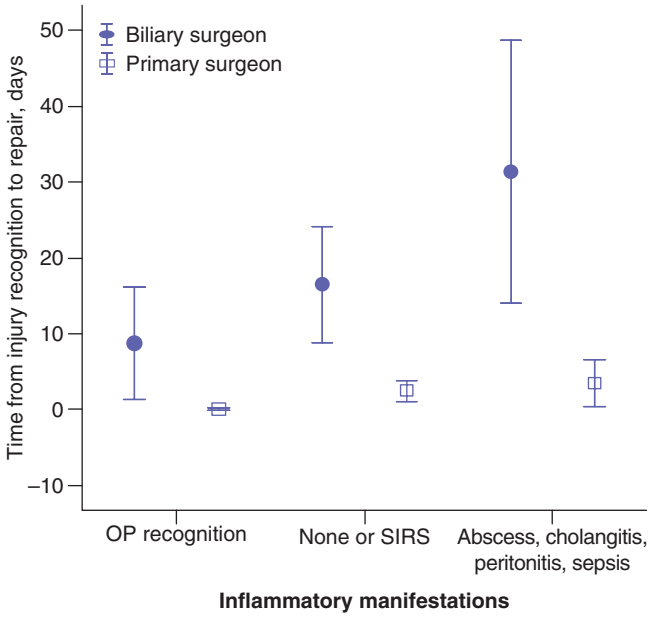

Figure 1 Time from injury recognition to biliary reconstruction by treating surgeon and patient's clinical manifestations. OP, operative; SIRS, systemic inflammatory response syndrome

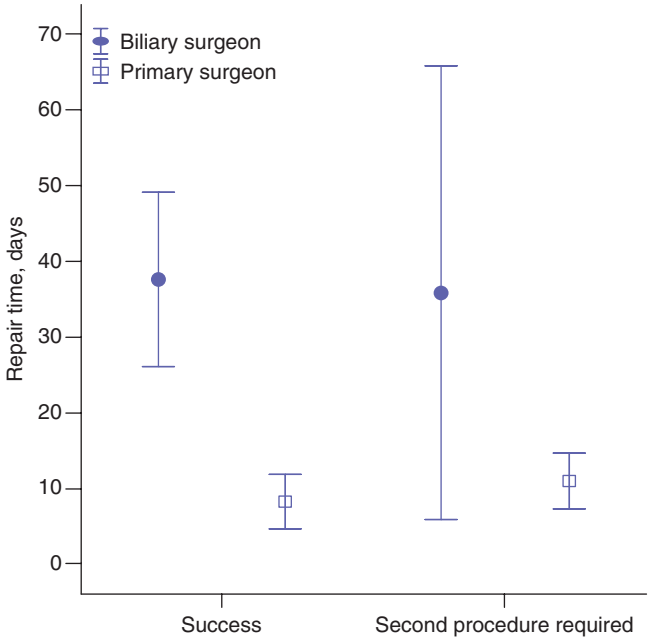

Figure 2 Timing of biliary reconstruction and outcomes by surgeon

diagnostic laparotomy before the repair; seven cases had a Jackson-Pratt drain (JP) drain placed at the initial laparoscopic cholecystectomy; 24 cases had abdominal fluid collections drained percutaneously preoperatively, and 43 cases had undrained fluid collections at the time of the repair. Complete imaging of the biliary tree was obtained before the repair in 32% of cases recognized in the postoperative period. In the remainder, no cholangiography was obtained before the repair in 21% of cases, incomplete endoscopic retrograde cholangiography (ERCP) without imaging of the proximally injured ducts was obtained in 29% of cases, and cholangiograms were obtained at re-operation in 18% of cases.

Of the 137 cases initially treated by a biliary surgeon, all underwent preoperative drainage of intra-abdominal fluid collections (when present). Of these, 18 cases were recognized during the initial laparoscopic cholecystectomy (and a drain was placed at that time); 25 cases had undergone a diagnostic laparotomy before referral; 37 cases did not have a biliary fistula at presentation (19 were class II injuries, 17 were class III injuries where the common hepatic duct was clipped and one was an isolated right hepatic duct stricture); six cases had a JP drain placed at the initial laparoscopic cholecystectomy and had no fluid collections on CT scan, and 51 cases underwent percutaneous drainage of abdominal fluid collections preoperatively. For cases with an abdominal drain in place at the time of referral, preoperative CT scans were obtained to determine whether there were residual fluid collections that needed to be drained. Complete imaging of the biliary tree was obtained before the repair in all cases initially repaired by a biliary surgeon (percutaneous transhepatic cholangiography was performed when the entire biliary tree was not imaged with ERCP).

