A COST ANALYSIS OF OPERATIVE REPAIR OF MAJOR LAPAROSCOPIC BILE DUCT INJURIES

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DECLARATION

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Abstract

Major bile duct injuries occur infrequently after laparoscopic cholecystectomy but may result in life-threatening complications. Few data exist about the financial implications of bile duct repair. This study calculated the total in-hospital costs of operative repair in a cohort of patients who underwent reconstruction of the bile duct after major ductal injury sustained during laparoscopic cholecystectomy.

A prospective database was reviewed to identify all patients referred to the University of Cape Town Private Academic Hospital between 2002 and 2013 for assessment and repair of major laparoscopic bile duct injuries. The detailed clinical records and billing information were evaluated to determine all costs from admission to discharge. Total costs for each patient were adjusted for inflation between the year of repair and 2013.

Forty four patients (33 women, 11 men, median age 48 years, range 30 – 78) underwent reconstruction of a major bile duct injury. First time repairs were performed at a median of 24,5 days (range 1 – 3662) after initial surgery. Median hospital stay was 15 days (range 6-86). Mean cost of repair was R215 711 (range R68 764 - 980 830). Major contributors to cost were theatre expenses (22%), admission to intensive care (21%), radiology (17%) and specialist fees (12%). Admission to a general ward (10%), consumables (7%), pharmacy (5%), endoscopy (3%) and laboratory costs (3%) made up the balance.

The cost of repair of a major laparoscopic bile duct injury is substantial due to prolonged admission to hospital, complex surgical intervention and intensive imaging requirements.

Introduction

Gallstones and their associated complications represent a major healthcare and economic burden. It has been estimated that ten to fifteen percent of adult gallbladders in developed countries contain gallstones [1]. A developed country such as the United States of America (USA), with a population of 321 million [2], may consequently have up to 48 million citizens with gallstones. Fortunately, research evaluating the natural history of incidentally discovered gallstones has shown that the majority (80%) of these patients will remain asymptomatic [3,4].

Gracie and Ransohoff reported in their landmark paper in 1982 that asymptomatic subjects developed symptoms attributable to gallstones at an approximate rate of 2% per year for the first five years after an incidental diagnosis of gallstones [3]. The rate of conversion to symptomatic gallstones decreased gradually after this five year period, with 18% being symptomatic after a follow-up period of fifteen years. Crucially, none of their subjects developed complications such as acute cholecystitis or acute pancreatitis before the emergence of gallstone dyspepsia or biliary colic. This study recommended that prophylactic cholecystectomy for asymptomatic cholelithiasis was not necessary. This observation has been confirmed by subsequent data [4-6] and prophylactic cholecystectomy is currently not indicated for clinically silent cholelithiasis.

Once cholelithiasis has become symptomatic, cholecystectomy is indicated to prevent subsequent complications. Published data suggest that approximately 60 000 [7] and up to 750 000 [8] cholecystectomies are performed in the United Kingdom and the United States of America respectively on an annual basis. Cholecystectomy has now become one of the most commonly performed elective operations and is offered as both an inpatient and outpatient procedure.

Removal of the gallbladder and the gallstones contained therein relieves patients of pain and prevents future gallstone-related complications, which include acute cholecystitis, ascending cholangitis, obstructive jaundice, acute pancreatitis and gallbladder cancer. These complications may be life threatening.

By virtue of the high prevalence of gallstones, they account for large numbers of both outpatient consultations and admissions to hospital. It has been reported that gallstones are the second highest cause of healthcare spending arising from any gastrointestinal disease, leading to annual direct costs of $ 5.8 billion in the USA, as far back as the year 2000 [9]. A comprehensive survey in the USA estimated that during the year 2000, a staggering 262 411 admissions to hospital and 778 632 outpatient visits occurred due to gallstones [1]. More contemporary data suggest that gallstones are resposible for up to 1.8 million ambulatory care visits per year in the USA.

Gallstones: types and risk factors

Three types of gallstones may develop in the human gallbladder. Black pigment stones, composed of polybilirubinate, occur in association with diseases where excessive breakdown of haemoglobin occurs, e.g. haemolytic anaemias. Brown pigment stones (calcium-bilirubinate stones) are a consequence of chronic biliary infection and stasis and are more common in Eastern Asian populations where biliary infestation by liver flukes such as *Opisthorchis viverrini* and *Clonorchis sinensis* is a major public health problem.

Cholesterol stones are the most common of the three types, especially among Western populations. Important risk factors for the development of cholesterol gallstones include female sex, age, genetics and obesity, especially central obesity. Less common risk factors are rapid weight loss, as seen after bariatric surgery, total parenteral nutrition, liver cirrhosis, terminal ileum disease or absence and increases in oestrogen levels.

Obesity is an accepted major risk factor for the development of cholesterol gallstones [1]. It is also the most troubling of the risk factors, as not only is obesity often accompanied by other co-morbid conditions of the metabolic syndrome and associated with higher peri-operative risk, it has shown an alarming increase in prevalence in modern times.

Since 1980, areas of the USA, the United Kingdom, Eastern Europe, the Middle East, the Pacific Islands, Australasia and China have experienced a three-fold increase in the rate of obesity. Worldwide, more than one billion adults are now overweight, with 300 million satisfying the criteria for clinical obesity [10]. This is ascribed to the combination of overconsumption of energy dense foods and a decrease in physical activity. Alarmingly, this increase is increasing more rapidly in developing countries than the developed world[10].

The obvious inference is that the rising global obesity epidemic will lead to a further increase in the number of patients who will seek medical care and require surgery for gallstone-related symptoms and complications.

The evolution of open to laparoscopic cholecystectomy

The first operation to remove gallstones was performed by John Bobbs in Indiana on 15 July 1867 [11]. The cholecystolithotomy that he performed consisted of stone extraction after an incision in the gallbladder, followed by careful suture closure without externalisation. Surgical removal of the stones without cholecystectomy subsequently became the preferred surgical procedure for the treatment of complicated gallstones.

Carl Langenbuch, a German surgeon observed that gallstones tended to recur and that the gallbladder was not essential to life, after taking note of experimental work done by Zambeccari in 1630 and Teckoff in 1667 who performed investigational cholecystectomies in dogs [11] . Langenbuch is credited with performing the first elective open cholecystectomy in Berlin in 1882 [12]. The patient spent two months in hospital.

After a period of skepticism in the surgical community of the day regarding the superiority of cholecystectomy over cholecystolithotomy, open cholecystectomy gradually became established as the procedure of choice for symptomatic cholelithiasis in the succeeding decades. During the early twentieth century, family physicians without proper experience and training in surgical technique performed many of these early cholecystectomies, frequently resulting in extrahepatic bile duct injury and haemorrhage [12]. Progressive refinement of the surgical technique and the timing of cholecystectomy with respect to acute cholecystitis improved morbidity and mortality rates to acceptable levels by the 1980s.

Large case series of open cholecystectomy performed during the 1980s and 1990s, the period before the widespread introduction of laparoscopic cholecystectomy, reported low overall morbidity rates of 10-15% and low rates of bile duct injury, ranging from 0,1% to 0,2% [12,13].

Laparoscopic examination of the peritoneal cavity was first attempted by George Kelling in 1901 [14]. Thereafter stepwise innovations led to basic procedures such as adhesiolysis and diagnostic biopsies performed under laparoscopic vision, mostly by gynaecological surgeons [14]. Further refinements in image acquisition, magnification and projection eventually enabled attempts at more advanced laparoscopic procedures.

