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Causes and Prevention of Laparoscopic Bile Duct Injuries

Analysis of 252 Cases From a Human Factors and Cognitive Psychology Perspective

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Objective

To apply human performance concepts in an attempt to understand the causes of and prevent laparoscopic bile duct injury.

Summary Background Data

Powerful conceptual advances have been made in understanding the nature and limits of human performance. Applying these findings in high-risk activities, such as commercial aviation, has allowed the work environment to be restructured to substantially reduce human error.

Methods

The authors analyzed 252 laparoscopic bile duct injuries according to the principles of the cognitive science of visual perception, judgment, and human error. The injury distribution was class I, 7%; class II, 22%; class III, 61%; and class IV, 10%. The data included operative radiographs, clinical records, and 22 videotapes of original operations.

Results

The primary cause of error in 97% of cases was a visual perceptual illusion. Faults in technical skill were present in only 3% of injuries. Knowledge and judgment errors were contributory but not primary. Sixty-four injuries (25%) were recognized at the index operation; the surgeon identified the problem early enough to limit the injury in only 15 (6%). In class III injuries the common duct, erroneously believed to be the cystic duct, was deliberately cut. This stemmed from an illusion of object form due to a specific uncommon configuration of the structures and the heuristic nature (unconscious assumptions) of human visual perception. The videotapes showed the persuasiveness of the illusion, and many operative reports described the operation as routine. Class II injuries resulted from a dissection too close to the common hepatic duct. Fundamentally an illusion, it was contributed to in some instances by working too deep in the triangle of Calot.

Conclusions

These data show that errors leading to laparoscopic bile duct injuries stem principally from misperception, not errors of skill, knowledge, or judgment. The misperception was so compelling that in most cases the surgeon did not recognize a problem. Even when irregularities were identified, corrective feedback did not occur, which is characteristic of human thinking under firmly held assumptions. These findings illustrate the complexity of human error in surgery while simultaneously providing insights. They demonstrate that automatically attributing technical complications to behavioral factors that rely on the assumption of control is likely to be wrong. Finally, this study shows that there are only a few points within laparoscopic cholecystectomy where the complication-causing errors occur, which suggests that focused training to heighten vigilance might be able to decrease the incidence of bile duct injury.

Bile duct injuries are the main serious technical complication of laparoscopic cholecystectomy.[1,2] Data are insufficient to determine precisely the frequency of bile duct injuries, but a reasonable estimate is one in 1,000 cases.[2] A decade ago, as the technique of laparoscopic cholecystectomy was first being learned by otherwise fully trained, practicing surgeons, the injury rate was noted to be greater during an individual's first dozen cases than in subsequent ones.[2] This learning curve contribution is now much less important, for surgical residents learn the procedure under direct supervision of more experienced surgeons.

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Surgeons have always analyzed their technical complications for insights that might be translated into improved performance. In the past the information available from such reviews could rarely go much beyond a tabulation of results. An understanding of the root causes of technical complications remained elusive. This report takes analysis of technical complications to greater depths, for it integrates the findings of videotapes of operations involving bile duct injuries, operative notes dictated after the operation had been completed but before an injury had become apparent, and conceptual tools of human factors research and the cognitive science of human error.

METHODS

The operations of 252 patients who had major bile duct injuries during laparoscopic cholecystectomy were analyzed. The patients had been referred to the authors for evaluation or treatment, and the accompanying records were complete with respect to operative notes from the initial operation and any subsequent operations done to repair the injury. The injuries involved the common bile duct (CBD), common hepatic duct (CHD), lobar hepatic ducts, or segmental hepatic ducts. Bile leaks from the gallbladder bed and cystic duct were excluded. Operative notes, pathology reports, radiology reports, operative x-rays, postoperative x-rays, and 22 unedited videotapes of laparoscopic cholecystectomies that involved bile duct injuries were analyzed to determine the causes of the injuries and circumstances contributing to them.

Seventy-seven percent of patients were women and 23% were men. The average age was 46 years (range 19–86 years). The indications for the operation (i.e., the diagnoses) were chronic cholecystitis, 69%; acute cholecystitis, 29%; gallstone pancreatitis, 2%; and cholangitis, 0.4%.

The injuries were examined within the framework of human error analysis. The surgeon's performance was analyzed for: 1) perceptual input data (visual and/or haptic), 2) knowledge and decision-making, and 3) action (i.e., skill, the quality of the technical aspects of the operation). Data from imaging reports (operative and postoperative), reparative operations, and videotapes were analyzed and compared with the original operative reports to determine the cause of the injury and the working assumptions of the surgeon.

The following criteria were employed when categorizing the errors. We considered misperception to have occurred in instances where the data showed that 1) the surgeon had seen and deliberately cut a duct that he or she thought at that moment was a different duct (e.g., the surgeon cut the CBD thinking it was the cystic duct), or 2) the surgeon injured an unseen duct while performing a dissection that he or she believed was a safe distance from the duct (e.g., a scenario characteristic of class II injuries). The error was considered to represent faulty decision-making or a knowledge error if the data indicated that 1) the surgeon had departed from the orthodox operative strategy for performing a laparoscopic cholecystomy, or 2) had performed the operation in a setting where laparoscopic cholecystectomy was inappropriate. We considered that the fault was at the action or skill level when there was evidence that the dissection was performed in a clumsy way; when an identified duct being cleared of connective tissue was accidentally cut or cauterized. In the discussion section we have interpreted the findings according to accepted principles of cognitive psychology and human error. Although some of these ideas may be new to surgeons, we are unable to argue their validity within the context of this paper. Instead, we have cited representative literature that will allow the reader to determine for himself or herself the strength of their foundations.

