THE PSYCHOLOGY AND HEURISTICS OF CHOLECYSTECTOMY-RELATED BILE DUCT INJURY

Thesis submitted in partial fulfilment of the requirements for the MSc in Human Factors and System Safety

Thomas B Hugh M.B., B.S., F.R.C.S., F.R.A.C.S.

LUND UNIVERSITY
SWEDEN

Submitted: 20 May 2008

THE PSYCHOLOGY AND HEURISTICS OF CHOLECYSTECTOMY-RELATED BILE DUCT INJURY

Thomas B Hugh M.B., B.S., F.R.C.S., F.R.A.C.S.

ABSTRACT

Bile duct injury during cholecystectomy is a major unsolved surgical problem with serious consequences. The literature on this problem was reviewed and 49 cases of bile duct injury were analysed to identify the underlying predisposing causes of the injury, with specific reference to possible psychological factors and heuristics used in the operation.

Ductal misidentification was the central event in 42 cases (86%) and there was a failure to recognise the injury at operation in 34 (69%), despite in many cases retrospectively obvious cues. Delay in postoperative diagnosis occurred in 28 (58%), again often in the face of significant cues to the presence of ductal injury.

An important factor in misidentification seemed to be the unconscious superimposition by the surgeon of a preconceived mental map of a "normal" duct system on a different ductal arrangement constructed at operation by the processes of traction, duct dissection and display. Other psychological factors that were probably influential in the genesis and recognition of the injury were underestimation of risk, cue ambiguity, cognitive fixation and confirmation bias.

Bile duct injury meets the definition of a "normal accident" in a complex and tightly coupled procedure. Current categorisation of bile duct injury as due to negligence is not helpful to learning about or prevention of this accident and merits re-evaluation. Possible preventive measures based on an understanding of the psychology of bile duct injury are outlined.

TABLE OF CONTENTS

	Page
Introduction	**5**
Method	**7**
Results, analysis and discussion	
Results	**8**
Psychology and heuristics of duct misidentification	**9**
Underestimation of risk	**9**
Duct misidentification and cue ambiguity	**11**
Cognitive fixation and plan continuation	**13**
Illustrative cases	**15**
Is BDI a normal accident?	**20**
Possible preventive strategies	**21**
Limitations of the study	**23**
Conclusions	**25**
List of abbreviations	**26**
Related previous publications	**27**
References	**28**

INTRODUCTION

This research is in the fields of patient safety, human error, and accountability.

Unintended bile duct injury (BDI) during cholecystectomy (removal of the gallbladder) is a major unsolved surgical problem. Although BDI is an infrequent complication, cholecystectomy is a common operation, so that substantial numbers of injuries occur worldwide, usually as a result of duct misidentification (Way et al, 2003). BDI is a recognised complication of cholecystectomy, occurring with a frequency of 0.1-0.5%, in developed countries (Hugh, 2002) and patients are usually warned preoperatively about its possibility.

BDI is disastrous because it is followed by substantial morbidity, occasional mortality and large additional health care costs. Accidental cutting of the bile duct generally requires a "reconstruction" operation in which a new opening of the duct is made into a loop of intestine, but this is often followed by stricture formation (narrowing due to scar tissue) which renders the patient subject to recurrent attacks of inflammation in the bile ducts (cholangitis). This frequently means a lifetime of uncertain health for the patient, with sometimes far-reaching economic, social, and in the famous case of Sir Anthony Eden, one-time British Prime Minister, political consequences (Owen, 2005).

BDI is also followed by frequent litigation based on allegations that the surgeon was negligent (Strasberg et al, 1995). About one half of the patients who suffer BDI sue their surgeon; it is the third most commonly litigated complication in general surgery and in indemnity terms BDI ranks the sixth most costly iatrogenic surgical injury (Kern, 1995). When negligence is alleged, BDI has generally been accepted as indefensible by Australian medical defence organisations, which usually admit liability on behalf of the defendant doctor and negotiate a confidential settlement of the claim.

BDI is no respecter of the seniority or experience of the surgeon (Windsor et al, 1998; Archer et al, 2001; Francoeur et al, 2003). This is exemplified by the Eden case, in which the cholecystectomy was done by a senior consultant surgeon from London's prestigious St Bartholomew's Hospital. The persistence of this serious complication, even in the hands of experienced surgeons, and the ubiquity of several characteristics of the injury, indicate that

there may be unique features of cholecystectomy and of surgical behaviour in relation to it that predispose to this accident. These features are (Dekker & Hugh, 2008):

- The intractable frequency of BDI, at a remarkably constant rate in most developed countries, across a wide range of surgeons, patient types and varieties of gallstone disease
- Failure of intraoperative recognition of the injury in most cases, often despite retrospectively obvious cues
- Frequent failure by the operating surgeon to diagnose BDI in the early postoperative period, again despite retrospectively obvious cues, leading to substantial delay in definitive treatment

A large literature exists on the epidemiology, consequences, and surgical management of BDI. Many methods of prevention have been suggested (Strasberg, 2005), with little discernable effect on overall published injury rates. The technical factors predisposing to BDI, such as inflammation, adherence of the common bile duct (CBD) to the gallbladder infundibulum, and ductal anatomical variations have been well-described (Strasberg, 2005) but published evaluation of the underlying psychology and heuristics that are possibly important contributors to BDI is scanty. There is general agreement that the usual mechanism is misidentification of the bile duct (which should not be divided) for the cystic duct, which runs from the gallbladder and must be divided (Hugh, 2002; Way et al, 2003).

As also noted by Way et al (2003), the present frequency of bile duct injuries (1-5 per thousand cholecystectomies) "may be nearing the upper limits of human performance for this complex task" and these authors suggest that BDI may be considered a "normal accident". The term "normal accident" was coined by Perrow in 1984 to describe accidents due to unforeseen interactions in complex and tightly coupled systems. Tight coupling means a system that involves multiple and rapidly operating interdependent processes that cannot easily be stopped or reversed. Perrow (1999) used the word "normal" in the sense that it is an inherent property of such systems occasionally to experience unexpected interactions. Normal accident theory (NAT) has subsequently been validated in a number of diverse domains (Wolf, 2002; Weick, 2004; Sammarco, 2005). One important ramification of NAT is its exposure of the role of multiple interactions of small system-based failures in producing adverse outcomes previously attributed to "operator error". The psychological factors

underlying visual misperception of the biliary tree may be regarded as system-based failures. These factors, especially underestimation of risk, cue ambiguity, visual perception, cognitive fixation and confirmation bias were summarised by Dekker & Hugh, (2008) and have been shown to be important in decision-making in other types of complex tightly-coupled situations (Orasanu & Martin, 1998; Weick, 1995; Hastie &Dawes, 2001).