The first laparoscopic cholecystectomy was performed by Eric Muhe, a German surgeon in 1985 [15-17]. Serious initial reservations regarding the safety of laparoscopic surgery were dispelled and the technique was rapidly adopted by the worldwide surgical community. The speed with which laparoscopic surgery has been embraced by surgeons and the general population is unrivalled and has been responsible for significant innovations and changes in surgical care, the impact of which is matched by few other surgical milestones.

The perceived benefits of the laparoscopic approach and patient demand for operations performed through less traumatic entry into to the peritoneal cavity played a principal role in laparoscopic cholecystectomy replacing open cholecystectomy as the most popular operation to remove the gallbladder in patients with symptomatic cholelithiasis, whether uncomplicated or complicated by cholecystitis. The benefits of laparoscopic cholecystectomy to patients include less post-operative discomfort due to smaller incisions, a better cosmetic result, a shorter hospital stay and earlier return to work and daily activities [18,19]. Despite the increased cost of the operation itself when compared to the open procedure, laparoscopic cholecystectomy has also been shown to lead to significant cost savings due to shorter post-operative hospital stays [20].

The benefits of laparoscopic removal of the gallbladder to the operating surgeon are not as well documented, but the laparoscopic technique, performed with the aid of modern equipment, does permit outstanding and magnified visualisation of the sub-hepatic surface and portal area, enabling very precise dissection. To obtain the same view at open cholecystectomy and expose the porta hepatis for safe dissection, a large right subcostal incision may be required, especially in obese patients.

Soon after the widespread introduction of laparoscopic cholecystectomy, it became apparent that the technique was associated with a learning curve, due to factors such as a two dimensional view of the operative field with a lack of depth perception, error traps that need to be avoided during laparoscopic dissection of the gallbladder, a highly magnified operative field and a lack of tactile feedback, all leading to potential misidentification of and injury to critical structures in the hepatocystic angle and hepatoduodenal ligament [21-24].

The two critical steps in the performance of a cholecystectomy are the safe division and secure closure of the cystic duct and cystic artery where they enter the gallbladder neck. Without tactile feedback and three dimensional perception of the operative field, visual deception plays an important role in the occurrence of a major bile duct injury, irrespective of the surgeon’s experience [21]. Often, the common bile duct is mistaken for the cystic duct, leading to either a lateral injury or partial resection of a variable length of the bile duct. The right hepatic duct may also be injured due to the same error. A variety of factors exist that may increase the likelihood of such an event.

Acute or chronic inflammation may cause contraction and even obliteration of the hepatocystic angle, bringing the neck of the gallbladder (infundibulum) into close association with critical structures, namely the common hepatic duct, the right hepatic duct and the right hepatic artery [21]. A gallstone impacted in the lower aspect of the gallbladder and a thickened fibrotic gallbladder wall which is difficult to retract compound the difficulty and hazards of dissecting the cystic duct and cystic artery.

Multiple variations in the anatomy of the biliary system may also contribute to misidentification of structures. Especially troublesome are aberrant right-sided bile ducts, emanating from a single segment or sector of the right liver, which may join the common bile duct at inconstant positions [22]. These ducts are easily mistaken for the cystic duct due to their smaller diameter and right-sided position in the hepatocystic angle.

The rate of bile duct injuries during a surgeon's learning curve is reported to be higher compared with their later experience [25]. Adequate training in the technique and pitfalls of laparoscopic cholecystectomy and senior supervision during a surgeon's early experience is therefor of vital importance. It is unsettling that a significant proportion of bile duct injuries are caused by experienced surgeons who have moved past the learning curve, suggesting that even the experienced surgeons are liable to fall victim to error traps during laparoscopic cholecystectomy.

How to minimise the misidentification of the cystic duct is the subject of many published papers and an area of ongoing research. An important contribution by Strasberg was the introduction of the critical view of safety that has to be achieved before any structures are to be divided during cholecystectomy [26]. The critical view of safety hinges on three elements: the clearance of connective tissue from the hepatocytstic angle, the demonstration of the entry of only the cystic duct and cystic artery into the gallbladder, and the partial dissection of the neck of the gallbladder off the cystic plate so as to exclude the coursing of any aberrant ducts and arteries towards the liver. Only after these three conditions are satisfied, is the surgeon permitted to divide the cystic duct and cystic artery.

Although the critical view of safety is an important objective, the dissection required to satisfy the three required elements may itself lead to injury if performed injudiciously and may not even be possible to achieve due to the presence of fibrotic scarring. Under these circumstances authors have suggested the performance of a subtotal cholecystectomy after early entry into the gallbladder lumen as an aid to anatomic orientation [27].

Other authors have suggested the use of routine intra-operative cholangiography to define the anatomy of the biliary system at laparoscopic cholecystectomy and facilitate the safe division of structures. Whether or not routine cholangiography does have a protective effect on specifically the incidence of bile duct injury is a matter of divided opinion. Proponents of routine cholangiography argue that there is evidence to support their claim and that its routine use will also aid in the intra-operative diagnosis of an injury [28-30].

Opponents of routine intra-operative cholangiography argue that some of the data is heterogenous and retrospective in nature [28,30] and that by the time a cholangiogram is performed, biliary injury may have occurred already. Other studies have not shown a protective effect on the incidence of bile duct injury [31-34]. Another important drawback is the incorrect interpretation of cholangiograms as pointed out by a recent survey where surgeons of varying seniority, as well as hepatobiliary experts made mistakes in their assessment of anatomical variations of the biliary tree [35].

A recent publication, investigating the association between the use of selective intra-operative cholangiography and the risk of bile duct injury, demonstrated no protective effect with respect to uncomplicated gallstone disease, but did show that the intention to perform a cholangiogram in patients with concurrent or a history of acute cholecystitis did reduce the risk of a bile duct injury [36]. The same author previously showed that the intention to use intra-operative cholangiography reduced the risk of bile duct injury by 62% [33]. The rate of bile duct injury in the population based cohort used for these two studies was an alarming 1,5% [33,35]. This figure is likely to represent all types of bile duct injury, including minor injuries resulting in bile leakage, as well as major injuries to the common or right hepatic ducts.

Near-infrared fluorescence imaging of the extrahepatic biliary system at laparoscopy, approximately twenty minutes after the intravenous injection of indocyanine green, can identify the common bile duct and cystic duct in 83% and 97% of cases respectively, at an earlier stage during the procedure [37]. A second injection can also identify the cystic artery in 87% of cases. This non-invasive modality shows promise as an aid in identifying biliary structures correctly.

Although laparoscopic cholecystectomy was introduced more than two decades ago and despite the marked improvement in video-laparoscopic equipment, the incidence of major bile duct injuries has not diminished and is still commonly quoted to occur in 0.4% of operations, which is twice as common as compared to data from the era of open cholecystectomy [29,31,38]. The rate of bile duct injury in South Africa has not been investigated, neither is there any reporting system from which reliable prospective data can be generated.

The consequences of bile duct injury

An injury to the extrahepatic bile duct is one of the most feared complications in surgery. Few other surgical complications effect such a drastic alteration of a patient's expected post-operative recovery.

The injury may be recognised at the time of laparoscopic cholecystectomy or during the post-operative period. Early recognition may lead to open surgery through a sizeable incision and an attempt at repair if suitable expertise and equipment is available. Even in the event of an immediate repair by a surgeon experienced in the reconstruction of bile duct injuries, resulting in an uncomplicated recovery, the news of an injury and it's implications are expected to deal the patient a psychological blow, regardless of the impact of an unexpected sizeable incision.