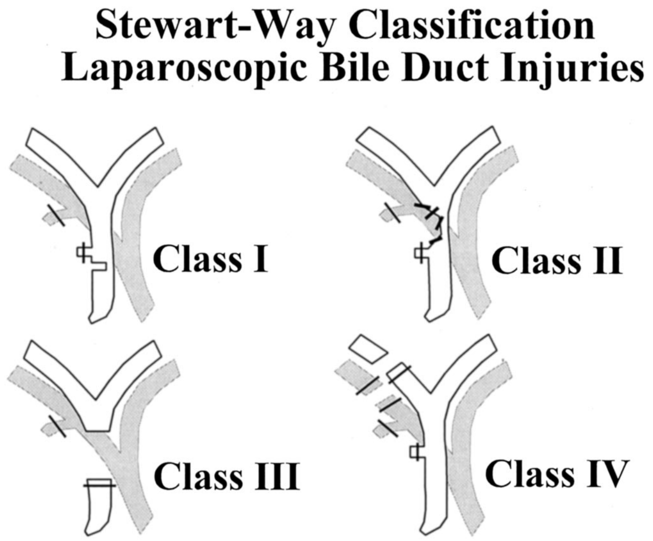

Figure 1. Classification of laparoscopic bile duct injuries. The mechanism of the injury is in the text and Table 1. Class III injuries are subdivided according to the location of the proximal line of transection.

RESULTS

Mechanism of Injury and Injury Classification

The patients were grouped into four classes (Fig. 1) based on the mechanism and anatomy of the injury (Tables 1 and 2). Class I injuries (7% of cases) involved an incision (an incomplete transection) of the CBD with no loss of duct. Class I injuries occurred in two ways: either 1) the CBD was mistaken for the cystic duct (72%), but the mistake was recognized, usually by operative cholangiography, before the duct was completely transected; or 2) an incision made in the cystic duct for the cholangiogram catheter was unintentionally extended into the CBD (28%). The right hepatic artery was injured in one (5%) of these cases.

Class II injuries (22% of cases) consisted of lateral damage to the CHD that produced stricture and/or fistula formation. These injuries usually involved the placement of

Table 1. MECHANISM OF INJURY

Class I	CBD mistaken for cystic duct, but recognized
	Cholangiogram incision in cystic duct extended into CBD
Class II	Lateral damage to the CHD from cautery or clips placed on duct
	Associated bleeding, poor visibility
Class III	CBD mistaken for cystic duct, not recognized
	CBD, CHD, R, L hepatic ducts transected and/or resected
Class IV	RHD mistaken for cystic duct, RHA mistaken for cystic artery, RHD and RHA transected
	Lateral damage to the RHD from cautery or clips placed on duct

clips on the duct in conjunction with cautery damage during attempts to control bleeding (23%) or as a result of poor exposure (68%). Class II injuries never completely transected or occluded the CHD; they involved severe lateral damage leading to stricture formation (with or without a bile leak). In two patients the right hepatic artery originated from the superior mesenteric artery, and the anomaly probably contributed to the injury. In six cases (9%) strictures followed CBD exploration with T-tube placement into normal-sized ducts. The right hepatic artery was injured in 18% of these cases.

Class III injuries, the most common (61% of cases), involved transection of the CBD and excision of a variable portion proximal to the first transection, including the cystic duct–common duct junction. They were subdivided based on the proximal extent of the injury as follows: class IIIa, 104 patients (68%) who had a remnant of CHD remaining; class IIIb, 27 patients (18%) in whom the CHD was transected at the bifurcation; class IIIc, 16 patients (10%) whose bifurcation had been excised; and class IIId, 6 patients (4%) where the proximal line of resection was above the first bifurcation of at least one of the lobar ducts. Class III injuries occurred when the CBD was mistaken for the cystic duct. The surgeon transected the CBD early in the operation and excised a portion during extirpation of the gallbladder. Adhesions held the gallbladder infundibulum against the common duct, hiding the cystic duct. In 31 cases (20%) the proximal hepatic duct was clipped. In the remaining 122 cases the proximal hepatic duct was left open, and bile ascites developed postoperatively. The right hepatic artery was injured in 27% of the class III cases.

Class IV injuries (10% of cases) involved damage (transection or injury) to the right hepatic duct (or a right segmental hepatic duct), often (60%) with injury of the right hepatic artery. Class IV injuries resulted from misidentification of the right hepatic duct (or a right segmental hepatic duct) as the cystic duct (64%), or from a lateral injury to an unseen low-lying right hepatic duct during dissection (36%). The injury involved the main right lobar duct in 68%, a segmental duct in 28%, both in 4%, and a segmental duct plus the CHD in 12%. The right hepatic artery was injured in 60% of these cases ($P < .003$, compared with class I, II, or III, chi-square).