Visual perception during an operation is a form of heuristics – rules of thumb that assist in performing complex tasks and in making the mental construction that constitutes vision. Advances in the understanding of cognitive psychology and heuristics in technical errors seem likely to provide useful insights into the problem of BDI.

The aim of this thesis research was to evaluate the clinical records of a number of BDI cases to identify possible psychological and perceptive factors that may have contributed to the injury, and to examine whether NAT may be applicable to BDI. The implications of the findings will be discussed in relation to possible preventive measures and to current surgical and legal responses to BDI.

METHOD

A qualitative approach was used.
The research involved the following steps:

1. A review of the published literature from 1987-2007 retrieved in a Medline and EMBASE search on "Cholecystectomy/ and Bile Ducts/ and intraoperative complications".
2. An examination of the clinical records of 49 cholecystectomy cases in which there was a BDI involving transection or complete occlusion of a major extrahepatic bile duct, and which were referred to the author for surgical management or in a medico-legal context. An attempt was made, based on the reported circumstances of the injury, to identify factors important in duct misidentification.
3. Examination in depth of specific cases in which sufficient information was available to assess the relative importance of underestimation of risk, cue ambiguity, visual misperception, cognitive fixation and confirmation bias in duct misidentification and in the subsequent recognition and management of BDI.

RESULTS AND ANALYSIS

Details of the patients and the course of the BDI in the presently studied series are shown in the following table:

	Males	***Females***	***Total***
Median age (years)	49 (range 42-76)	44 (range 21-78)	
Death (early/late)	1	3	4(*8%*)
Misidentification	5	37	42(*86%*)
Not recognised at operation	4	30	34(*69%*)
Delayed diagnosis (> 24 hrs)	3	25	28(*57%*)
Litigated	4	13	17(*35%*)
No.	7	42	49

Table. Patient details and outcomes in 49 cases of BDI (index age is at the time of the injury).

Two patients died in the early postoperative period from sepsis associated with the injury. There were three late deaths – two from cholangiocarcinoma associated with recurrent strictures and repeated attacks of cholangitis; stricture complications also caused one late death from biliary cirrhosis (Figure 1), demonstrating the disastrous long-term effects of BDI in some patients.

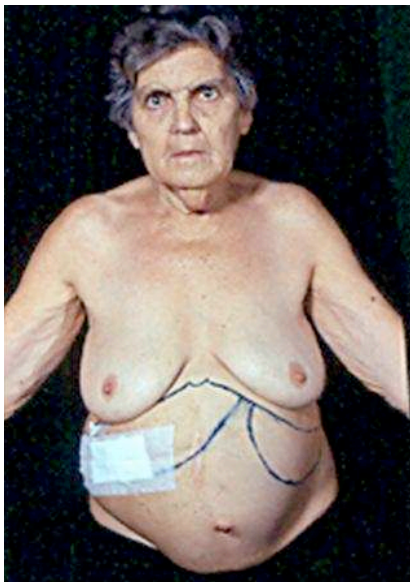


Figure 1. Patient six weeks before her death from biliary cirrhosis due to long-standing bile duct stricture and recurrent attacks of cholangitis following BDI 30 years previously. Markings show an enlarged liver (cirrhosis) and spleen (portal hypertension). The dressing is at the site of an intrabiliary drainage tube.

Misidentification was the mechanism of injury in 42 cases (86%). Other mechanisms such as diathermy injury or CBD damage during control of haemorrhage occurred in four cases and there was insufficient information to deduce the mechanism of injury in three cases.

The injury was not recognised at operation in 34 patients (69%) and there was a delay of >24 hours in making a diagnosis of BDI in 28 (57%). The dominance of misidentification and the failure to recognise BDI in the majority of cases illustrate the ubiquity of psychological factors in this event. In seven patients the delay in diagnosis and instituting definitive treatment exceeded one month and in two patients several years elapsed before the injury became evident. This highlights the often subtle and elusive presentation of this injury. In one patient an almost silent complete occlusion of the right hepatic duct, which caused secondary atrophy of the right lobe of the liver, was diagnosed for the first time by CT scanning and percutaneous cholangiography 15 years after cholecystectomy.

Psychology and heuristics of duct misidentification

Much of the literature on iatrogenic bile duct injury emphasises the need for clear identification of bile duct anatomy before dividing, clipping or cauterizing any structure (Blumgart et al, 1984). The flaw in this advice was pointed out by Dekker & Hugh (2008): "*no surgeon would deliberately divide a structure without having identified it and no surgeon would transect the CBD during cholecystectomy knowing it was the common duct*". In every case in the present series the surgeon was convinced, up to the time of recognition of the injury, that the "cystic duct" had been correctly identified before clipping and dividing it. As Dekker & Hugh (2008) also point out, "*the psychology in duct misidentification lies in a surgeon being persuaded sufficiently, if not believing completely, that the structure being transected is the correct one, the cystic duct.* ***Underestimation of risk*** *and* ***cue ambiguity*** *are critical contributory factors to the construction of this belief, even when in hindsight it turns out to have been false (Orasanu & Martin, 1998)*".

Underestimation of risk

A large amount of empirical research has been done on how people perceive risk. In many cases perception of risk is not strictly rational and does not match measurable probabilities,

largely because of the influence of the *availability heuristic* (Tversky & Kahneman, 1982) and by what Margolis (1996) has termed "*visceral"* risk perception.

The *availability heuristic* refers to the ease of recall of an outstanding and usually recent instance of an adverse outcome, which makes people think that outcome is more probable than the statistics indicate; conversely, they will assess it as less probable if no easily recalled example is available. In the case of experienced surgeons it is possible that a preoperative underestimation of the risk of BDI, arising from an inverse application of the availability heuristic, may contribute to duct misidentification. Risk underestimation in complex procedures may occur on the basis of past success in avoiding error (Hollenbeck et al, 1994); this is particularly likely in BDI because of the infrequent exposure of individual surgeons to the problem. Strasberg et al. (1995) calculated (on a basis of a rather high rate of injury of 0.4%) that a general surgeon would, on average, incur a BDI at most once every five years. Experienced surgeons may have a false sense of "this can't happen to me", unaware that past success is no guarantee of future safety (Dekker, 2005).