The complications of a major bile duct injury can be profound [39]. Patients are for the most part hospitalised for protracted periods and may become desperately ill due to septic complications which include intraperitoneal leakage of bile and less commonly, vascular injuries to the right hepatic artery resulting in varying degrees of liver ischaemia. The majority of bile duct injuries are missed during the index laparoscopic cholecystectomy [40-43], which results in a delayed presentation with septic complications requiring careful resuscitation and interventions such as peritoneal lavage, drainage of septic bilomas, percutaneous transhepatic biliary drainage, intensive care unit admission, haemodialysis and intravenous antibiotics to stabilise and reverse life-threatening complications. Thereafter often follows a series of investigations to characterise the biliary injury and further temporising interventions to control the biliary fistula or biliary obstruction and improve the patient's physiological status before repair is comtemplated.

While minor injuries with duct continuity resulting in bile leakage can be successfully treated with endoscopic retrograde stenting without recourse to operation, major injuries with duct division are life-threatening and may require complex biliary reconstructive surgery [44]. Leakage from a partially injured common bile duct can be treated successfully in 89% of cases, while the success rate for patients presenting at a later stage with partial common bile duct strictures is up to 74%, the remainder requiring surgical repair [44].

Optimal management of a major bile duct injury requires careful, co-ordinated, multidisciplinary assessment and intervention by a knowledgeable and experienced group of surgeons, intensivists, endoscopists and interventional radiologists [40,45]. Reparative biliary surgery is technically demanding and should be undertaken only by a surgical team with expertise and established credentials [46]. In rare circumstances, where injury has occurred to the bile duct and the hepatic arteries and/or portal vein, liver transplant may be indicated for liver failure, in which case the outcome of transplantation is poor [47].

Where a major injury to the extrahepatic biliary system has occurred, definitive operative repair requires a high hepatico-jejunostomy which is typically performed six to twelve weeks after the injury has occurred [40,48]. The reasons to delay the repair are optimisation of patients' physiological and nutritional status, often deleteriously affected by septic complications, as well as to give the inflamed and scarred portal region a chance to settle and permit safer dissection on the day of repair. In the case of an associated injury to the right hepatic artery, which is a vital source of blood supply to the common bile duct [49], a waiting period permits the bile duct to atrophy back to a point where an anastomosis can be performed on well perfused and healthy bile duct tissue, thereby minimising the possibility of a post-operative anastomotic stricture [50].

During the interim, patients are often confined to hospital due to the high volume of external biliary losses, consisting of fluids, electrolytes and bile salts. These losses often require intravenous replacement and the risk of malnutrition due to impaired digestion and absorption of fat and fat-soluble vitamins is high, requiring various nutritional interventions and refeeding of bile through a nasogastric tube in certain cases. Patients who are candidates for delayed repair are often unable to earn an income during the interim between the injury occurrence and recovery from the often delayed major reparative surgery required to conclusively repair the biliary defect.

In cases where biliary injury is correctly suspected and/or diagnosed during laparoscopic cholecystectomy, early bile duct repair may be attempted under strict circumstances [17,23]. Experts agree that the injury should be repaired by an experienced unit, familiar with the principles of biliary reconstruction, as the outcome of repair by the surgeon responsible for the occurrence of the injury is poor, with only 22 to 27% of injuries not requiring revision surgery [51,52].

The obvious advantages of early repair are the potential avoidance of septic complications and a shorter recovery and hospitalisation period, with an earlier return to work and daily activities. However, in order to guarantee a

high likelihood of success when early bile duct reconstruction is contemplated, the following criteria need to be met:
(i) no accompanying vascular injury has occurred, (ii) the patient is systemically fit for a lengthy open operation, (iii) an absence of sepsis and severe local inflammation in the sub-hepatic space, (iv) the repair is to be performed by a surgeon with expertise in biliary reconstruction, and (v) the biliary injury and anatomy must be clearly delineated with identification of all the relevant segmental/sectoral bile ducts to be included in the repair.

A successful and durable repair of the injury by an expert surgeon is a critical factor in securing a satisfactory longterm outcome, an important factor taken into account when patients consider legal action [52]. The outcome of repair and a delay in diagnosis are key factors that play a role in the calculation of damages awarded to patients who are successful in their legal pursuit of compensation [53].

Iatrogenic injury to the bile ducts after laparoscopic cholecystectomy has an unescapable impact on a patient's short-term physical quality of life, due to the need for hospitalisation, septic complications and interventions, e.g. laparotomy and percutaneous drainage catheters that result in physical discomfort. The effect of the injury on a patient's long-term physical quality of life, after successful repair of the injury is less obvious but of great significance, particularly when the outcome of reparative surgery is assessed.

Publications examining long-term physical quality of life outcomes utilised different assessment questionnaires at different intervals after occurrence of the injury, which affects the comparability of the data [54-57]. While some of the studies do not report any statistically significant negative effect, the data does however demonstrate that patients report less of an impact the longer the intervening period between the injury and the assessment of their physical quality of life [54-57].

Ejaz et al evaluated health-related quality of life in a cohort of patients with the longest reported length of follow-up (median169 months; IQR 125 to 222 months). The majority of respondents (65,6%) reported good to excellent health, with only 8% of patients reporting severe pain 10 to 15 years post-operatively. No patients reported severe pain more than 15 years after the repair and most patients (84,3%) were able to return to work. Patients have nevertheless been shown to return to work on average three months later than patients who underwent an uncomplicated laparoscopic cholecystectomy [58]. Encouragingly, only 2,9% of patients were found to have a failed repair, requiring reinsertion of stents and/or surgical revision of the hepatico-jejunostomy.

Mental quality of life does seem to be affected in the long-term [55,57-59]. Patients often experience depression and low levels of energy. Whereas up to half of patients may experience these symptoms before repair of the injury, only 18% will continue to be aware of depression or low energy levels in the years following successful biliary reconstruction [57]. There are however conflicting data that does not show a detrimental effect of bile duct injury on long-term mental quality of life [60,61]. Once again, these contrasting findings may be explained by the difference in follow-up time and use of different survey tools, as well as a possible difference in the cohorts studied.

The consequences of bile duct injury extend beyond the physical and psychological morbidity caused by complications, prolonged hospitalisation and multiple surgical procedures. It not only affects a patient’s eventual quality of life, but also leads to loss of income due to time of work and unexpected hospital charges and, in some cases, result in prolonged and unpleasant litigation [54-56].

It has been reported that between 22% and 71% of patients seek litigation after an iatrogenic bile duct injury [57,58]. Delays in diagnosis, repair by the injuring surgeon and a perceived incomplete recovery are factors associated with a higher likelihood of litigation [52,62]. Interestingly, De Reuver and colleagues found that patients reported higher health-related quality of life when litigation had ruled in their favour [55]. This contrasts with the findings of Ejaz et al, who failed to demonstrate a significant association between the outcome of a lawsuit and health-related quality of life [57].

Most lawsuits initiated after iatrogenic bile duct injury find in favour of the plaintiff [52,53,63]. In the UK, between 2000 and 2005, a total of 208 claims related to laparoscopic surgery were reported to the National Health Service Litigation Authority. Of these claims, 133 were related to laparoscopic cholecystectomy. Iatrogenic bile duct injury accounted for the majority of claims (72%), resulting in a mean amount of £53 901 awarded per claim. This amount consists of a total of the damages awarded and the cost of litigation carried by the National Health Service [53]. In the USA, damages awarded to patients are higher, ranging from $214 000 to $496 167 [52,64].
The direct and indirect costs generated by iatrogenic bile duct injury are manifold and are highly individualised. No comprehensive data exist to quantify or accurately predict the total cost of bile duct injury.

The financial burden implicit in injury management is significant, yet no local and few international data are available to accurately assess the cost of definitive bile duct reconstruction [65-68]. Furthermore, factors that affect the cost of repair are poorly described. In this study we calculated the total in-hospital costs of the definitive repair of major laparoscopic bile duct injuries by including all costs incurred from referral to discharge from hospital with a durable repair.