Operative Reports

Operative reports were reviewed for the following: 1) mention of any unusual findings; 2) factors contributing to making the operation difficult, which may have hampered identification of the bile duct (e.g., inflammation and bleeding); 3) conversion to an open operation and the reason (e.g., exposure problems, CBD stones); 4) suspicion of anatomic variations or anomalies; and 5) whether a bile duct injury was recognized at the time.

In 188 cases (75%), the operation was completed without the surgeon suspecting that an injury had occurred. In 57 cases (22%) the operative report recorded nothing unusual. Difficulty in obtaining exposure caused by adhesions or bleeding was mentioned in 16% of class I, 60% of class II, 29% of class III, and 28% of class IV injuries. In 33 cases the operation was converted from a laparoscopic to an open procedure because of difficulties with exposure. Nevertheless, the injury was discovered in only six (18%) of these patients.

Table 2. DISTRIBUTION OF BILE DUCT INJURIES

			Level			
Class	**# (%)**	**Right Hepatic Artery Injury # (%)**	**CBD/CHD # (%)**	**Bifurcation # (%)**	**Hepatic Ducts # (%)**	**Segmental Ducts # (%)**
I	19 (7%)	1 (5%)	19 (100%)	0	0	0
II	55 (22%)	10 (18%)	53 (96%)	2 (4%)	0	0
III	153 (61%)	41 (27%)	104 (68%)	27 (18%)	16 (10%)	6 (4%)
IV	25 (10%)	15 (60%)‡	0	0	18 (72%)*	7 (28%)†
Total	252 (100%)	67 (27%)	176 (70%)	29 (11%)	34 (14%)	13 (5%)

* Includes one patient with injuries to both the right hepatic duct and a segmental duct.
† Includes three patients who had injuries to the common hepatic duct as well.
‡ $P < .0001$ compared to class I, II, and III (chi-square).

The surgeon noted anatomic variations worthy of mention in 124 cases, including extra tubular ductal structures (88 cases), additional vascular or lymphatic structures (33 cases), a short cystic duct (14 cases), a wide cystic duct (7 cases), and/or a fibrotic liver bed (8 cases). In 36 cases the anatomic abnormality did not include a ductal structure, and the bile duct injury was not recognized during the operation in any of them. In 88 cases an extra tubular (ductal) structure or a bile leak was seen. In 55 cases the bile duct injury was identified: 17 cases by cholangiography, 7 from inspecting the removed gallbladder, 6 class I injuries when bile was seen to be leaking from the CBD, and 26 by operative identification of injured hepatic ducts. In the other 33 cases, the biliary anatomy was misinterpreted. In three class II injuries, the surgeon concluded that the bile duct injury had occurred because the gallbladder was connected directly to the CBD without an intervening cystic duct. In 30 cases, bile leakage (5 cases) and accessory ducts were reported.

Sixty-four injuries were recognized at the initial operation, but only 15 were identified early enough for the surgeon to limit the injury. Nine were diagnosed from routine operative cholangiograms, 17 from cholangiograms obtained specifically to look for an injury, 7 from examining the specimen, and the rest when an injured bile duct was seen.

Videotape Evidence

The operations recorded on the 22 videotapes were distributed at follows: class I, 2; class II, 4; class III, 13; and class 4, 3. The class I injuries included one where the common duct had been misidentified as the cystic duct, but the error was recognized on a routine cholangiogram. In another, the incision for the cholangiogram extended partially into the CBD. The class II operations were influenced by difficulties with visibility. Image quality was poor for technical reasons in three cases done in the early 1990s, but whether this contributed to the complications is questionable. In the class II injuries, clips were placed into areas that were incompletely exposed, and details of the anatomy were sometimes obscure because of bleeding or inflammation. In one case a replaced right hepatic artery was injured, and clips were placed rapidly in efforts to control bleeding. In the class III injuries, one could see that the dissection started not along the inferior edge of the triangle of Calot but below this area, as the common duct had been misidentified as the cystic duct. Connective tissue bridging the gallbladder infundibulum and common duct (thereby hiding the cystic duct) was misinterpreted as tissue covering the infundibulum and cystic duct. As the common duct was dissected free of enveloping connective tissue, it progressively looked more like the cystic duct, for the duct now moved simultaneously with the gallbladder. In six cases, the surgeon's main traction on the gallbladder infundibulum was in a cephalad rather than a lateral direction, which aligned the base of the cystic duct with the common duct and enhanced the illusion that the latter was the cystic duct. Extensive inflammation or stones impacted in the gallbladder infundibulum were not present to mask the anatomy. The normal tissue plane between the common duct and gallbladder went undetected and unopened. The common duct (thought to be the cystic duct) was deliberately transected after being cleared. In hindsight, the videotapes contained subtle clues that the common duct was being dissected instead of the cystic duct. For example, there were often additional lymphatic structures surrounding the common duct; in seven cases the right hepatic artery was seen and clipped after the common duct had been divided; the clips placed on the common duct did not completely traverse the duct; the common duct could be traced to go posterior to the duodenum in all class III cases; and in eight cases the proximal CHD could be seen during the dissection (but it was not detected by the surgeon in four). In four cases, the surgeon did diagnose the injury after recognizing the proximal CHD attached to the mobilized gallbladder. There were no differences on the videotapes that would explain why the proximal hepatic duct was detected in four cases but not in the other four cases. In the three class IV injuries, the bifurcation of the CHD was low, which led to the right hepatic duct being confused with the cystic duct. In one case the cystic duct entered the RHD; the RHD was damaged during the dissection, but the event could not be identified in our retrospective review of the videotape.

