The “critical view of safety (CVS)” cannot be applied – What to do? Strategies to avoid bile duct injuries

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Summary Laparoscopic cholecystectomy has become the standard procedure worldwide since the early 1990s for those patients whose gallbladder has to be removed as part of their underlying disease (NIH Consensus Statement 1992). The most common complication is iatrogenic bile duct injury, which has not improved significantly since the introduction of open laparoscopic cholecystectomy as compared with open cholecystectomy. The intraoperative injuries are mostly the result of a misinterpretation of anatomical structures due to severe inflammation or topographical variations. In order to minimize this risk, a number of improved operative techniques and behavioral measures have been formulated. Here, we present methodological and operative possibilities as well as techniques that in unclear situations can help to minimize the risk of intraoperative injuries of the biliary tract and the accompanying vascular system.

Keywords Laparoscopic cholecystectomy · Biliary anatomy · Critical view of safety · Calot’s triangle · Common bile duct injury · Intraoperative cholangiography · Management challenge

Introduction

Bile duct injuries have long-term consequences that are associated with a lower quality of life as well as with reduced life expectancy [1, 2]. After the introduction of laparoscopic cholecystectomy, the injury rate within the learning curve averaged 1.5%, significantly higher than that with open cholecystectomy [3, 4].

In order to minimize this risk, a number of improvements concerning surgical techniques and behavioral measures have been inaugurated [5–7]. Even as surgeons became more experienced and results improved in an era beyond the laparoscopic learning curve the initially incurred high complication rate significantly persists [8, 9]. Taking into account meta-analyses and prospective studies, the incidence of serious injury patterns now seems to be between 0.08 and 0.5% [10–12]. If minor injuries are included, an overall incidence of 0.3–1.5% can be expected [13–17]. The severity of a biliary tract injury depends on various factors, including: a poor review of advanced pathology, a lack of recognition of anatomical variants, and a lack of experience of the surgeon. Larger complications result in a morbidity of 40–50% and a mortality rate of 2–4% [18–21].

A standardized procedure is recommended to avoid intraoperative bile duct injuries. The strategy of the “critical view of safety” is recommended as the most effective method to identify crucial structures, such as the cystic artery and the cystic duct, in the best possible way [22].

Definition of a standard method

A prerequisite for a safe, operative procedure is knowledge of the topography of decisive and trend-setting structures. Anatomical landmarks with surgical relevance are the hepatocystic triangle (Budde–Rocko triangle), the Calot triangle, the cystic plate, the Rouviere sulcus, and liver segment IV, as well as the anatomical variations (Fig. 1).

Dissection begins with exposition of the hepatocystic triangle and preparation of its anterior and posterior surface. In the literature, there is often no difference in the definition of the Calot triangle and the hepatocystic triangle (Budde–Rocko), which in-

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Fig. 1 Hepatocystic triangle and triangle of Calot. Hepatocystic triangle (*blue*): Upper boundary of hepatocystic triangle is the inferior border of liver. Lateral, the cystic duct and the neck of the gallbladder. Medial, the common hepatic duct. Triangle of Calot (*yellow*): Upper boundary is the cystic artery. Lateral the cystic duct. Medial the common hepatic duct, CBD Common bile duct

evitably can lead to errors in interpretation. While the cranial border in Calot's triangle is defined by the cystic artery, the cranial border in the hepatocystic triangle is determined by the lower margin of the liver. The constant limit that results from this, also in view of the wide range of variations of the cystic artery, provides better preparative safety ([23]; Fig. 1).

To find a safe level of dissection, it is of critical importance to prepare the lower circumference of the infundibulum from back to front, for a safe level to expose the cystic plate. It is crucial for safety that no tubular structure may be severed until the cystic duct and the cystic artery have been identified as such without any doubt. Only when, at the end of the preparation, both structures, the cystic artery and the cystic duct, also end at the infundibulum and the gallbladder infundibulum itself is released circularly from the liver bed can a proper dissection be assumed.