Primary aim of the study

To calculate the total in-hospital cost of definitive operative repair of major extrahepatic bile duct injuries, sustained during laparoscopic cholecystectomy.

Secondary aim

To detect factors responsible for increasing the cost of repair, e.g. late referral, type of injury, complications, prior attempt at repair by a non-expert.

Methods

Study design and ethical approval

Retrospective cohort study

The study was approved by the University of Cape Town Health Research Ethics Committee (HREC REF 600/2014).

Study population

Between March 2002 and October 2013, 52 patients were referred to the University of Cape Town Private Academic Hospital (UCTPAH) for assessment of a suspected or confirmed major injury to the extra-hepatic bile duct sustained during a laparoscopic cholecystectomy. This hospital serves as a referral centre for private patients with complex hepatic, biliary and pancreatic conditions and is serviced by academic surgeons experienced in the management and repair of bile duct injuries.

Demographic and clinical information was obtained from a prospective database kept specifically for all patients referred with a laparoscopic bile duct injury. The database is maintained in the Surgical Gastroenterology Unit of Groote Schuur Hospital by a dedicated research assistant. Data collected and entered included patient demographics, indication for laparoscopic cholecystectomy, recognition of injury during or subsequent to cholecystectomy, mode of delayed presentation, delay in referral, timing of referral, investigations and procedures performed prior to referral, type of injury according to the Strasberg classification [22], investigations and procedures prior to definitive surgery, timing of repair, length of intensive care unit and total hospital stay, investigations and procedures after repair and complications. In this study a cohort of 44 patients who had an operative repair of a major bile duct injury was identified and analysed. Eight patients were excluded because they had a minor bile duct injury which did not require surgery (n=2 patients), or complete and detailed billing information was not available on the hospital computer records (n=6 patients).

Inclusion criteria

- Adult patients undergoing definitive repair of a major laparoscopic bile duct injury at UCT Private Academic Hospital between 2002 and 2013.

Exclusion criteria

- Incomplete clinical records
- Incomplete or unavailable detailed hospital charge sheet
- Minor duct injuries not requiring a bilio-enteric anastomosis

The information captured in the database, as well as the detailed original clinical notes were reviewed to ensure accuracy of the data. Some patients required interventions aimed at the management of septic complications. Each patient underwent detailed pre-operative assessment to define the extent of the bile duct injury including a multiphase CT scan, MRI and MRCP scans and percutaneous transhepatic cholangiography (PTC) with percutaneous biliary drain placement. Possible arterial injuries were identified by contrast-enhanced CT scan and if required, ultrasound guided duplex Doppler flow assessment. The demographic and clinical details were recorded on a new pro forma spreadsheet for each individual case, an example of which is represented by Table 1.

The interval from initial injury to definitive repair was defined as the number of days from initial injury to definitive repair at the University of Cape Town Private Academic Hospital. This interval was inclusive of previous repairs performed at outside medical centres. For the purpose of the study, “first repairs” were defined as patients without a prior attempt at repair or an attempted repair by any method other than a bilio-enteric anastomosis.

“Revision surgery” was the term used when a repair was performed on patients with a previous hepatico- or choledocho-jejunostomy. Biliary strictures were classified using the Strasberg classification of bile duct injuries[9] (Figure 1):

Type A: bile leak from cystic duct stump or gallbladder bed
Type B: aberrant right hepatic duct occlusion
Type C: aberrant right hepatic duct transection
Type D: partial (<50%) transection of a major bile duct
Type E: >50% transection or complete transection of a major bile duct, further sub-classified as:

- E1: more than 2 cm from the confluence of the left and right hepatic ducts
- E2: less than 2 cm from confluence
- E3: no common hepatic duct remnant with an intact hepatic duct confluence
- E4: destruction of the hepatic duct confluence
- E5: aberrant right sectoral duct in conjunction with an injury to the common hepatic duct.

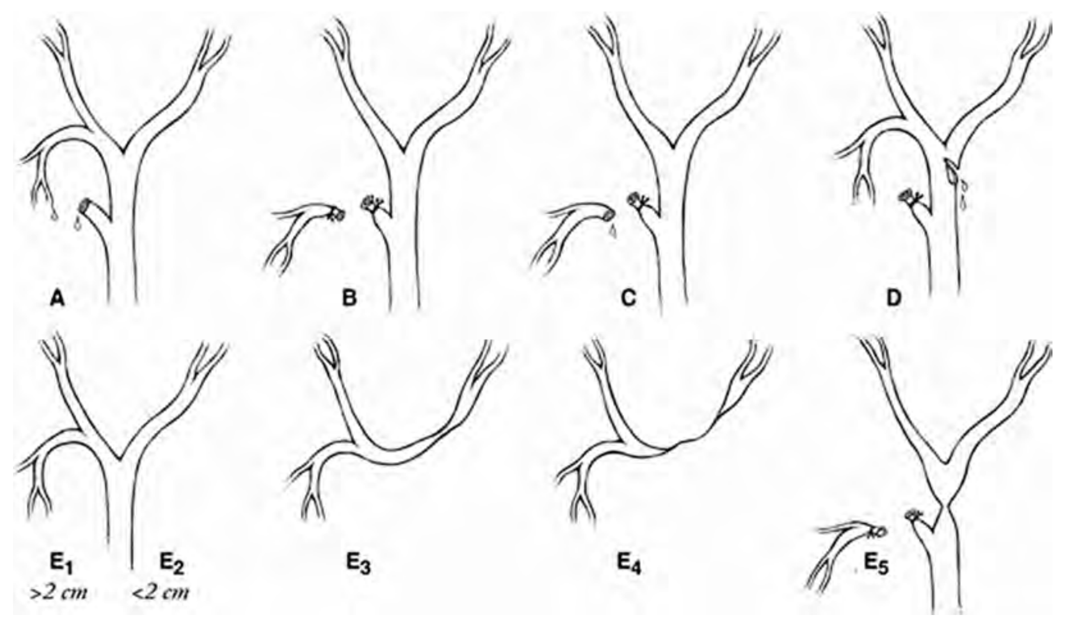


Figure 1: Strasberg classification of bile duct injuries

Table 1: **Example summary of demographic and clinical data per case**				
Patient/Study nr				
Age, Sex				
Duration admission				
File number				

Table 1: **Example summary of demographic and clinical data per case**					
Indication index surgery	Uncomplicated symptomatic gallstones, Acute Calculous Cholecystitis, Acute Acalculous Cholecystitis, Gallstone Pancreatitis, Choledocholithiasis				
Date index surgery					
Recognition of BDI at index case	Yes/No				
Procedure at index case if recognised	Converted Yes/No				
	Drainage, Primary repair without Ttube, Primary repair over Ttube, Hepaticojejeno				
Imaging subsequent to index case and recognition +/- repair (nr)	CT				
	US				
	ERCP				
	PTC				
	MRCP				
Procedures subsequent to initial repair, before referral to UCT PAH	Hepaticojejunostomy				
	Redo Hepaticojejunostomy				
	Drainage				
	Primary repair				
If not recognised, delay until recognition in days					
Mode of presentation after delay	Jaundice, Bile leak, Intra-abdominal sepsis, Deranged LFT, Cholangitis, Abnormal Postoperative pain				
Imaging performed after delayed recognition (nr)	CT				
	US				
	PTC				
	ERCP				
	MRCP				
Procedures subsequent to delayed recognition, before referral to UCT PAH	Laparotomy and drainage				
	Hepaticojejunostomy				
	Primary repair				
	Percutaneous drainage				

Table 1: **Example summary of demographic and clinical data per case**				
Time: Index surgery to referral				
Time: Index surgery to surgery UCT PAH				
@ UCT PAH				
TYPE according to Strasberg Class.				
Pre-operative imaging (n)	CT			
	US			
	PTC			
	ERCP			
	MRCP			
Pre-operative intervention	Yes/No			
	Procedure(s)		Perc drainage, stent etc	
Surgery performed	Yes/No			
	Procedure		Hepaticojejunostomy, Primary repair + Drainage	
Major complications / Morbidity				
Post-operative imaging				
Follow-up visits				
Follow-up imaging				
Follow-up procedures				
Mortality (Yes/ No)				
Additional notes				

Complications were graded according to the Dindo-Clavien classification system (Table 2) for the standardised reporting of postoperative surgical complications [69].