Specimen Examination

In seven cases the surgeon decided to open the abdomen after a ductal branching (the cystic duct–common duct junction) was noted on examination of the gallbladder specimen. Specimen examination in two other cases failed to uncover the injury in one and led to postoperative imaging in the other with identification of the injury. The pathologist did not independently discover the piece of common duct attached to the cystic duct in any class III case.

Operative Cholangiography

Of 60 routine operative cholangiograms, 43 demonstrated the bile duct injury. Nine were correctly interpreted when the surgeon noted that the proximal ducts did not opacify. In two of these cases, the surgeon divided the CBD before a static film was developed. In 28 cases the proximal biliary tree was not opacified during the cholangiogram (Fig. 2), or the common duct was narrowed at the point where the catheter entered (Fig. 3), but the significance of these findings was overlooked. In six cases the cholangiograms were thought to be normal, but the catheters were actually in the RHD instead of the cystic duct (Fig. 4). Eighteen cholangiograms were obtained after an injury was suspected; in 17, the surgeon detected the injury.

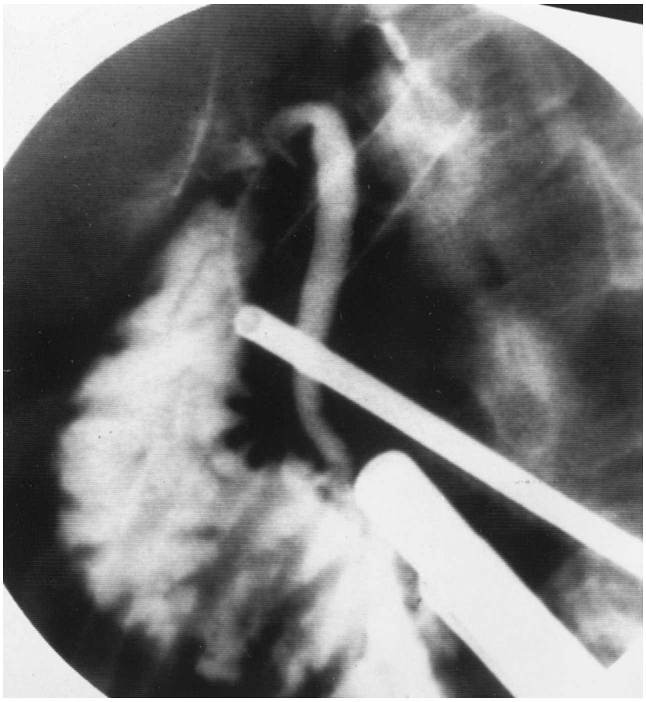

Figure 2. Operative cholangiogram demonstrating nonopacification of the hepatic ducts. This was misinterpreted as normal, and a class III injury ensued.

DISCUSSION

In response to the need to limit the frequency and severity of unwanted events in high-risk industries, such as commercial aviation and nuclear power, cognitive psychology has given rise to a subspecialty dealing with the science of human error.[3–9] The accumulated knowledge in this field has recently been applied to analyzing complications of healthcare delivery.[3,10–13] The present report consists of an analysis of technical complications in surgery employing these concepts.

The existence of videotapes and operative notes from cases where the injuries were not diagnosed during the operation allowed the events as seen by the surgeon to be compared with reality as recorded on the videotapes, postinjury x-rays, and the findings during reparative operations. The operations recorded on videotape were all performed by different surgeons. In each case, we judged that the surgeon carried out the procedure with adequate skill: blood loss was minimal, and the tissue planes were dissected cleanly, but in retrospect, incompletely. The fault was not at the action end of the sequence (i.e., skill).

In class I, class III, and some class IV injuries the mistake involved misidentifying the common duct (or right hepatic duct) for the cystic duct, followed by deliberate cutting of the misidentified duct. In the class II and some class IV injuries, the mistake consisted of performing the dissection in the triangle of Calot unintentionally too close to the bordering common hepatic or right hepatic duct. The ducts were not seen because they were covered by connective tissue or inflammation. The underlying nature of the error in either case was misperception.