The isolation of both structures creates two windows that offer a view of the liver surface lateral to the gallbladder bed when the camera is in the medial position. This aspect is referred to as the "critical view of safety" [24]. It defines the topographical situation that allows for unequivocal identification of the cystic duct and the cystic artery and thus minimizes the risk of subjectivity (the human factor) in the identification of the biliary anatomy.

Strategic concepts with a security view that cannot be represented (CVS)

Difficult pathological conditions can make it difficult to reliably display the relevant bile duct anatomy and thereby create a higher risk of surgical complications.

Validated risk scores that indicate an increased risk of conversion to open cholecystectomy could help

identify patients at risk. In this context, several parameters have emerged that indicate a difficult cholecystectomy. These include old age, male gender, body mass index (BMI), physical status classification (ASA, American Society of Anesthesiologists) and inflammatory changes in the hepatocystic triangle. Thickening of the gallbladder wall, a porcelain gallbladder, and impacted stones on the infundibulum up to the Mirizzi syndrome can also lead to surgically difficult constellations [25].

"Time out"

In the event of anatomical or topographical uncertainties, "time out" means interrupting the operation in good time to counteract another problematic course (dangerous surgery; [26, 27]). Spatial, often unnoticed, disorientation is the most common cause (over 70%) of iatrogenic, biliary complications [28, 29].

Way et al. were able to show that laparoscopic cholecystectomy only leads to misinterpretations at a few critical but crucial points. These errors in perception and interpretation are mostly based on the fact that frequently you see what you believe and you do not believe what you actually see [27, 30].

The time out also serves to realign learned patterns (cognitive maps) to the current situation using anatomical landmarks in order to correct spatial disorientation (Fig. 2). It is crucial in this situation not to cut through any tubular structures without first identifying them, and only to continue the procedure after certainty has been gained.

Sutherland recommends five subhepatic fixed points (landmarks) for orientation and summarizes them in the term "B-SAFE" as a pragmatic mnemonic device ([31]; Table 1).

Fig. 2 Intraoperative strategies in difficult situations. *LCHE* laparoscopic cholecystectomy, *IOC* intraoperative cholangiography, *CVS* critical view of safety

Critical view not achieved

- Difficult LCHE
- Doubt
- Visual misperception*

Table 1 Cognitive map to avoid bile duct injury

<i>B</i>	Bile duct, basis segment 4
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<i>S</i>	Sulcus of Rouviere
<i>A</i>	Arteria hepatica
<i>F</i>	Fissura umbilicalis
<i>E</i>	Enteric viscera (pylorus, duodenum)
<i>S</i> Rouviere's sulcus, <i>A</i> hepatic artery, <i>F</i> umbilical fissure, <i>E</i> enteric visceral (duodenum)	

Intraoperative orientation/re-evaluate the anatomical landmarks

Five landmarks

A fixed, anatomical cornerstone that can be helpful in an unclear anatomical situation is Rouviere's sulcus (*incisura hepatica dextra*), an anatomical 2–3-cm-long depression in the right lobe of the liver that runs in an anterior direction toward segment I. It is 75–90% detectable and marks the course of the underlying right pedicle of the liver [32–34].

Another anatomical fixed point is the base (lower edge) of segment IV, between the umbilical fissure and the gallbladder. If one mentally forms a plane/line between the sulcus and the lower edge of segment IV, dissection is ventrally possible at this level and within the hepatocystic triangle [32]. The bile duct (*B*, bile duct), the hepatic artery (*A*, hepatic artery), the umbilical fissure (*F*, umbilical fissure), and the duodenum (*E*, enteric/duodenum) complete the five sub-hepatic landmarks (Fig. 3).

Lymph nodes

The cystic lymph node, also called Calot's (also Mascagni's or Lund's) lymph nodes, can serve as a guide or anatomical landmark for non-obese patients. It marks the exit of the cystic artery from the right branch of the *arteria propria* [35].