Table 2: Dindo-Clavien Classification of Surgical Complications	
Grade I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions Allowed therapeutic regimens are: drugs as antiemetics, antipyretics, analgetics, diuretics, electrolytes, and physiotherapy. This grade also includes wound infections opened at the bedside
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications Blood transfusions and total parenteral nutrition are also included
Grade III	Requiring surgical, endoscopic or radiological intervention
Grade IIIa	Intervention not under general anaesthesia
Grade IIIb	Intervention under general anaesthesia
Grade IV	Life-threatening complication (including CNS complications)* requiring IC/ICU management
Grade IVa	Single organ dysfunction (including dialysis)
Grade IVb	Multiorgan dysfunction
Grade V	Death of a patient
Suffix “d”	If the patient suffers from a complication at the time of discharge (see examples in Table 2), the suffix “d” (for “disability”) is added to the respective grade of complication. This label indicates the need for a follow-up to fully evaluate the complication.
*Brain hemorrhage, ischemic stroke, subarrachnoidal bleeding, but excluding transient ischemic attacks. CNS, central nervous system; IC, intermediate care; ICU, intensive care unit.	

Operative technique

A standard operative technique was used for all bile duct reconstructions [70]. A bilateral subcostal incision 3 cm below the costal margin was used, followed by placement of an Omnitract ® fixed body wall retractor to provide adequate exposure to the upper abdomen. All adhesions in the right upper quadrant were carefully dissected free and released to gain access to the liver hilum. The hepatic arterial and portal venous vasculature in the hepatoduodenal ligament was identified and preserved.

The site of the bile duct injury was identified, an action greatly facilitated by the location of the pre-operatively placed percutaneous transhepatic biliary drain, which was visible at the site of injury or indicated the site after the injection of a coloured dye via the drain. All fibrotic tissue in the proximal hepatoduodenal ligament adjacent to the injury was excised. The hepatic ducts identified at the level of the hepatic duct confluence were exposed by incising the hilar plate at the base of the quadrate lobe, thereby lowering the extrahepatic left hepatic duct and the hepatic duct confluence. The ducts were dissected until healthy well vascularised ductal mucosa was identified. An anterior longitudinal incision between serially placed stay sutures was made in the extrahepatic component of the left hepatic duct using the Hepp-Couinaud approach [71,72].

Careful choledochoscopy was done to identify the right and left hepatic ducts and ensure the absence of intrahepatic stones. The operative choledochoscopic findings were reconciled with the pre-operative MRCP and PTC imaging to ensure identification of all ducts. A 40 cm retrocolic jejunal Roux-en-Y loop was fashioned and a side-to-side hepato-jejunal anastomosis constructed using pre-placed 5/0 absorbable monofilament sutures. The hepato-jejunal anastomoses were stented using the existing percutaneous transhepatic biliary drainage catheters. A side-to-side entero-enterostomy anastomosis was done in the infra-mesocolic compartment.

One week after the operative repair, percutaneous cholangiography was performed via the biliary drainage catheters to confirm an intact and unobstructed biliary-enteric anastomosis. The percutaneous drains were removed 14 days later.

<u>Calculation of financial data</u>

All patient costs from admission to discharge as captured daily into the hospital billing system were accessed. The hospital charge sheets were remarkably detailed and reflected all costs incurred during a patient’s hospital stay under various categories. The charge sheets also provided accurate data regarding time spent in hospital (both in general wards and the intensive care or high care units), as well as time spent in operating rooms, fluoroscopy suites and endoscopy suites.

The complete hospital charge sheet, as well as the invoices for laboratory investigations, radiology services and all specialist clinicians contributing to care were reviewed and aggregated to calculate the total cost per patient. Costs were classified under the following categories: hospital bed costs which were subdivided into general ward, intensive and high-care; cost of ward consumables (swabs, dressings, intravenous cannulas and lines, etc); pharmacy costs; operating theatre costs (theatre time, consumables including sutures, anaesthetic gases, etc.), radiology costs, laboratory costs and specialist fees. An example of the pro forma documents used to calculate the total cost for each patient is reflected by Table 3.

The inflation rate of health care expenditure in South Africa has consistently exceeded the average consumer price inflation in recent years. During the study period from 2002 to 2013, inflation specific to health care in the private sector was almost double that of consumer price inflation, leading to a large difference, in real terms, between costs generated during the twelve years that the study covered. This fact necessitated adjustment of all costs to figures comparable to costs in 2013 in order to make meaningful statistical calculation possible. Costs were adjusted with year on year data, specific to medical inflation available from Statistics South Africa (www.statssa.gov.za). A compound inflation calculator was used to perform the calculations (Table 4).

Previous studies reporting on the cost of bile duct repair [65-68] did not adjust for inflation, presumably due to the lower rate of inflation in the countries involved, namely the USA and Sweden, where inflation has been low, especially since the 2008 global financial crisis [73].

Table 3: **Cost summary: operative repair of laparoscopic bile duct injury**

Patient						
Age						
Sex						
File number						
Admission dates						
WARD COSTS					days	cost (R)
	BED		ICU/HIGH CARE			
			GENERAL WARD			
			TOTAL		0	0
	EXTRAS/CONSUMABLES					
	DISPENSARY DRUGS					
	TOTAL					0
SPECIALIST FEES	SURGEON					
	ANAESTHETIST					
	CRITICAL CARE SPECIALIST					
	PHYSIOTHERAPY					
	TOTAL					0
THEATRE COSTS	THEATRE TIME				minutes	cost (R)
	CONSUMABLES/FLUIDS/DRUGS/GAS					
	TOTAL					0
ENDOSCOPY COSTS		nr before surgery	cost (R)	nr after surgery	cost (R)	combined cost (R)
	ERCP +/- STENT					
	UPPER GIT ENDOSCOPY					
	TOTAL	0	0	0	0	0
RADIOLOGY COSTS		nr before surgery	cost (R)	nr after surgery	cost (R)	combined cost (R)
	PLAIN X-RAYS					0
	SONOGRAPHY					0
	COMPUTED TOMOGRAPHY					0
	MRCP					0
	PTC +/- STENT					0
	PERCUTANEOUS DRAINS					0
	TOTAL	0	0	0	0	0
LABORATORY COSTS	HAEMATOLOGY					
	CHEMISTRY					
	MICROBIOLOGY					
	TOTAL					0
OUTPATIENT FOLLOW-UP COSTS					number	cost (R)
	SPECIALIST VISITS					
	PROCEDURES					
	TOTAL				0	0
	TOTAL COST (ZAR)					0

Table 4: **Inflation calculator**

	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Medical inflation (STATSSA)	-	9,8%	10,1%	7,3%	6%	5,6%	6,2%	11,4%	11,2%	9,1%	8,4%	4,7%
Inflation adjusted cost of operation	1,00	1,10	1,21	1,30	1,37	1,45	1,54	1,72	1,91	2,08	2,26	2,37

Data safety

After identification of patients from the database, registered with the Health Research Ethics Committee of the University of Cape Town, data could only be entered into the study spreadsheet under a study number. The master sheet, matching the patients to a study number was locked with the database information in the office of the Surgical Gastroenterology Unit research assistant, in the E23 Gastroenterology clinic, Groote Schuur Hospital. The study spreadsheet was only used by Prof JEJ Krige and Dr S Hofmeyr. It was not distributed to any other colleagues, except in part and as an anonymous form to Dr M Setshedi, employed within the Division of Medical Gastroenterology, Groote Schuur Hospital, who assisted with the performance of the multivariate statistical analysis.