Limited information was available about the previous experience of most of the surgeons in the present series, but 46 were fully qualified and in specialist surgical practice. Nine of the surgeons had done >200 laparoscopic cholecystectomies without incurring a BDI and on that basis may have underestimated the risk. None of the cholecystectomies were done by surgical trainees, whose judgment of cholecystectomy-associated risks is known often to be deficient (Jacklin et al, 2008).

Margolis defined "visceral" risk perception as "*a sense of more than normal apprehension or vigilance...in connection with some statistical risk"*. This corresponds to what has been described as the "*dread"* factor in risk perception (Covello et al, 1987), noted particularly in relation to nuclear accidents, getting cancer, and newsworthy events such as fatal shark attacks. The distortion of this perception is shown by the fact that death from shark attack causes much greater public apprehension than death from falling coconuts although coconuts kill fifteen times more people each year (Burgess, 2002). An inverted "visceral" risk perception (a lack of a sense of dread about BDI), supported by overoptimistic published views about the success of bile duct reconstruction, may have diminished vigilance about the risk of BDI on the part of some surgeons.

Duct misidentification and cue ambiguity

Constructing a mental image that convinced the surgeon that the CBD or the right hepatic duct was the cystic duct amounted to the central error in the majority of cases in the present series.

The possible psychological and heuristic sources of misidentification were explored by Way et al. (2003), who pointed out that intraoperative decisions in cholecystectomy have to be made from ambiguous cues forming a pattern of "signals" (duct borders) and "noise" (connective tissue, adhesions, blood). These authors concluded that an important factor in misidentification was the absence of haptic perception in the laparoscopic technique. Haptic perception describes the perceptual information gained by active touch, as in manually examining an object such as the gallbladder. They suggested that absence of haptic perception is a laparoscopy-specific problem, based on their view that misidentification ductal injuries "were relatively uncommon in the pre-laparoscopic era" when haptic perception was available to the surgeon at open cholecystectomy.

There is, in fact, no firm evidence that haptic perception is important in duct identification and it seems likely, therefore, that duct misidentification in both open and laparoscopic cholecystectomy is based on similar visual misinterpretation (Dekker & Hugh, 2008). The frequency and type of BDI are comparable in both operative methods (Hugh, 2002).

Visual perception is one form of heuristics – the process of acquiring, interpreting, selecting and organizing sensory information, especially uncertain, probabilistic information, and using it as a basis for action; actions that themselves will make more information about the world available, thereby informing further action, and so forth (Hastie & Hawes, 2001; Weick, 1995). As noted by Dekker &Hugh (2008): "*What is done influences what is seen, which then helps constrain and determine what can be done"*. This continual interweaving of action with perception means, for example, that retracting the gallbladder in a superior rather than a lateral direction increases the risk of misidentification because it tends to align the cystic duct with the CBD (Perissat, 1993).

Strasberg (2005) has pointed out the deceptive "hidden cystic duct" situation created when there is difficulty retracting the gallbladder. This appeared to be a factor in association with

inflammatory changes in 11 of the cases in the present series. In the remainder, detailed operative information was not available: operation notes frequently recorded "routine cholecystectomy", reflecting an absence of suspicion by the surgeon that there was anything amiss. In six of the cases the operation note described a thin-walled mobile gallbladder without adhesions, a testament to the wise surgical observation "a nice, easy, but dangerous cholecystectomy" (anon).

Visual perception is not a replica of reality. It is a continual mental construction that informs and is informed by interaction with the world, where "rules" or "scripts" build expectations about what we (should) see (Hoffman, 1998). As Reason (1990) points out, "perceptions, memories, thoughts and actions have a tendency to err on the side of the familiar and the expected". When the subhepatic field is visualized at laparoscopy the surgeon usually matches what is seen with a learned mental map of the "normal" biliary tree. This matching is a rapid and largely subconscious process integrated with visual perception and may sometimes be a matter of "seeing what you believe" (Perrow, 1999), rather than believing what you see (Figure 2).

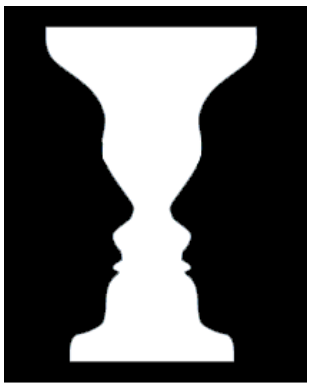
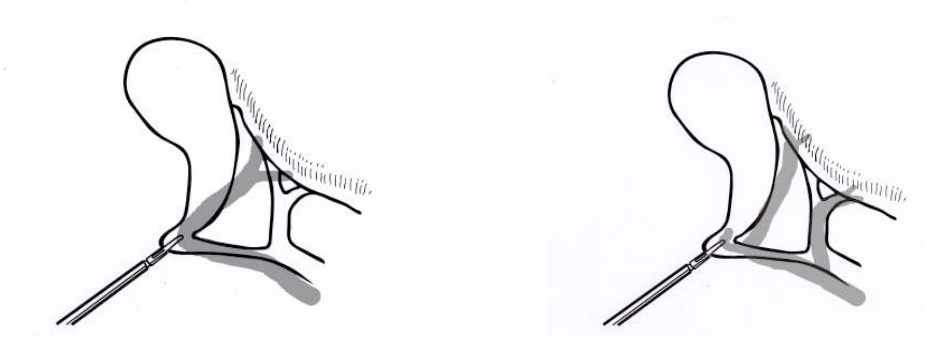


Figure 2. Visual perception of this picture can be switched at will to represent an urn, or two people in conversation – an example of "seeing what you believe".