Timing of surgical repair and outcomes

The success rate with respect to the timing of the repair is shown in Fig. 2 and Table 3. Timing as an individual variable had no effect. In general, repairs by primary surgeons were performed earlier than those by biliary surgeons (11 vs. 59 days; $P < 0.0001$), principally because of obvious logistical factors associated with referral and because biliary surgeons took the time to achieve eradication of intra-abdominal inflammation. However, a large number of injuries were repaired early by biliary surgeons: 23% were repaired within the first week and 44% were repaired within the first 2 weeks. When each repair interval was examined (<1 week, <2 weeks, 3-6 weeks, and >6 weeks), outcomes were nearly identical (Table 3). Outcomes were better for biliary surgeons, but outcomes were not influenced by the timing of repair in either group (Table 3).

Neither did the timing of the biliary reconstruction influence the length of postoperative course. The median postoperative stay for cases initially repaired by a biliary surgeon was 7 days (range 5–64 days) regardless of the timing of the reconstruction. The length of stay was a linear function with a nearly 0 slope (slope = –0.0039), suggesting that it was unaffected by the timing. (Fig. 3)

Statistical analysis of factors influencing repair outcomes

Bivariate analysis (Table 4) suggested that later repairs were more successful than those carried out earlier (17 vs. 50 days; $P = 0.003$), but this was because repairs by primary surgeons were generally performed earlier than those by biliary surgeons (Figs 1 and 2). Multivariate analysis demonstrated that the timing of repair was not significant ($P = 0.572$). Instead, success correlated with the

Table 3 Success of initial biliary reconstruction by surgeon and timing of repair

Timing of repair	Biliary surgeon				Primary surgeon			
	n	Success initial repair	Cumulative success with dilatation	Bivariate *P*-value	*n*	Success initial repair	Cumulative success with dilatation	Bivariate *P*-value
Operative repair	–	–	–	0.854	60	10%	12%	0.103
1 week	31	90%	100%		35	20%	29%	
2 weeks	30	93%	93%		30	17%	27%	
3–6 weeks	33	91%	91%		29	14%	28%	
>6 weeks	43	88%	95%		9	0%	22%	
Total	137	91%	95%		163	13%	21%	

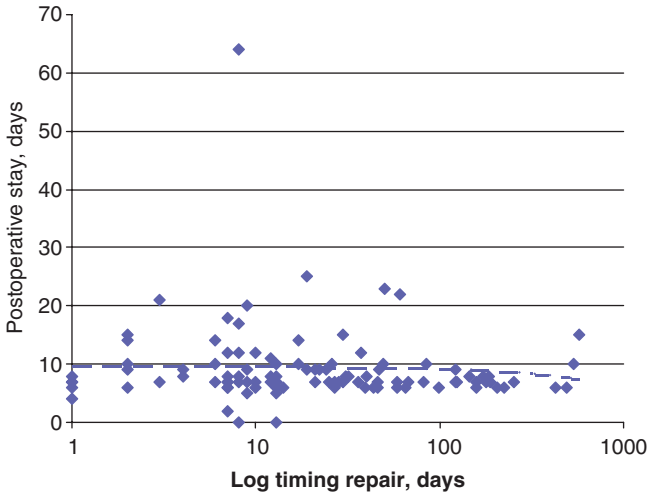

Figure 3 Length of postoperative hospital stay as a function of timing of biliary reconstruction for cases repaired by a biliary surgeon

Table 4 Bivariate and multivariate analysis of factors influencing the success of biliary repair in the entire group

	Bivariate *P*-value	Multivariate *P*-value
Surgeon (primary or biliary surgeon)	<0.0001	<0.0001
Clinical presentation group (operative recognition, none/SIRS, complicated)	0.065	0.226
Preoperative control of intra-abdominal infection/inflammation	<0.0001	<0.0001
Complete preoperative cholangiography	<0.0001	0.002
Correct surgical technique	<0.0001	<0.0001
Timing of repair	<0.0001	0.572
Level of injury	0.197	–
Associated right hepatic artery injury	0.918	–

SIRS, systemic inflammatory response syndrome

eradication of intra-abdominal infection ($P < 0.0001$), complete preoperative cholangiography ($P = 0.001$), use of correct surgical technique ($P < 0.0001$), and repair by a biliary surgeon ($P < 0.0001$). Likewise, success was unaffected by the level of injury ($P = 0.197$) or associated right hepatic artery injury ($P = 0.918$).

For the cases repaired by the primary surgeon, factors associated with success (multivariate analysis) included: the eradication of intra-abdominal infection ($P = 0.004$); the provision of complete preoperative cholangiography ($P = 0.018$); the use of the correct surgical technique ($P < 0.0001$), and Stewart–Way injury class ($P < 0.0001$). The timing of the repair, level of injury, and associated right hepatic artery injury did not correlate with surgical outcomes ($P > 0.371$).