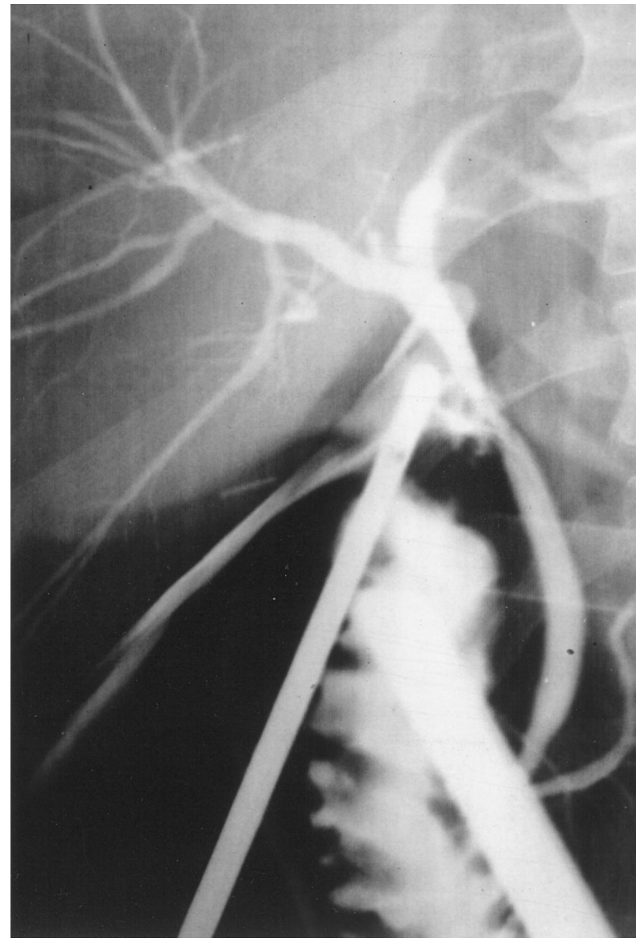

Figure 3. Operative cholangiogram demonstrating narrowing of the common bile duct. The cholangiocatheter is located in the common duct rather than the cystic duct. This patient went on to have a class III injury.

On the videotapes of the class III injuries, one could see that the CBD (adherent to the infundibulum) became prominent as traction was placed on the gallbladder at the start of the dissection. The cystic duct was partially or completely hidden from view by the infundibulum. The resulting arrangement made the common duct appear as if it continued directly into the base of the gallbladder. In other words, the anatomic relationship between the CBD and the gallbladder in these cases mimicked the surgeon's mental model of the relationship between the cystic duct and the gallbladder. The illusion was compelling, and it was accepted by the surgeon as reality.

The degree of anatomic similarity among the injuries within each class was striking. In the class III injuries, once the surgeon decided that the cystic duct had been located and mobilized, he or she proceeded to divide it. During the next step, separating the gallbladder from the liver, any structures encountered while opening this plane were inter-

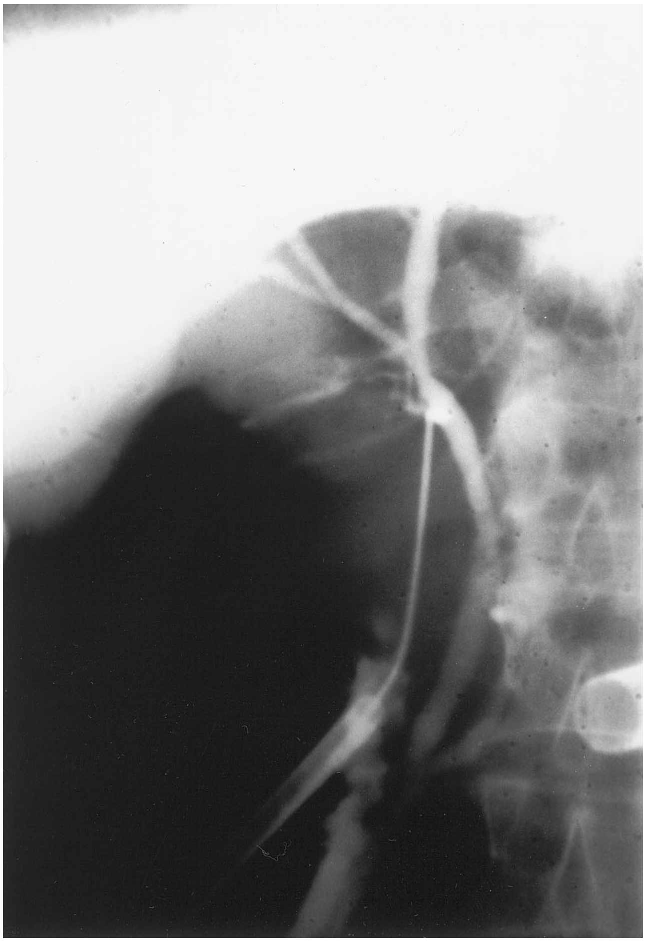

Figure 4. Operative cholangiogram interpreted as normal. The cholangiocatheter is located in the right hepatic duct rather than the cystic duct. This patient had a class IV injury.

preted as being adhesions; if a duct was identified, it was usually thought to be an "accessory" duct. Since the dissection at this point was taking place on the (patient's) left side of the CBD, not in the triangle of Calot as the surgeon believed, the right hepatic artery was often transected as it was mistaken for the cystic artery. Thus, the entire class III complex really consists of the fallout from a single initial misperception.