The familiar and expected in the case of BDI is the "normal" pattern of the biliary tree (right and left hepatic ducts merge to form the common hepatic duct, which is joined by the cystic duct to form the common bile duct). That pattern may be mentally superimposed on a very different ductal disposition created by the processes of retraction and dissection and by anatomical variations. A duct that appears to merge with the infundibulum of the gallbladder may be accepted as the cystic duct when in reality it is the CBD or the right hepatic duct (Figure 3).



a **b**

Figure 3. A mental map of the "normal" biliary tree may be superimposed by the surgeon on a different ductal arrangement (shadowed) when the CBD is tented excessively by traction or is adherent and posterior to the infundibulum of the gallbladder (a). The distal CBD appears to run downwards from the gallbladder, mimicking the cystic duct. In (b) an anatomical variation (shadowed) may lead to the right hepatic duct being perceived as the cystic duct.

Misinterpretation led to subsequent attribution of the BDI by the operating surgeon in seven cases as being due to "abnormal biliary anatomy". While it is true that variations in the anatomy of the extrahepatic biliary tree are so common as to negate somewhat the concept of a "normal" ductal pattern, in four of these cases at the reconstructive operation there was no evidence of any anatomical variation. It seems likely the "abnormal" anatomy was created by inflammatory adherence of the bile duct to the gallbladder infundibulum or by surgical traction resulting in "tenting" of the CBD. In two cases in the present series this tented appearance was interpreted by the operating surgeon as representing a "double cystic duct", a further example of action influencing perception. There was a true anatomical variation in three cases, in the form of entry of the cystic duct into the right hepatic duct, the latter being inadvertently divided or resected.

Cognitive fixation and plan continuation

As pointed out by Dekker & Hugh (2008) "*the nature of perception and action..... not only helps construct a surgeon's belief that the correct structure has been found and is being operated upon. It can also sustain that belief during and after the procedure even as the dissection unfolds new information, despite cues that, in hindsight, point to the true nature of the situation*".

The usual consequence of identifying a major bile duct incorrectly as the cystic duct is that it is clipped and divided. Taking action, says Weick (1988), simplifies the problem but it also implies a commitment to action which in turn can produce blind spots. Once surgeons have committed themselves to a particular course of action they will build an explanation that justifies that action, and that also guides further action. This explanation tends to persist, and gets transformed into an assumption ("I am working on the correct structure") that is taken for granted during the rest of the procedure and beyond, a feature which characterised almost all the cases in the present series.

In the cases studied in this thesis subsequent steps in removal of the gallbladder after division of the spurious "cystic duct" usually led to an encounter with the proximal hepatic end of the divided duct (the common hepatic duct or the right hepatic duct) which was then divided a second time, resulting in resection of a substantial length of duct. This second cutting of the duct was often not recognised, even when there was unexpected intraoperative biliary leakage, which was sometimes dismissed as due to an insignificant "accessory" duct. In several cases, however, this second ductal division did trigger intraoperative recognition of the injury.

When ambiguous cues in the initial situation (and actions on it), biased the surgeon in some direction, this then appeared to elevate certain cues at the expense of others, behaviour also noted in pilots by Beaty (1995). The initial interpretation typically persisted throughout the dissection and division of a mistakenly identified duct, even when extra lymphatic and vascular structures showed up in close proximity, when there was non-opacification of proximal ducts on cholangiography, or when the duct could not be fully encompassed by a 9mm clip (which to an objective observer would seem to have indicated the duct was abnormally large for a supposed cystic duct).

Such "plan continuation" often persisted post-operatively. There was a delay > 24 hours in recognition of the injury in the post-operative period in 28 of the 49 cases (57%). Plan continuation was in some cases remarkably strong and persistent, for example on occasions causing the surgeon repeatedly to reassure juniors anxious about the patient's progress, even in the face of postoperative cues such as jaundice, biliary leakage or signs of biliary peritonitis that may seem in retrospect obvious indicators of duct injury (vide case 1, below).

Often, none of those emergent cues was strong enough to push the surgeon off the interpretation subscribed to, or the path taken, as none of them fitted the assumption that was the basis for all action and perception up to that point. Attention was first drawn to this phenomenon of cognitive fixation, a frequent and widespread apparent illogicality in human reasoning, by Wason (1960). De Keyser &Woods (1990) aptly described the reasoning involved as "*this and nothing else*".

Illustrative cases

Case 1. A 49-year old man had a laparoscopic cholecystectomy by a teaching hospital surgeon. The operation note recorded that the procedure was difficult due to inflammatory adhesions but the surgeon subsequently noted (in a report to the Coroner) that "the anatomy of the cystic artery and cystic duct appeared to be normal". There were also some difficulties with visualisation of the operative field due to a faulty intraperitoneal gas insufflator. An operative cholangiogram was done through a tube inserted into what was thought to be the cystic duct; the X-rays showed flow of contrast in a distal direction only, an appearance which was explained by the surgeon to his assistant as "*nothing to worry about, it's something that happens all the time due to low resistance at the distal opening of the bile duct"*. In fact, the failure of contrast material to delineate the proximal ducts was due to placement of the cholangiogram tube into the misidentified CBD rather than into the cystic duct. There was a small amount of bile leakage during dissection of the gallbladder from its bed but this was considered to be coming from "*an insignificant accessory duct"* (but in retrospect was actually from the proximal end of the resected CBD). An abdominal drain was inserted at the end of the cholecystectomy.