Statistical analysis

After data had been gathered and summarised for each individual case, the data were entered into a Microsoft Excel (Microsoft Corp, Redmond, WA, USA) master spreadsheet for univariate analysis. Results were presented as percentages, median, mean and range. Further multivariate analysis to determine the correlation between postoperative complications, sepsis on admission, conversion to open surgery upon recognition and cost of repair was performed by applying the Pearson $\chi 2$ test or Kruskal-Wallis test, depending on the distribution of continuous variables. STATA (STATA for Windows, version 11, Stata corp, College Station, TX, USA) was used to perform the multivariate analyses. A p-value of less than 0.05 was considered significant.

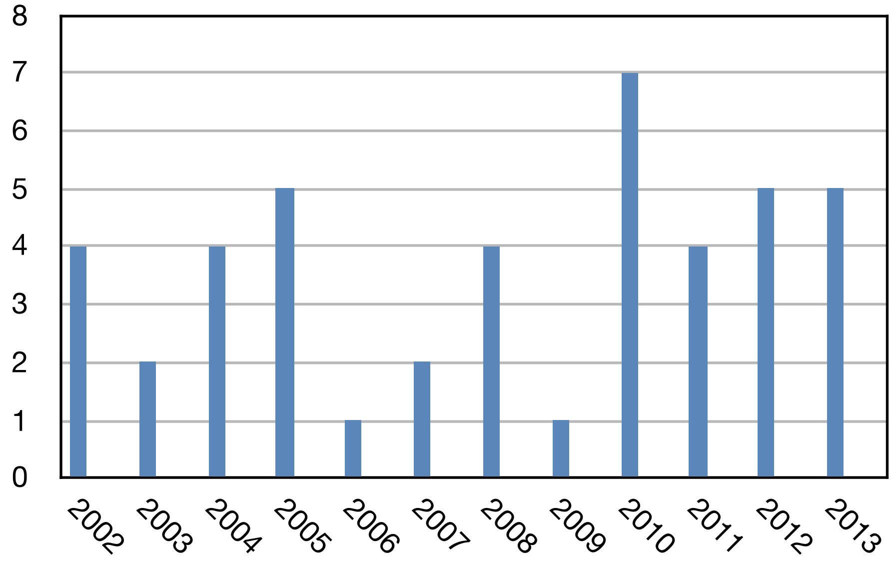
Results

During the study period, spanning 2002 to 2013, 44 patients with major bile duct injuries were assessed and repaired at UCT Private Academic Hospital. As expected, 33 (75%) patients were female and 11 (25%) male. The median age of the cohort was 48 years, ranging from 30 to 78 years old (Table 5). Table 6 illustrates the annual incidence of major bile duct injury repair for the study period.

The indication for laparoscopic cholecystectomy was uncomplicated symptomatic gallstones in 80% and acute cholecystitis in 20% of patients. For the whole cohort of 44 patients, including those who were referred for first repairs or revision surgery, 43% of bile duct injuries were recognised during the index operation.

Table 5: Patient demographics (n=44) and general data	
MEDIAN AGE (RANGE)	48 yr (30-78)
MALE	11 (25%)
FEMALE	33 (75%)
INDICATION: UNCOMPLICATED SYMPTOMATIC GALLSTONES	35/44 (80%)
INDICATION: ACUTE CHOLECYSTITIS	9/44 (20%)
INJURY: RECOGNISED AT CHOLECYSTECTOMY	19/44 (43%)
INJURY: NOT RECOGNISED AT CHOLECYSTECTOMY	25/44 (56%)
TOTAL DAYS IN HOSPITAL (MEDIAN, RANGE)	15 (6-86)
DAYS IN ICU/HIGH CARE	5,5 (2-55)
DAYS IN GENERAL WARD	9 (2-46)

Table 6: Annual incidence of major bile duct injury repair



Of the bile duct injuries that were recognised during the initial laparoscopic cholecystectomy (n=19), conversion to open surgery occurred in 12 (63%) cases. Repair by hepatico-jejunostomy was performed by the injuring surgeon in 6 of the 12 (50%) cases converted to open surgery. Hepatico-jejunostomy was performed in 4 of the 25 (16%) cases with delayed recognition of their injury. Specifically for patients referred for first repairs (n=34), 38% of injuries were recognised at laparoscopic cholecystectomy, with conversion to open surgery in 6 of 13 patients.

Patients were referred for evaluation and management of new injuries after a median of 14,5 (range 1-3 662, IQR 3-26) days and definitive repair was performed at a median of 24,5 (1-3 674, IQR 7-64) days after injury. Nine (26%) repairs were done within 7 days of the injury, 6 (18%) between 7 and 14 days, 6 (18%) between 2 and 6 weeks and 13 (38%) after 6 weeks.

Strictures of ten previous repairs done elsewhere required re-operation at a median of 5 years (range 240 days-16 years, IQR 330 days-6 years) after the initial repair.

Patients spent a median of 15 (6-86) days in hospital after referral, of which a median of 5,5 (2-55) days were in the high care or intensive care unit. There were no peri-operative deaths. Two (5%) patients had Strasberg type C injuries, 6 (14%) had type E1 injuries, 33 (75%) had type E2 injuries, 2 (5%) had E3 and 1 (2%) had a type E4 injury (Table 7).

Table 7: Distribution of new injuries for first repair by type	
Type (Strasberg classification)	**n**
C	2
E1	5
E2	24
E3	2
E4	1
Total	34

Theatre and intensive care/high care admission were the major contributors to cost accounting for 22% and 21% of the total costs of repair respectively. The contributors to cost are summarised in Table 8. The inflation-adjusted mean total cost of repair was R215 711 (range R68 764 - 980 830).

***Table 8*: Contributors to total cost of definitive repair**		
	%	mean cost (ZAR)
THEATRE	22	47 883
BED (ICU/High Care)	21	44 985
RADIOLOGY	17	37 259
SPECIALIST FEES	12	26 595
BED (General ward)	10	21 322
WARD CONSUMABLES	7	14 053
PHARMACY	5	10 785
ENDOSCOPY	3	6 359
LABORATORY	3	6 469
TOTAL		215 711

With regard to specialist fees, 46% of the total fee was generated by the specialist surgeon and 29% by the anaesthetist. Critical care specialists were responsible for 12% of the fee and physiotherapy for 13%. The fees charged by radiologists were included under radiology costs.

The data were scrutinised to detect factors that were responsible for increasing the cost of repairing new bile duct injuries. The correlations between the cost of repair and the presence of sepsis on admission (cholangitis, infected bilomas, bile peritonitis), the occurrence of post-operative complications and conversion to open surgery after recognition at the index laparoscopic cholecystectomy are illustrated by Table 9.

The association between these factors and increased cost could not be demonstrated to be statistically significant, most likely due to a type 2 statistical error.