Class III injuries constituted the majority of this series, similar to other reports.[1,14–17] Although bile duct injuries with this pattern were encountered in the prelaparoscopic era, they were relatively uncommon. This suggests that something about the laparoscopic environment predisposes to the misperception underlying class III injuries. The possibilities include loss of haptic information, loss of stereoscopy, limitations in perspective (the position of the laparoscope is fixed), and so forth. All probably contribute, but we believe that loss of haptic perception is most important. Haptic perception is a complex process described as active touch as opposed to passive touch.[18,19] If one brushes up against something, the experience is passive touch; active touch occurs when one manually examines an object (e.g., a gallbladder covered by connecting tissue; or coins in your pocket) and can discern its size, shape, texture, hardness, borders, and mobility. In the examples given, the surface of a gallbladder, even when hidden by connective tissue, can be felt; the denominations of the different coins can be determined. Haptic perception constitutes a form of visualization, and experiments have shown that the visual cortex is among the higher centers involved in processing the information. The paucity of references to haptics, an imaging system of substantial day-to-day utility for surgeons, suggests that the importance of this sophisticated source of information is not fully appreciated.

Figure 5, depicting the general features of human cognition,[5,20,21] can be applied to the cognitive processes involved in performing a laparoscopic operation. Perception provides information from the environment about the gallbladder and adjacent tissues; long-term memory is the repository of the operative plan and the procedural skills. The input information from these sources is first processed at a subconscious level, and conscious thinking makes decisions and directs the actions that result in a cholecystectomy. Defects in the outcome could theoretically occur as a result of errors at any point in this sequence. As this analysis shows, however, laparoscopic bile duct injuries are predominantly a result of misperception, not inadequate knowledge of how to proceed (i.e., departures from an orthodox strategy) or deficiencies in manual skill.

Mental procedures that solve problems by making use of uncertain, probabilistic information are called heuristic processes.[5,20–23] Heuristics are normal, unconscious decision-making algorithms that work quickly and relatively effectively, but they do not always provide correct solutions. Heuristics are integral to human decision-making. Visual perception is one example.[9,11,22,24,25] The visual system implicitly makes plausible assumptions about the environment as it analyzes the imaging information being processed on its way towards the conscious mind. Because the assumptions are simplifications, visual perception provides an estimate of reality, not a replica. The extent to which these innate assumptions control perception can be appreciated by studying visual illusions.[7,22,26] For example, most people will see an illusory white triangle in the center of Figure 6. The brain automatically makes the simplifying assumption that the three black Pac-Men would most likely result from occlusion by another figure. This is beyond conscious control, and knowing that the white triangle is an illusion does not make it disappear.

Figure 7 demonstrates how the mind fills gaps in the continuity of form and creates in this example the image of a dog from a coarse arrangement of black spots on a white background. Once one sees the dog in this illusion, it cannot be made to disappear. The illustrations in Figures 6 and 7 show how innate neurophysiologic assumptions governing heuristic perception make the process vulnerable to the creation of false images. Our conscious minds are at the mercy of the subconscious heuristics. According to Hoff-