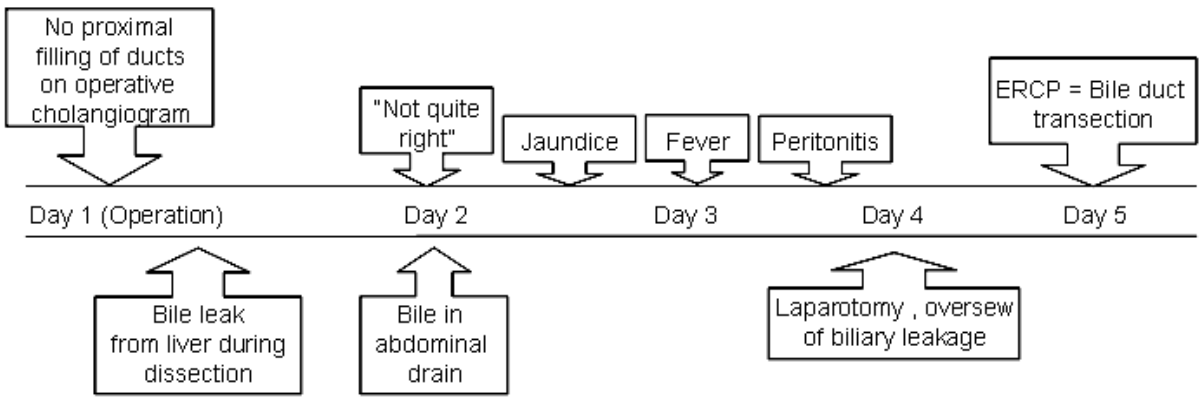
The patient complained of abdominal pain and distension on the first postoperative day, but this was attributed to "ileus", a condition of temporary intestinal dilatation sometimes seen after abdominal operations. In retrospect, it was due to inflammation secondary to intraperitoneal bile leakage. These symptoms persisted and on the second postoperative day an abdominal CT scan showed free intraperitoneal fluid. This was attributed to residual irrigation fluid introduced at the operation, but was in fact intraperitoneal bile extravasation.. On the third postoperative day the patient was mildly jaundiced and bile-stained fluid appeared in the drain; when informed of this the surgeon told the surgical registrar it was "*unlikely there was a significant bile leak because I saw the cystic duct well and applied two clips across it"*. On the fourth postoperative day the patient's condition worsened and the

surgeon did a laparotomy (opening of the abdomen). He found and evacuated a large quantity of intraperitoneal bile and oversewed what he thought was a bile leak in the bed of the gallbladder, but did not recognise this as the proximal end of the transected bile duct. The patient remained unwell, was transferred to the care of another surgeon, and underwent a series of operations which revealed there had been resection of a length of the CBD, as well as complete division of the right hepatic artery. The patient died from sepsis and hepatic complications 17 days after the cholecystectomy.

Comment: The original operating surgeon, experienced and fully surgically qualified, was unaware that he had divided and resected the CBD after mistakenly identifying it as the cystic duct, and that he had similarly mistakenly identified the right hepatic artery as the cystic artery and divided it also. This surgeon had done a substantial number of cholecystectomies without a biliary injury and it is possible that this induced subconscious underestimation of risk. Cue ambiguity was probably present at the cholecystectomy, due to adhesions. Cognitive fixation that the cystic duct was correctly identified would have facilitated the erroneous explanation and acceptance of the operative cholangiogram appearances as "normal".

Fixation and confirmation bias manifested themselves strikingly and persistently as plan continuation in the postoperative period in spite of cues suggestive of BDI, such as pain, abdominal distension, jaundice, free intraperitoneal fluid, and external biliary drainage. The failure of recognition of the BDI continued through and after an exploratory laparotomy (Fig. 4).

Figure 4. Timeline of unrecognized cues to the presence of BDI in Case 1. This was typical of a number of cases of delayed diagnosis in the present series.



Case 2: A 28-year old woman had several attacks of biliary pain due to gallstones and underwent a laparoscopic cholecystectomy by an experienced consultant surgeon. The operation note recorded "*the gallbladder was thickened and adhesions were present. Identification of the cystic duct and gallbladder were done. Three metallic clips were placed on the cystic duct and three more clips on the cystic artery. No bile leak was detected"*. An abdominal drain was inserted, and this drained a large quantity of bile on the first postoperative day. Over the next few days the patient complained "*persistently*" of severe abdominal pain and continued to drain bile. The surgeon noted in a subsequent statement "*during that period her demands for increasingly higher doses of pethidine became a concern for us. I tried to strike a balance between providing adequate pain relief and at the same time to prevent the development of addiction to pethidine."* The surgeon believed at this time that the leakage of bile was from the cystic duct stump.

Several unsuccessful attempts were made to do an endoscopic cholangiogram (an endoscopically performed X-ray of the bile ducts) with a view to inserting a stent (a type of tube) into the lower end of the CBD to release pressure and allow the supposed leaking cystic duct stump to seal itself. The pain eventually became so severe that the surgeon did a laparotomy eight days after the cholecystectomy and recorded "*at surgery bile was seen coming from the cystic duct stump; after the stump was ligated there was no evidence of any biliary leak"*. No attempt was made to do an intraoperative cholangiogram to check the patency of the bile duct. In retrospect, the ligated "stump" was the proximal end of the transected CBD. After this operation the patient became jaundiced and was transferred to another hospital, where she was found to have a complete transection of the CBD. A reconstruction operation was done. Litigation ensued; the surgeon conceded "*the second operation may not have correctly identified the problem"* and the claim was settled by negotiation.

Comment: Cue ambiguity may have been present at the cholecystectomy because of inflammatory adhesions. Failure to recognise anything unusual at that operation signified misperception, fixation, and the effect of confirmation bias (*I have dissected the cystic duct and it is the correct duct that I am clipping and dividing)*. Confirmation bias was also manifested as plan continuation in the postoperative period, with elevation of cues favouring the "*correct duct"* view *(the pain is exaggerated due to a developing pethidine addiction)*

over cues indicating BDI (*bile drainage and severe abdominal pain)*. The "*correct duct"* view persisted through the exploratory laparotomy, contributing to a failure to see the need for radiological delineation of the biliary tree, which would have revealed the injury. It is interesting to note that the patient, uninfluenced by confirmation bias, expressed a wish to defer the laparotomy until an X-ray of the bile duct had been achieved, but was persuaded otherwise by the surgeon.

Case 3: A 61-year old woman underwent a laparoscopic cholecystectomy at a large regional hospital by a surgeon who had trained in a prestigious Australian hepato-biliary unit. The surgeon clipped and divided what she thought was the cystic duct and proceeded with dissection of the gallbladder from its bed when she encountered a structure that leaked bile when incised. She then realised the CBD had been misidentified as the cystic duct. The procedure was converted to a laparotomy; when further dissection confirmed her fears she packed the operative field and called a surgeon in her parent hepato-biliary unit to arrange transfer of the patient for a biliary reconstruction, which was successful.

Litigation ensued and the head of the hepato-biliary unit provided a defendant expert report, which was supportive of the prompt action by the original surgeon after the injury was discovered, but which categorised the injury, in a sympathetic tone, as due to "*pilot error"*. Legal opinion indicated that the expression "*pilot error"* would be fatal to any possible defence and the surgeon's medical defence organisation settled the claim.