Fig. 3 Safe dissection zone. The R4U line is formed by Rouviere's sulcus (*RS*, four arrows) and runs from the base of liver segment IV to the hepatic ligament (*R4U*, red dotted line). This plane is the caudal border of the safe dissection zone. Above this plane is also the safe dissection triangle (*T*). Preparation above this plane ensures a safe distance to the main hepatic duct, its right branch, and its first bifurcation as well as the right hepatic artery. *CD* cystic duct, *RHD* right hepatic duct, *PS* Plane for safe surgery

Safe dissection zone

Safe dissection begins with the presentation of the cystohepatic trigonum, which is formed by the common hepatic duct, the cystic duct and the gallbladder wall (*infundibulum*), and the lower margin of the liver. This dissection zone is delimited caudally by the plane formed by the Rouviere incision, the base of segment IV, and the umbilical fissure (*R4U* level).

Deeper preparations are associated with a high risk of injury to the bile duct system and the arterial vascular system [23].

Anatomical variations

The norm variants of the cystic duct, the right hepatic duct, and the accessory bile ducts are of particular relevance for cholecystectomy. A normal course of the cystic duct can only be seen in 50% of patients. One fourth of cases show a long common course of the cystic duct with the common bile duct and the other 25% show different variations such as the medial part of the common bile duct and the abnormally caudal cystic duct [36].

Accessory bile ducts have a prevalence of 3–10% and are also known as “Luschka ducts.” Aberrating bile ducts, which deviate from the norm, occur with an incidence of 14–28%. They are characterized by their varying junctions. Their most frequent form is a common drainage of the right, posterior segments VII and VIII (11%) that flow into the left hepatic duct (5%), the hepatocholedochal duct (4%), or the cystic duct (2%) [34, 37, 38].

The normal variant of the artery is a singular branch that arises in 80% of cases from the right hepatic artery. In 6–16% of cases, it crosses the hepatocholedochal duct primarily dorsally, as an anterior variant. In 8.9% of cases there are several branches. The artery can also originate from the left hepatic artery, the gastroduodenal artery, and the celiac artery. The cystic artery is found in more than 70% of hepatocystic triangles and more than 30% is outside the Calot triangle. Particular caution is required for large tubular structures over 3 mm, because in 10–16% of cases the right hepatic artery lies in Calot’s triangle, near the cystic duct [39, 40].

Intraoperative imaging

Intraoperative cholangiography enables the identification of the extra- and intrahepatic bile duct system as well as the differentiation between the cystic duct and the common bile duct. It is a good method to gain certainty intraoperatively about the course of the bile ducts and to avoid possible confusion or to recognize bile duct injuries in good time. The routine use of intraoperative cholangiography has been the subject of debate for many years. Some studies show that the risk of bile duct injuries is reduced, while other studies have contradictory findings [16, 41, 42].

It is possible that intraoperative cholangiography may not prevent iatrogenic bile duct injury, but it does help identify injuries and, if used in a timely manner, reduces the extent of the injury. In view of the fact that only approximately 30% of iatrogenic bile duct injuries are detected intraoperatively, this additional examination method can contribute to an increase in patient safety.

Injection of indocyanine green

By injecting indocyanine green, the intra- and extrahepatic bile ducts can be made visible by infrared light during the operation. This ensures that confusion of the cystic duct with the common bile duct can be avoided as best as possible. The limitations of the technology lie in the limited penetration depth of the near infrared light, which limits the results in the case of pronounced visceral obesity and inflammatory processes. With regard to the assessment of intrahepatic bile ducts, anatomical norm variants, and choledocholithiasis, the method is inferior to intraoperative cholangiography for technical reasons [43].

Second opinion

Misinterpretation of anatomical structures is mostly (>60%) responsible for biliary and vascular injury patterns. The main causes are technical issues, depending on operational performance and surgical experience, and the extent of topographical changes based on pathological influences or anatomical variants. Before a passage through the supposed trigonum cystohepatic is forced and tubular structures are severed, it is advisable to get a “second opinion” from colleagues experienced in unclear situations. This is especially so because they are not subject to the bias of the OR team and the previous operational process.

Rescue measures (bailout strategies)

Rescue measures must be adapted to the local findings. Care must be taken with the possible rescue strategies, since the alternative approaches can also lead to a blind alley.