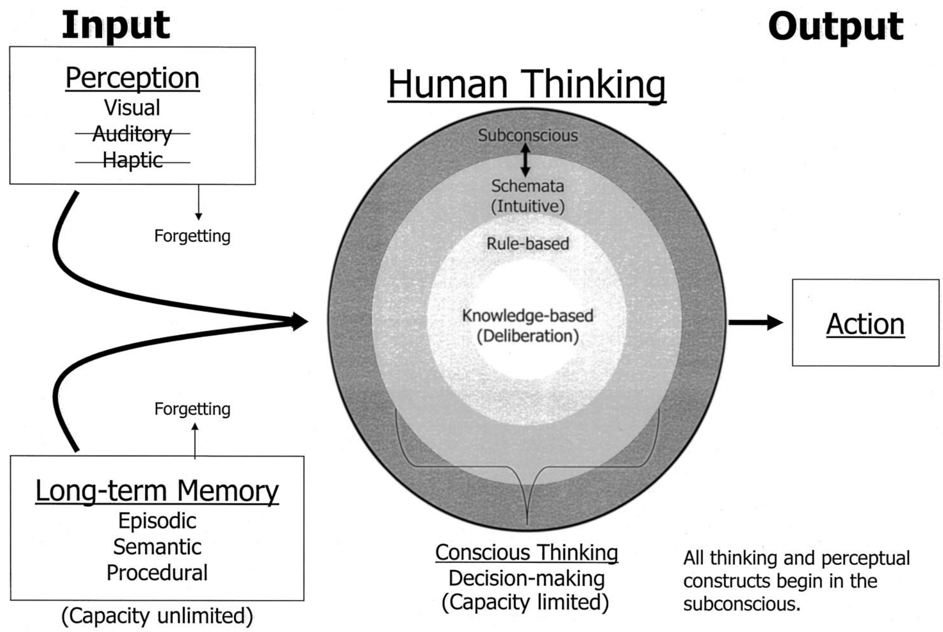

Figure 5. Conceptual model of human cognition (adapted from references 5, 20, 21). The decision-making part of the mind is depicted by the four concentric circles in the center. Conscious thought is represented by the innermost three circles, where decisions require varying levels of cognitive energy: schemata or intuitive decisions require the least resources. Accurate intuitive decision-making comes as a result of extensive experience and training. All expertise is largely intuitive. Uneducated intuitive decisions, however, have a low accuracy level. Rule-based thinking invokes learned responses that might not have become intuitive: "turn the wheels in the direction of the skid" is an example. Knowledge-based thinking requires the greatest amount of attention and deliberation (for example, complex decisions involving large amounts of data; creative thinking; etc.). Everything that reaches the conscious mind is first processed in the subconscious, which filters the virtually limitless number of possible thoughts and allows a select few to reach consciousness. Even perceptual information is highly filtered. We are consciously aware at any moment of only a small portion of the images, sounds, tactile and proprioceptive stimuli, and smells that are reaching us. We can selectively focus attention from one to another but not to more than a few at a time. It is impossible, for example, to follow two busy independent audible conversations simultaneously. Perception of events in the operating field might include visual, haptic (see text), or auditory information. Laparoscopic surgery eliminates the very useful haptic input and stereoscopic depth perception. Guidance for the operation relies almost entirely on visual data, so imaging equipment should be of the highest quality.

man,[24] "Subjective figures are not just part of picture perception. They are part of ordinary seeing. You construct every figure you see. So, in this sense every figure you see is subjective." Although the illusions in Figures 6 and 7 have nothing to do with bile duct injuries per se, they show how easily perception of form can be faulty and beyond the individual's knowledge or control. This is central to the mechanism of bile duct injuries.

When surgeons inspect the gallbladder and surrounding structures to identify the cystic duct, the subconscious brain seeks a pattern to match the mental model of the biliary tree stored in long-term memory. The tissues, however, do not have clean uninterrupted borders, but are partially obscured by connective tissue, inflammation, or blood. The decision, therefore, is made from a pattern consisting of a combination of signals (duct borders) and noise (occluding connective tissue, blood, etc.). When enough duct is visible, subconscious decisions are made concerning form.[9,11,22,24,25] Being subconscious, the brain processes are not available for introspective analysis, and unless contradictory findings are detected and acted on, a decision is made that the cystic duct has been identified. The steps involved in identifying the cystic duct are the same as for all visual perception. Tentative estimates of form (of the biliary anatomy in this example) are subconsciously tested with respect to similarity to previous cases and to the frequency of various possibilities from experience and memory. Referring to heuristic problem-solving such as this, Reason[5] stated, "The price we pay for this automatic processing of information is that perceptions, memories, thoughts, and actions have a tendency to err in the direction of the familiar and the expected." The comment is relevant to the mechanism of laparoscopic class III bile duct injuries.

The ability to characterize human performance and anticipate its failure modes has contributed substantially in recent years to the analysis of problems involving human error and the design of more reliable systems.[4,6,8,27–31] The corrective options include retraining the individuals who were involved in the event and altering the design of the system. Traditionally, the individual operator has received

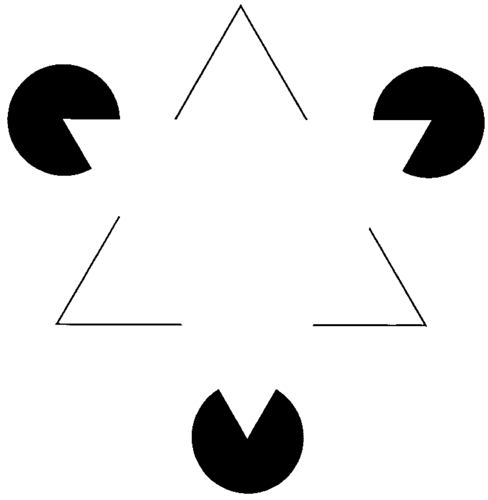

Figure 6. Kanizsa Triangle. Most people see a bright white triangle occluding an underlying triangle and parts of the three black circles. The white triangle is a creation of visual heuristics.

Figure 7. An illusory dog assembled automatically by subconscious processes.

most of the attention (blame), and retraining has received the most emphasis as a corrective measure.[3,5] In the case of bile duct injuries, educational efforts (e.g., articles such as this one) should be of value. Knowing that the complications occur from errors at just two steps in the operation, for example, should lead to enhanced vigilance at these critical points.

In some cases the operative note included unexpected observations that in retrospect were manifestations of the faulty operation. At the time they were encountered, their significance went unrecognized, but why? Research has demonstrated that human decision-making is often influenced by what is called "confirmation bias."[20,21,32,33] Once we commit ourselves to a judgment (e.g., about the biliary anatomy), we subsequently tend to discount the significance of new disconfirmatory evidence in favor of the confirmatory evidence. This should not be misconstrued as a character defect, for cognitive biases are normal features of the way humans reason. There is evidence, however, that confirmation bias in specific settings may respond to educational efforts that spell out and explain the significance of specific disconfirmatory findings.[32] For example, rules of thumb such as those listed in Table 3 could alert operators to potentially important departures from normalcy and increase the weight placed on disconfirmatory observations.[5]

Nevertheless, experience in other high-risk occupations has regularly shown disappointing and transient influences of additional training on performance failures grounded in the heuristics and biases of the human mind.[3,20] Expectations that additional training would be effective have overlooked the fact that human performance cannot be pushed to perfection; that sporadic failure is inevitable and its form is often predictable; and most importantly, that the innate heuristics and biases cannot be expunged from human decision-making.[20] Therefore, the most fruitful corrective strategy often lies outside the individual—in system changes: the processes or technology.[3,6,8,10,27,34]

Within the present context, process change might, for example, entail a change in the conduct of the operation. In open cholecystectomy top-down mobilization of the gallbladder was found to be safer than beginning the dissection at the base of the gallbladder. Part of the explanation is probably that haptic perception helps guide the surgeon to the cystic duct when it is otherwise difficult to see. Top-down cholecystectomy is cumbersome laparoscopically, however, and there have been no proposals for change in the process of the laparascopic operation that seem likely to improve its safety.