Comment: Despite excellent training in the specialty of hepato-biliary surgery and considerable operative experience, this surgeon misidentified the CBD and evidently failed to note cues such as additional lymphatic structures alongside the supposed "*cystic duct"* and the proximity of hepatic arteries that might have suggested she was dissecting the wrong structure. She did recognise the cue of proximal biliary leakage and thus avoided delay in definitive treatment of the injury, a factor which undoubtedly contributed to the success of the biliary reconstruction. The unfortunate use of the term "*pilot error"* in an otherwise supportive medical expert report precluded defence of a negligence claim even though the BDI was recognised promptly and managed impeccably.

Case 4: A 30-year old woman was admitted to hospital with an attack of acute cholecystitis (inflammation of the gallbladder). The attack settled with antibiotics and a month later she

had a cholecystectomy by an experienced senior surgeon. The operation note records a "*routine cholecystectomy*". An abdominal drain was inserted.

On the first postoperative day the patient was generally unwell, with abdominal distension and more than usual pain. A large amount of bile drained from the abdominal tube, but the drainage volume rapidly decreased and the tube was removed on the third day. The patient became jaundiced the next day. Small amounts of bile were discharged intermittently from the drain site and the jaundice persisted, but the patient was thought well enough to go home on the 11th postoperative day. The jaundice deepened and the patient was readmitted three weeks later. Investigations revealed a large intraperitoneal bile collection and a bile duct injury with stricture formation. The patient's CBD was very small and several reconstructive operations were required. The patient has continuing problems with re-stricturing.

Comment: The patient's very small CBD may have provided the setting for misidentification and may have facilitated confirmation bias because of its resemblance to the expected small-diameter cystic duct. Cognitive fixation and the associated plan continuation led to the sending of the patient home with what were in retrospect obvious cues to BDI. Delay in diagnosis and definitive treatment of the injury probably contributed to the poor outcome of reconstructive surgery, but stricture problems were always likely because of the patient's unusually small extrahepatic biliary tree.

Case 5: A 37-year old woman had an open cholecystectomy by an experienced surgeon for symptomatic multiple large gallstones. There were no significant adhesions and the operation was apparently uneventful apart from some bile leakage in the gallbladder bed which was attributed to "*an accessory duct*" and which was controlled by ligation. There was more than usual postoperative abdominal and right shoulder pain, accompanied by fever, for which no clear explanation was found. The patient recovered after an unusually long hospitalisation, during which there were abnormalities in blood levels of liver enzymes, attributed at the time to side-effects of antibiotic therapy.

Fifteen years later, the patient experienced abdominal pain and was investigated by CT scanning, which showed complete atrophy of the right lobe of the liver. Further endoscopic and percutaneous radiological investigations showed this atrophy was secondary to complete occlusion of the right hepatic duct. Endoscopic cholangiography showed that a segment of the right hepatic duct had been resected. There was no evidence of a cystic duct stump

attached to the CBD and it is presumed the cystic duct originally joined the resected right hepatic duct, as in Figure 3 (b). The patient's abdominal pain appears unrelated and settled spontaneously. No further biliary treatment has been necessary.

Comment: This patient had an anatomical variation in biliary anatomy, in which the cystic duct drained into the right hepatic duct, instead of the more usual arrangement in which it drains into the CBD. The patient's anatomy evidently did not match the surgeon's mental map of the "normal" biliary anatomy and a misidentification BDI ensued. Confirmation bias meant that the significance of the cue of intraoperative biliary leakage was not recognised. It is fortunate for the patient that postoperative intraperitoneal biliary leakage did not occur and that the secondary effect of the right hepatic duct occlusion on the liver was relatively silent and uncomplicated by sepsis. In retrospect the pain in the shoulder (referred from subdiaphragmatic inflammation), the fever, and the abnormal liver enzyme levels were manifestations of liver necrosis. Confirmation bias at the time of the event supported interpretation of the enzyme abnormalities as antibiotic-related, rather than as a cue to BDI.

IS BDI A "NORMAL ACCIDENT"?

The process of removal of the gallbladder is both complex and tightly coupled; these features, together with the intractable (although low) world-wide frequency of BDI and its unanticipated occurrence in both open and laparoscopic techniques suggest that the injury meets the definition of a normal accident. This categorisation is supported by the frequent intraoperative non-recognition of BDI, noted in this series and by other authors, a feature consistent with the unexpected and at the time not understood nature of normal accidents in other domains.

Although Way et al (2003) suggest the present frequency of bile duct injuries (1-5 per thousand cholecystectomies) "may be nearing the upper limits of human performance for this complex task" the acceptance of BDI as a normal accident does not mean that increased efforts to prevent the injury may not be effective in reducing the overall number of cases, especially if those efforts are based on a deeper understanding of the system factors involved in the accident. A focused systems approach may reduce the injury rate to vanishing point. Hugh (2002), using systems-based training, reported 2000 consecutive laparoscopic cholecystectomies from one surgical unit, including many cases done by trainees, without any

bile duct injuries. Continuing success of such an approach is heavily contingent on the difficult task of maintaining awareness of the ever-present risk. As Reason (2000) points out, when describing safety as a long guerrilla struggle, "*a lengthy period without a bad accident does not signal the coming of peace*....(cognisant organisations) *see it as a period of heightened danger*".

POSSIBLE PREVENTIVE STRATEGIES

Analysis of the cognitive psychology and heuristics of major bile duct injuries in cholecystectomy provides a platform for developing preventive strategies. Perhaps the most important strategy pre-operatively is to encourage a deliberate sense of heightened awareness of the risk. One method is for the surgeon to repeat as a mantra while scrubbing for a cholecystectomy: "this could be the one" or to visualize the axiom "think safety" (Hugh, 2002; Strasberg, 2005).

Use of the availability heuristic is another possible method of enhancing risk awareness by regularly reminding surgeons of the number of BDI's still occurring. Unfortunately the secrecy accompanying confidential settlement of BDI negligence claims is a significant barrier to dissemination of this information and surgeons frequently express surprise when told that 150 BDI's occur in Australia each year (Hugh, 2002). Enhancement of "visceral" risk assessment (dread of the injury) may be assisted by the publication of more realistic studies of the relatively poor long-term outcomes after BDI, including the development of incurable bile duct cancer in some patients, as noted in the present series.