Antibiotic therapy

Before getting into a surgical disaster, there is the option of interrupting the procedure at a point in time where it is still possible to initiate antibiotic therapy and to perform the cholecystectomy later, in about 3 months.

Fundibular approach

The fundamental procedure (dome-down, fundus first, or antegrade technique) is mentioned in the literature as a possible option for pronounced, inflammatory local findings or anatomical variants. Precise knowledge of the cystic and hilar levels must be assumed, as well as the preparation, which should be carried out as close as possible to the gallbladder wall, in the subserosal layer (subserosal-inner (SS-inner) layer; [44]). However, it should be borne in mind that, due to its susceptibility to errors, this technique can also be associated with a higher rate of iatrogenic bile duct injuries. Especially in inflammatory processes that lead to thickening of walls and shrinking

processes in the gallbladder bed, the risk of injury to vessels and the bile ducts is significantly increased due to the proximity to the right pedicle [45]. If the artery and cystic duct cannot be isolated using this technique, there is still the option to perform the cholecystectomy in a subtotal form.

Subtotal cholecystectomy

Subtotal cholecystectomy is an operative alternative for local, risky conditions due to which the safe dissection with total removal of the gallbladder is not possible. After a period in which the form of subtotal resection was subject to different interpretations, Strasberg introduced the term “subtotal cholecystectomy” for those with almost complete gallbladder ablation and defined the type that corresponds to fundus ablation as “fundectomy.” Subtotal cholecystectomy, the remaining part of which can be closed, is categorized as a reconstructive form. The fenestrated form of subtotal cholecystectomy is the procedure in which the remains of the gallbladder are left open and the remaining part of the wall (back wall) remains fixed to the gallbladder bed of the liver (cystic plate). The inner mouth of the cystic duct can be closed with a suture [46].

Conversion

Conversion from laparoscopic to open cholecystectomy is a strategy that is used either to prevent iatrogenic injury or to repair injuries. It is not a failure, but reflects the surgeon's sense of responsibility and may save the patient's life. The extent of the pathological/inflammatory changes, the anatomical conditions, and the experience of the individual surgeon influence the intraoperative decision to convert.

So-called preoperative risk factors could also be identified that make conversion likely. These include the male sex, old age, obesity, previous operations, the severity of the inflammation, and the laparoscopic emergency cholecystectomy for acute cholecystitis [47, 48].

Conversion should be aimed for in cases where the representation of the Calot triangle is poor or impossible, the anatomical conditions remain unclear, heavy (excessive) bleeding occurs, if the operation does not progress (for high-risk patients >30 min and for low-risk patients >60 min), or a bile duct injury has occurred.

Likewise, with laparoscopic cholecystectomy, the risk of perioperative complications is four times greater if it lasts longer than 2 h instead of the usual 30–60 min [49].

Summary

Since the worldwide introduction of laparoscopic cholecystectomy, there has been a clear discrepancy

between open (0.2–0.3%) and laparoscopic procedures (0.5–0.8%) with regard to iatrogenic bile duct injuries [50, 51]. But even with an adequate, standardized procedure (checklists, guidelines), pathological processes in the context of gallbladder diseases can result in situations where the danger is expressed by intraoperative injuries to the biliary and vascular systems. In order to minimize this risk, it is important to not only master the standardized course of laparoscopic cholecystectomy, but also to adhere to essential rules, such as knowledge of preoperative risk factors that may lead to a complicated course of the operation.

Controlling unexpected circumstances or situations that block operational progress is also an essential element of a species-appropriate approach. Knowledge of the time out, the application of safety rules (B-SAFE), and the use of intraoperative cholangiography are part of the set of tools for carrying out a properly performed operation [16]. This also includes a precise understanding of the regular course of anatomical structures in the portal of the liver, as well as knowledge of their topographical norm variants in order to realign learned patterns (cognitive maps) in the current context based on the anatomical landmarks and to correct spatial disorientation [10].

The concept of reducing biliary tract or associated vascular injuries requires knowledge not only of how to avoid intraoperative complications, but also of possible exit scenarios and surgical alternatives (bailout techniques/strategies).

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