***Table 9*: Factors associated with increased cost of repair**

MEAN COST OF NEW REPAIRS	n=34	R230 452	p=0,44†
MEAN COST OF REVISION SURGERY	n=10	R165 589	
MEAN COST NEW REPAIR (recognised, not converted)	n=7	R175 349	p=0,42†
MEAN COST NEW REPAIR (recognised, converted)	n=6	R350 611	
MEAN COST WITHOUT POSTOPERATIVE COMPLICATIONS	n=35	R208 606	p=0,43†
MEAN COST WITH POSTOPERATIVE COMPLICATIONS (> Gr 1 Dindo-Clavien)	n=9	R243 338	
MEAN COST IF PRESENTED WITH SEPSIS	n=10	R317 949	p=0,35*
MEAN COST IF PRESENTED WITHOUT SEPSIS	n=34	R185 641	

*Chi-squared test, †Kruskal-Wallis test

Table 10: **Summary of postoperative complications**		
Grade according to Clavien-Dindo system	**n**	**Description**
Grade 1	5	Wound sepsis
Grade 2	2	Wound sepsis
Grade 3a	2	Perihepatic abscess, perihepatic abscess
Grade 3b	3	Biloma, Incisional hernia, Early postoperative small bowel obstruction
Grade 4	2	Myocardial infarction, Cerebrovascular accident

Fifteen postoperative complications occurred in 14 patients (32%), as shown in Table 10. Patients with postoperative complications spent a median of 23 total days in hospital compared to a median of 13 total days in hospital for those without complications. On multivariate analysis, delay in referral did not appear to influence the cost of repair.

Table 11 **: Summary radiological investigations at UCT Private Academic Hospital**				
	%	Median	Min	Max
PREOPERATIVE CXR/AXR	86%	1	0	11
POSTOPERATIVE CXR/AXR	75%	1	0	9
PREOPERATIVE US ABDOMEN	16%	0	0	2
POSTOPERATIVE US ABDOMEN	16%	0	0	2
PREOPERATIVE CHECK CHOLANGIOGRAM	11%	0	0	2
POSTOPERATIVE CHECK CHOLANGIOGRAM	82%	1	0	4
PREOPERATIVE PTC +/- DRAINAGE	80%	1	0	4
POSTOPERATIVE PTC +/- DRAINAGE	7%	0	0	2
PRE-/POSTOPERATIVE PERCUTANEOUS BILOMA DRAINAGE	9%	0	0	2
MRCP	27%	0	0	1
POSTOPERATIVE CONTRAST MEAL	2%	0	0	3
PREOPERATIVE CT ABDOMEN	11%	0	0	5
POSTOPERATIVE CT ABDOMEN	16%	0	0	2

Table 11 summarises the diagnostic and interventional radiology procedures undergone by patients in this cohort. The table shows the percentage of patients who underwent a specific investigation, as well as the median, minimum and maximum numbers for each.

Discussion

The benefits of laparoscopic over traditional open cholecystectomy include less post-operative pain, earlier ambulation, less respiratory morbidity, fewer intra-peritoneal adhesions, shorter hospital stay and smaller incisions, thus avoiding the sequelae of large abdominal wall incisions [18,19, 74]. The major disadvantage of the laparoscopic technique is the increased incidence of bile duct injuries which may result in considerable morbidity [18,22,23,31,38].

Compared to the bile duct injury rate of 0,1-0,2% reported in the literature for open cholecystectomy during the 1980's and early 1990's, the rate of injury has more or less doubled after the introduction of laparoscopic cholecystectomy as the favoured technique for removal of the gallbladder [22,75]. The figure most often quoted in the literature is 0,4% for bile duct injury during laparoscopic cholecystectomy [22,75.] Although rates as low as 0,11% are reported, figures as high as 1,5% have also been communicated [33,75,76].

Single incision laparoscopic cholecystectomy has also recently been introduced in the continual quest to perform intra-abdominal procedures through smaller and smaller incisions. Worryingly, cautionary publications have appeared to warn surgeons of high rates of bile duct injury of up to 0,72% associated with this new and challenging technique [77]. No accurate data regarding the rate of bile duct injury have been published by any South African institutions.

In addition, it has been reported that more bile duct injuries are missed during laparoscopic cholecystectomy, as compared to open cholecystectomy, leading to a delay in diagnosis of the biliary injury [12]. A delay in diagnosis in turn exposes the injured patient to considerable morbidity due to septic biliary complications and a decreased likelihood of a feasible attempt at an early definitive bile duct reconstruction. The net result is longer hospital stays, higher costs and delayed return to work and daily activities.

Intuitively, a patient's quality of life is expected to be negatively impacted following an unexpected complication after what is sometimes erroneously viewed as routine surgery. The prolonged hospital admission, of which a considerable period may be spent in an intensive/high care unit, together with sepsis, percutaneous interventions and complex reconstructive surgery via a large right subcostal incision are expected to, especially in the short term, affect a patient's ability to perform physical tasks. These factors, including the unexpected nature of such a serious complication, are anticipated to also result in a significant psychological blow.

It is therefore surprising that the reported data on the subject of quality of life after bile duct injuries have not been able to show a consistent negative impact with regard to physical and psychological outcomes. The data generated by the use of different instruments to measure health related quality of life, at inconsistent periods after the injury, may be subject to recall bias and non-responder bias, as up to 63% of patients contacted may fail to respond to questionnaires [57,78].

While five studies report some degree of impairment of physical and/or mental quality of life after injury [54,55,57,58,79], two studies report quality of life that compares favourably to control groups who underwent an uncomplicated laparoscopic cholecystectomy [60,61]. A recent meta-analysis of six of these studies, which controlled for the period of time between the injury and the various surveys, indicated that physical outcomes were similar to control groups, but that mental quality of life was adversely affected [59].

These studies are nonetheless consistent with their finding that a successful bile duct repair is critical in ensuring a favourable outcome in terms of quality of life. One year after repair, quality of life improves dramatically and plateaus after five years [79]. Interestingly, the presence of litigation also seems to affect quality of life, especially in terms of its outcome [55,56].

Little information is available to accurately quantify the overall financial implications of a bile duct injury, incorporating such diverse costs as loss of income due to time off work, travel expenses, medical fees, rehabilitation and possible litigation. A quality of life study reported as an associated finding that 44,3% of patients indicated that they had endured substantial financial hardship [57].

Loss of income encompasses not only time away from work while in hospital, but also the convalescent period and follow-up visits and may extend to a partner or spouse involved in a supportive capacity who may need to travel long distances between home and the hospital where the repair is performed. These costs are, by their very nature, difficult to calculate accurately and comprehensively, as there is expected to be significant variation in income and domestic circumstances between injured individuals.

Scant information on medico-legal costs and compensation from malpractice claims is available [53], especially locally. Between 1995 and 2009, the average compensation awarded to plaintiffs after a successful lawsuit was £102 827 in England [63], and $507 000 in the USA between 1993 and 1996 [80].

The cost of definitive bile duct reconstruction has been reported on previously [65-68]. Savader et al, in 1995, reported a mean cost of $51 411 specific for all care related to the repair of a bile duct injury [65]. The cost of repair ranged from 4,5 to 26,0 times the cost of an uncomplicated laparoscopic cholecystectomy for a cohort of 49 patients that were admitted to Johns Hopkins Hospital, where the repair was performed, for a mean of 32 days.

A Swedish cost analysis, reported by Anderson et al in 2008, contained a cohort of 10 patients with major bile duct injuries who underwent repair by hepatico-jejunostomy [66]. The mean cost per patient corresponding to inpatient care was €14 251. The study also calculated a total cost per patient of €107 568, inclusive of the cost of repair, loss of productivity, outpatient care and costs generated by sick leave.

Cost calculations in large tertiary hospitals are notoriously difficult. Woods, suspecting that costs reported in the literature may be an overestimation, calculated the cost of inpatient care for bile duct injury and repair from actual hospital charge sheets and the application of a Medicare cost-to-charge ratio. His study estimated the cost to be $9 061 ± $5 112 for repair of major bile duct transections or excisions, vs. $2 689 ± $1 469 for uncomplicated laparoscopic cholecystectomy controls ($p<0.015$) [67]. This figure excluded the fees of medical professionals, but it is nevertheless substantially below figures from other institutions in the USA [65,81].