Cognitive fixation is a fundamental human attribute and difficult to eliminate but its effects may be modified by educating surgeons in specific counter-strategies. As noted by Dekker & Hugh (2008), "*fixation is one possible side-effect of a mental balancing act: should a surgeon maintain stability of interpretation and course of action in the face of changing, contradictory or ambiguous cues? Or should he or she shift course of action with each newly incoming cue? Neither is desirable in most clinical situations, but ending up at one extreme (fixated on one interpretation) or the other (vacillating among multiple possible interpretations) is sometimes part of doing expert work in complex, dynamic situations (de Keyser, V., & Woods, D.D., 1990). One way out is the recruitment of additional, outside expertise that has not been part of the initial formulation of the problem. But when a surgeon believes that he or she has operated on the correct structure, then there is no trigger for seeking a second opinion*".

A number of useful intraoperative heuristics at laparoscopy were suggested by Way et al (2003) who also made technical suggestions, such as retraction of the infundibulum of the gallbladder laterally to open out the triangle of Calot. An alternative technique (Hugh, 2002) is to retract the infundibulum medially to expose the posterior aspect of the triangle and to evaluate its relationship to Rouviere's sulcus, a landmark which indicates the plane of the CBD (Figure 5).

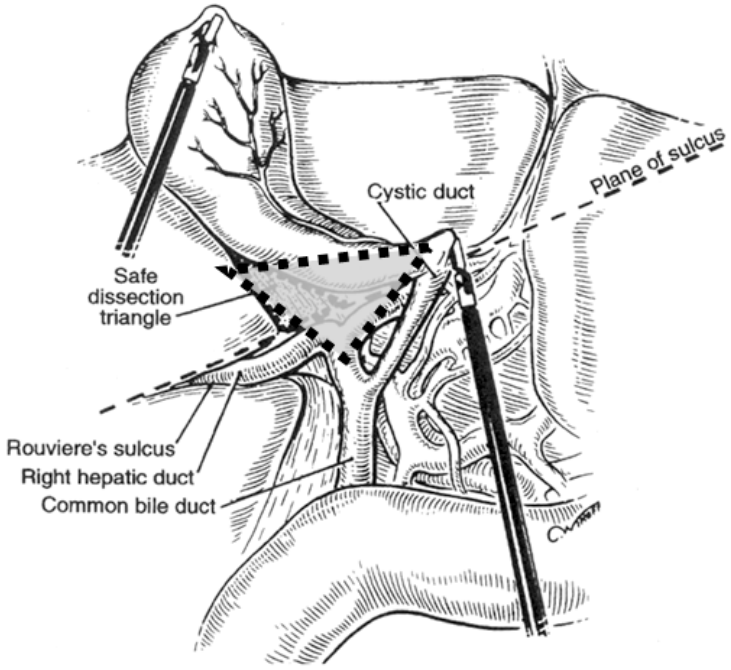


Figure 5. Rouviere's sulcus, a cleft in the liver recognizable in > 90% of patients, runs to the right of the hilum, marks the plane of the CBD, and is revealed by retracting the gallbladder infundibulum medially. Dissection in laparoscopic cholecystectomy may be commenced safely in the triangle ventral to the plane of the sulcus.

A further technical strategy is for the surgeon to develop what Strasberg et al (1995) described as the "critical view of safety" in which no structure is clipped or divided until the gallbladder is sufficiently free from the liver to allow visualisation of just two structures entering it – the cystic artery and the cystic duct. Strasberg has also stressed the need to change the "culture" of cholecystectomy, and suggests the promulgation of "stopping rules" as used in aviation and some other industries. These might provide guidelines in difficult cases for converting to an open procedure or for modifying the operation (settling for cholecystostomy or partial cholecystectomy) before a zone of danger is entered.

The role of operative cholangiography in preventing BDI is controversial. Although operative cholangiography probably does not reduce the frequency of BDI its use increases the chance of intraoperative recognition that a duct has been misidentified, possibly lessening the extent of the injury or reducing the severity of the consequences of delayed recognition (Strasberg, 1995; Way et al., 2003). These beneficial effects are predicated on correct interpretation of the cholangiogram, and especially on recognition of the significance of non-filling of proximal ducts. Most authors advocate a selective but liberal use of cholangiography if difficulties arise in the dissection or identification of biliary anatomy.

LIMITATIONS OF THE STUDY

The selection of cases in this study, based on referral for biliary reconstruction (often after multiple previous reconstructive attempts) or evaluation in a medicolegal context, may have resulted in an over-representation of patients with a severely adverse outcome or with postoperative management open to criticism. Similar problems exist with other studies, most of which are based on referred cases (Way et al, 2003). National, state-based or regional audits are likely to produce more representative samples, but suffer problems of under-reporting and scanty or incomplete clinical records which make in-depth analysis difficult.

Ascertaining the exact operative details surrounding the BDI was extraordinarily difficult and in the majority of cases impossible. The level and type of injury usually had to be inferred from the findings at the time of a reconstructive operation. This was because the cholecystectomy notes were often sketchy (as is usual in many "routine" operations) and did not reflect anything unusual because of non-recognition of the BDI. Additionally, feelings of guilt and the ever-present fear of litigation frequently inhibited subsequent communication from the original operating surgeon. Confidentiality agreements in the settlement of negligence claims and the operation of privacy laws were significant hurdles to the procurement of detailed information from medical defence organisations.

Occasionally, *post hoc* legitimisation of the operative technique was evident in accounts given by the surgeon, a phenomenon noted in relation to "deviance" in other domains by Vaughan (1999): "*individuals may justify deviance in retrospect by constructing accounts that bring their actions into harmony with social expectations*". Similar difficulties arose in

the identification of psychological factors, which necessarily had to be inferred from the facts of the injury and the postoperative course and outcome.

CONCLUSIONS

Ductal misidentification was a central element in the majority of the studied cases of BDI. Underestimation of risk, cue ambiguity, cognitive fixation and plan continuation were common features and were associated with a failure of intraoperative recognition of the injury and postoperative delay in diagnosis in many cases.