For the cases repaired by a biliary surgeon, eradication of intra-abdominal infection, complete preoperative cholangiography, and correct surgical technique were standard therapy, so, on bivariate analysis, these factors did not correlate with outcomes. Among the other factors analysed (timing of repair, Stewart–Way injury class, level of injury, associated right hepatic artery injury), only level of injury was associated with success on bivariate analysis ($P = 0.014$). Concomitant right hepatic artery injury showed a trend towards significance on bivariate analysis ($P = 0.06$). On multivariate analysis, no factors independently correlated with outcomes, although level of injury showed a trend ($P = 0.062$).

Discussion

Bile duct injuries following laparoscopic cholecystectomy continue to be a problem.[1–4] Although prevention would be ideal, limiting morbidity is critical. The most important factor in this regard is early recognition and the provision of appropriate treatment.[6–33] Biliary reconstruction is often challenging because most of these injuries are high-level injuries (class III injuries represented 60% and high class III and class IV injuries represented 36% of cases in this series). We and others have shown that success depends on the complete eradication of intra-abdominal infection and inflammation, complete preoperative imaging of the biliary tree, and repair by a surgeon with expertise in biliary reconstruction.[6–8,11–23]

Recently, a number of studies have reported that the timing of biliary reconstruction influences outcomes. A number of series have reported worse outcomes for biliary reconstructions per-

formed at <1 week[16] or within 6 weeks[15,17] of injury, whereas others[12,14] report no differences in outcomes related to the timing of the repair, although many routinely allow 5–12 weeks for intra-abdominal inflammation to subside.[12,15,17,25–27] In the current study, we found no correlation between timing of biliary reconstruction and successful repair. We have a standard policy of controlling intra-abdominal infection and inflammation using percutaneous drainage of all abdominal bile/fluid collections. We have previously noted that undrained bile collections can become infected after 9–10 days.[7] In these cases there may be a need for a longer preoperative period. Moreover, in the current study, cases with a more complicated clinical presentation at the time of diagnosis required a longer period of preoperative treatment. However, in cases referred early, with good control of intra-abdominal inflammation, we found no need to delay operative repair. In the current study 44% of cases were repaired in the first 2 weeks with good outcomes. Success of biliary reconstruction and length of postoperative hospitalization were identical, irrespective of the timing of surgical repair. The key objective was the eradication of intra-abdominal infection and inflammation, and the time required to achieve this varied greatly. Complete eradication of intra-abdominal infection and inflammation, by contrast, was a significant predictor of outcomes on multivariate analysis.

In this study we only examined factors influencing the success of the initial surgical repair because we felt that this repair was the most relevant to the question of timing of surgical reconstruction. We examined repairs performed by biliary surgeons as well as those carried out by the surgeons who performed the initial laparoscopic cholecystectomy (the primary surgeon) in order to fully elucidate the factors crucial to a successful repair. The study group was composed of patients who had been referred to us either for repair or an opinion following repair. Overall, we found that repairs by the primary surgeon (or non-biliary surgeons) were successful in only 21% of cases. This number is lower than that reported in studies of cases undergoing litigation (27%),[34] or Medicare beneficiaries,[3] and probably reflects the fact that this is a referral-based population. Although repairs by the primary surgeon may be more successful than the 21% rate reported in the current study, biliary reconstructions by the primary surgeon have been shown to correlate with an earlier death rate compared with those performed by a biliary surgeon.[3] We also wondered whether the timing of the repair might influence outcomes for less experienced surgeons, but this did not seem to be the case. It would be interesting to study the effect of timing in population-based studies of cases with bile duct injuries repaired by the primary surgeon.

Numerous studies have noted that level of injury correlates with surgical outcome, with worse outcomes in patients with higher levels of biliary injury.[12,18–20] We found that the level of injury correlated with outcome on bivariate analysis for the cases repaired by a biliary surgeon, although this was not the case on multivariate analysis. Although higher-level injuries are more difficult to repair, this was not an independent predictor of outcomes. Outcomes for primary surgeons correlated with the Stewart–Way class of injury. Primary surgeons generally had better success rates in class I and II injuries, but were usually unsuccessful in repairing class III and IV injuries. This probably reflects the difficulty of identifying injured bile ducts in these resectional injuries.

It has been reported that associated right hepatic artery injury is correlated with worse outcomes following biliary reconstruction.[28–33] We previously reported that right hepatic artery injury is associated with a higher incidence of bleeding and hepatic abscess at presentation, but noted no influence on the success of biliary reconstruction.[10] This observation held true in the current study.

In conclusion, this study demonstrates that the most important factors associated with the success of biliary reconstruction include the complete eradication of intra-abdominal infection (drainage of all bile and fluid collections), complete characterization of the injury with cholangiography, use of the correct surgical technique, and repair performed by an experienced biliary surgeon. The timing of repair, in this study, was not a factor in outcome success once the above factors had been achieved.

Conflicts of interest

None declared.

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