Kapoor et al published a cost analysis on a cohort of 47 patients in India undergoing major bile duct repair after laparoscopic cholecystectomy. To put this surprisingly low median figure of $1 626 in perspective, the study mentions that it is ten times the cost of an uncomplicated laparoscopic cholecystectomy at the same centre and 8,4 times the median monthly income of the patients concerned [68].

The cohort of 44 patients who form the basis of this study all had a variation of Type E major bile duct injuries repaired by Roux-en-Y hepatico-jejunostomy. It is unique with respect to the number of patients evaluated, the inclusion of all applicable costs plus adjustment for significant inflation, as well as including the time from hospital admission for the definitive repair to discharge. The mean cost of R 215 711 is substantial and is 6,4 times the cost of an uncomplicated laparoscopic cholecystectomy as performed at the same institution. The most expensive repair in this study amounted to R980 830, incorporating 86 days spent in hospital, of which 55 were spent in the intensive or high care unit. This illustrates the potential impact of bile duct injuries and the high cost imposed on medical insurance and/or patients.

Costs generated in theatre, consisting of the fee for time spent in theatre (calculated to the minute), as well as consumables such as anaesthetic gasses, swabs, sutures, etc., account for the largest contributor to total cost at 22%. Patients undergoing definitive repair spent a median of 236 minutes (range 115-376) in theatre, reflecting the complex and lengthy nature of reparative biliary surgery.

Intensive and high care unit costs, making up 21% of the total, was the next largest contributor. Patients spent a median of 5,5 days (range 2-55) in these units, which often was before and after the repair in cases where septic complications were present.

Predictably, diagnostic and interventional radiology accounted for 17% of the total cost. Radiological investigations play an integral part in diagnosing and managing septic complications, as well as delineate the injured ductal anatomy before attempting definitive repair. In this series, 80% of patients underwent pre-operative percutaneous transhepatic cholangiography and biliary drainage. The remainder were patients with injuries that were diagnosed during the laparoscopic cholecystectomy and were transferred to UCT Private Academic Hospital for repair within 72 hours, or had T-tubes placed in the injured biliary system. The study did not account for radiological investigations performed to diagnose the injury and/or septic complications at the hospital from which patients were referred.

Early recognition of a bile duct injury and referral to a hepatobiliary surgeon is essential to reduce morbidity and ensure a satisfactory surgical outcome [41]. Yet in this study, 57% of injuries were only recognised after a median delay of 5 days, with 10 out of 34 patients presenting with sepsis due to cholangitis, biliary peritonitis or septic bilomas, a finding similar to previously reported data [40]. These findings reinforce the maxim that all laparoscopic cholecystectomy patients require careful assessment and thorough investigation to exclude iatrogenic injury to the bile ducts in the event of any unexpected postoperative symptoms. As stated earlier in the text, prompt diagnosis of biliary injuries is also an important factor that may decrease the likelihood of a lawsuit or of patients seeking compensation.

For patients undergoing revision hepatico-jejunostomy, surgery was performed at a median of 5 years (range 240 days to 16 years) after the initial repair. As the actual rate of laparoscopic bile duct injury, as well as the actual number of non-expert duct repairs (by hepatico-jejunostomy) in the area referring to UCT Private Academic Hospital is unknown, it is impossible to estimate the failure rate of these repairs, as some of these repairs may have had a good outcome. Literature from other centres suggest that up to 78% of bile duct repairs performed by a non-expert surgeon require revision hepatico-jejunostomy, compared to a failure rate of 6% for expert repair [22,41,52]. Considering that a successful longterm repair is important in determining a patient's quality of life and pursuit of compensation, it is recommended that first repairs should be performed by an expert hepatobiliary surgeon, experienced in the care of bile duct injuries.

For methodologic reasons it was not possible to calculate costs incurred at the hospital where the injury occurred. Accumulated costs prior to referral were in some cases estimated to be substantial, including specialised imaging, attempted repair of the injury or re-operation for intraperitoneal sepsis. The costs generated before referral to a hepatobiliary surgeon have not previously been reported.

The inability of this study to account for costs generated before referral, as well as costs related to time off work, loss of productivity, travel and litigation, limit its ability to assess the full financial impact of bile duct injury.

Correlations with the cost of repair were studied with the aim of identifying those modifiable factors responsible for driving up the cost of repair. Intuitively, delayed recognition, sepsis and complications ought to have an adverse effect on the eventual outcome and cost of repairing a bile duct injury due to increased length of intensive care unit and hospital stay, increased imaging investigations and interventions to address intra-abdominal sepsis. However, these factors could not be proven to have a statistically significant effect on cost in this study, most likely due to Type 2 statistical error.

As bile duct injuries may be devastating and costly to patient and surgeon, they are best avoided, need to be diagnosed early and require successful repair. In order to avoid bile duct injuries surgeons need to be familiar with normal and aberrant biliary anatomy; they must recognise the effects of acute and chronic inflammation on these structures and how this may influence the safe dissection thereof [22,82].

Various strategies are promoted in the literature in an attempt to decrease the incidence of this serious complication. The critical view of safety, as detailed by Strasberg [26], aims to contend with the misidentification of the common hepatic duct, common bile duct or aberrant right-sided bile ducts for the cystic duct before structures are formally divided. To achieve the critical view of safety does require a degree of dissection of the hepatocystic angle, which itself can lead to duct injury before any of the dissected tissue has declared its identity. The critical view technique is thus best suited to situations where the hepatocystic angle has not become obliterated by chronic inflammation, or too heavily inflamed and haemorrhagic by acute cholecystitis.

In situations where hepatocystic angle dissection has become hazardous, subtotal cholecystectomy may be the safest solution [27]. Subtotal cholecystectomy requires entry of the gallbladder lumen at or above Hartmann's pouch, after which inspection of the lumen orientates the surgeon as to the position where the cystic duct enters the gallbladder. The gallbladder can then be circumferentially divided and dissected in a prograde fashion for a short distance to enable ligature or suture closure of the Hartmann's pouch stump. The rest of the gallbladder can then be removed in a subtotal fashion by leaving the back wall of the gallbladder on the cystic plate and taking care to remove all spilled stones.

The use of intra-operative cholangiography (IOC) has also been investigated as a safeguard against bile duct injuries. Whether routine IOC is effective in reducing the incidence of bile duct injury is an area of controversy. No randomised controlled trial evidence exists to mandate its use in all laparoscopic cholecystectomies. However, it has been reported that IOC may be effective if used in certain high risk situations, such as in patients with complicated gallstone disease or when utilised by inexperienced surgeons

[28,83,84]. It must be noted though that these studies have been heavily criticised for their potential for bias [45]. On the other hand, evidence does exist to show that routine IOC does aid in the early detection of bile duct injuries [85].

Conclusion

Bile duct injuries after laparoscopic cholecystectomy remain a serious problem in modern surgical practice. There is general consensus that patients who require evaluation and repair of a bile duct injury should be referred to a specialised centre. The present study shows that in a tertiary academic centre, reconstructive surgery for complex iatrogenic laparoscopic bile duct injuries has an acceptable morbidity and can be accomplished with no mortality.

The costs incurred as a consequence of a bile duct injury are considerable and result in a substantial economic burden. The absolute aggregated cost of a bile duct repair is dependent on a variety of factors. This study reflects the experience of a high volume referral centre and extrapolation to other centres may not be applicable. As the consequences of a bile duct injury can be devastating, prevention must remain the top priority during laparoscopic cholecystectomy.

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