Technology is a more likely source of help. Operative cholangiography is currently the most practical technological aid for verifying the anatomy.[13,35,36] Although surgical practice has largely settled on selective instead of routine use of operative cholangiography, if properly interpreted, cholangiography can limit the frequency and severity of bile duct injuries.[13,36] Without arguing for routine use, we believe that cholangiography should be employed more often during laparoscopic cholecystectomy than at present. We especially recommend that cholangiography be a part of the operation when difficulties are encountered in mobilizing the infundibulum of the gallbladder or identifying the cystic duct, or when the surgeon suspects the presence of anatomic anomalies, such as accessory or aberrant ducts. But what is needed is an even simpler method of locating the course of the ductal system during the operation, something simpler than cholangiography or ultrasonography.

The theory underlying malpractice law[37,38] rests on the principle that the physician has a fiduciary relationship to the patient, and as a consequence the patient can expect the physician's care to be of a certain high quality, defined as the standard of care. Practice below the standard that results in an injury may entitle the patient to monetary compensa-

Table 3. RULES OF THUMB TO HELP PREVENT BILE DUCT INJURIES

Optimize Imaging
- Use high-quality imaging equipment.

Initial Steps and Objectives
- Before starting the dissection, use the triangle of Calot for orientation; find the cystic duct starting at the triangle.
- Pull the gallbladder infundibulum laterally to open the triangle of Calot.
- Clear the medial wall of the gallbladder infundibulum.
- Make sure the cystic duct can be traced uninterrupted into the base of the gallbladder.
- Open any subtle tissue plane between the gallbladder and presumed cystic duct; the real cystic duct may be hidden in there.

Factors that Suggest One May Be Dissecting the Common Duct Instead of Cystic Duct
- The duct when clipped is not fully encompassed by a standard M/L clip (9 mm).
- Any duct that can be traced without interruption to course behind the duodenum is probably the CBD.
- The presence of another unexpected ductal structure.
- A large artery behind the duct—the right hepatic artery runs posterior to the CBD.
- Extra lymphatic and vascular structures encountered in the dissection.
- The proximal hepatic ducts fail to opacify on operative cholangiograms.

Obtain Operative Cholangiograms Liberally
- Whenever the anatomy is confusing
- When inflammation and adhesions result in a difficult dissection
- Whenever a biliary anomaly is suspected; assume that what appears to be anomalous anatomy is really normal and confusing until proved otherwise by cholangiograms.

Avoid Unintended Injury to Ductal Structures
- Only place clips on structures that are fully mobilized; the tip of a closed clip should not contain tissue.
- The need for more than eight clips suggests the operation may be bloody enough to warrant conversion to an open procedure.
- Consideration of a need for blood transfusion suggests the operation should be converted to an open procedure.
- Open when inflammation or bleeding obscures the anatomy.

Illusions
- Compelling anatomic illusions to which everyone is susceptible are the primary cause of bile duct injuries; experience, knowledge, and technical skill by themselves are insufficient protection against this complication.

tion. A central assumption is that the physician has the ability to control the events in question. When analyzed in detail, however, many examples of human error are seen not to be the result of willful substandard performance, but a predictable consequence of normal human performance in a high-risk, technology-rich setting. The misperception that underlies bile duct injuries occurs at a subconscious level in response to certain uncommon anatomic illusions. Norman[8] has pointed out the folly of using machine-centered standards for judging human performance. With current technology, the generally accepted estimate that bile duct injuries occur in one in 1,000 laparoscopic cholecystectomies may be nearing the upper limits of human performance for this complex task. Perrow,[39] an expert on high-risk technologies, has stated, "Most high-risk systems have some special characteristics that make accidents in them inevitable, even 'normal.' This has to do with the way failures can interact and the way the system is tied together. It is possible to analyze these special characteristics and in doing so gain a much better understanding of why accidents occur in these systems, and why they always will." We submit that the usual misperception error underlying laparoscopic bile duct injuries does not meet the defining criteria of medical negligence.

In conclusion, we have applied scientific principles from human factors research and cognitive psychology to the understanding of laparoscopic bile duct injuries. Our preliminary investigations into other kinds of surgical technical complications indicate that the underlying factors will be unique for each. Misperception is not a universal explanation. Experts have emphasized that fieldwork by those at the sharp end of the systems (i.e., the operators themselves) is required for this new science to be applied effectively. This means that only through direct involvement by surgeons knowledgeable in this area can systems of surgical practice be remedied to combat errors and prevent complications.

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