BDI meets the definitional requirements of a normal accident. Acceptance of this categorisation does not preclude increased efforts to reduce the frequency of BDI, but does merit a re-evaluation of the current surgical and legal responses to this accident, which is regarded as "surgical error" and therefore indefensible against claims of negligence. Many surgeons see that outcome as unfairly punitive for a recognised complication precipitated by an operative visual trap. That perception contributes to defensive medical practices and to reluctance by surgeons to participate in quality improvement activities and is thus harmful to patient safety. Additionally, the secrecy inherent in confidential legal settlements inhibits sharing of data and wider learning. General acceptance of BDI as a normal accident may facilitate learning about its underlying causes and prevention. Preventive strategies grounded in an understanding of the psychology of BDI are likely to be most successful in reducing the frequency of this problem.

ABBREVIATIONS

BDI	Bile duct injury
CBD	Common bile duct
EMBASE	A biomedical database
NAT	Normal Accident Theory

RELATED PREVIOUS PUBLICATIONS

Hugh, T. B. (2002). New strategies to prevent laparoscopic bile duct injury. *Surgery*. 132 (5), 826-835.

Hugh TB. (2002). Laparoscopic bile duct injury: some myths. *ANZ J. Surg*. 72, 164-167.

Dekker, S.W.A., & Hugh, T. B. (2008). Laparoscopic bile duct injury – understanding the psychology and heuristics of the error. *ANZ J Surgery*. (in press).

REFERENCES

Blumgart, L.H., Kelley, C.J., Benjamin, I.S. (1984). Benign bile duct stricture following cholecystectomy: critical factors in management. *Br. J. Surg*. 71,836-843.

Burgess, G. (2002). Relax: you're not that tempting. *New Scientist* **174**(2345): 25.

Covello, V. T. & Johnson, B.B. 1987. The social and cultural construction of risk: Issues, methods, and case studies. In B. B. Johnson & V. T. Covello (Eds), *The Social and Cultural Construction of Risk*, D Reidel Publishing Company: Dordrecht.

De Keyser, V., Woods, D.D. Fixation errors: failures to revise situation assessment in dynamic and risky systems. in: *Systems reliability assessment,* eds Colombo AG, Bustamante AS. Madrid: Springer, 1990.

Dekker, S.W.A. (2007). *Just Culture. Balancing safety and accountability*. Aldershot, England: Ashgate Publishing Limited.

Dekker, S.W.A. (2005).*Ten questions about human error*. Mahwah NJ: Lawrence Erlbaum Associates Inc.

Dekker, S.W.A., & Hugh, T. B. (2008). Laparoscopic bile duct injury – understanding the psychology and heuristics of the error. *ANZ J Surgery*. (in press).

Hoffman, D.D. (1998). *Visual intelligence. How we create what we see*. London: W.W. Norton & Company Ltd.

Hollenbeck, J., Ilgen, D., Phillips, J., Hedlund, J. (1994). Decision risk in dynamic two-stage contexts: Beyond the status-quo. *J. Appl Psychol*. 79,592-598.

Hugh, T. B. (2002). New strategies to prevent laparoscopic bile duct injury. *Surgery*. 132 (5), 826-835.

Hugh TB. (2002). Laparoscopic bile duct injury: some myths. *ANZ J. Surg*. 72, 164-167.

Jacklin R, Sevdalis N, Harries C, Darzi A, Vincent C. (2008). Judgment analysis: a method for quantitative evaluation of trainee surgeons' judgments of surgical risk. *Am. J. Surg*. **195**, 183-188.

Kern, K.A. (1995). The anatomy of surgical malpractice claims. *Bulletin of the American College of Surgeons*, 80, 34-49.

Margolis, H. (1996). *Dealing with Risk: Why the Public and the Experts Disagree on Environmental Issues*. University of Chicago Press: Chicago.

Orasanu J, & Martin L. (1998). Errors in aviation decision making: A factor in accidents and incidents. *Human Error, Safety and Systems Development Workshop (HESSD)*. accessed at: http://www.dcs.gla.ac.uk/~johnson/papers/seattle_hessd/judithlynne-p.pdf

Owen, L. (2005). The effect of Prime Minister Anthony Eden's illness on his decision-making during the Suez crisis. *Quarterly Journal of Medicine*. 98, 387–402. Accessed at: http://qjmed.oxfordjournals.org/cgi/content/full/98/6/387

Perissat, J. (1993). Laparoscopic cholecystectomy: The European experience. *Am J. Surg*. 165, 444-449.

Perrow, C. (1999). *Normal Accidents*. Princeton, N.J.: Princeton University Press.

Reason, J. (1990). *Human Error*. Cambridge, U.K.: Cambridge University Press.

Reason, J. (2000). *Managing the risks of organizational accidents*. Aldershot, U.K: Ashgate Publishing Ltd.

Sammarco, J. J. (2005). Operationalizing normal accident theory for safety-related computer systems. *Safety Science*. 43, (9), 697-714

Strasberg, S.M., Hertl, M., Soper, N.J. (1995). An analysis of the problem of biliary injury during laparoscopic cholecystectomy. *J. Am. Coll. Surg*.180,101-25.

Strasberg, S.M. (2005). Biliary injury in laparoscopic surgery. *J. Am. Coll Surg*. 201, 598-611.

Tversky, A., & Kahneman, D.(1982). Judgment under uncertainty: heuristics and biases. In D. Kahneman, P. Slovic & A. Tversky (Eds), *Judgment under uncertainty: Heuristics and biases*, Cambridge University Press: Cambridge.

Wason, P.C. (1960). On the failure to eliminate hypotheses in a conceptual task. *Quarterly J. Experimental Psychology*. 12,129-140.

Vaughan, D. (1999). The dark side of organisations: Mistake, misconduct, and disaster. *Annual Review of Sociology,* 25, 271-305.

Way, L.W., Stewart, L., Gantert, W., et al. (2003). Causes and prevention of laparoscopic bile duct injuries. *Ann. Surg*. 237, 460-469.

Weick KE. (1995). *Sense-making in organizations*. Thousand Oaks, CA: Sage Publications.

Weick, K. E. (2004). Normal accident theory as frame, link, and provocation. *Organization Environment*., 17, 27-31.

Weick, K.E. (1988). Enacted sense-making in crisis situations. *J. Management Studies*. 25,305-317.

Wolf, F. E. (2002). Complexity and tight coupling: a test of Perrow's theory in the petroleum industry. *Reliability and Maintainability Symposium Annual Proceedings*. accessed at: http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=981626