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Critical Line of Safety Guided Decision Making for Laparoscopic Subtotal Cholecystectomy in Difficult Gallbladder Surgery

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ABSTRACT

Objective: This article proposes incorporating the critical line of safety (CLS) as an anatomical and decision-making landmark to guide a safe laparoscopic cholecystectomy (LC); especially when critical view of safety (CVS) cannot be achieved.

Material and Methods: The CLS is defined as the caudocranial line running along the lateral edge of the hepatoduodenal ligament that extends from the duodenum to the cystic-hilar plate junction. Two key rules are emphasized: (1) no structure medial to the CLS should be divided and (2) dissection beyond the CLS should be avoided or performed with awareness of potential thermal injury. If completing total cholecystectomy requires resection beyond the CLS, this represents the "inflection point" to stop and perform a laparoscopic subtotal cholecystectomy.

Results: In difficult cholecystectomy, the key decision is to stop before bile duct injury (BDI) occurs. In cases of unattainable CVS, the CLS helps the surgeon identify the extrahepatic bile duct and thereby facilitates safe dissection. When difficult anatomy is combined with failure to achieve CVS, CLS-guided decision-making provides a foundation basis for the surgeon to recognize the inflection point and stop attempting total cholecystectomy.

Conclusion: CLS-guided decision-making provides an objective and anatomical reference for identifying the safe limit of dissection and determining when to terminate attempts at total cholecystectomy. Incorporating this landmark into standard practice may enhance surgical awareness, reduce perception bias, and prevent BDI. Further clinical validation is warranted to establish the role of CLS in safe LC.

Keywords: anatomical landmark of bile duct; cholecystectomy; critical line of safety; critical view of safety; laparoscopy; safe cholecystectomy

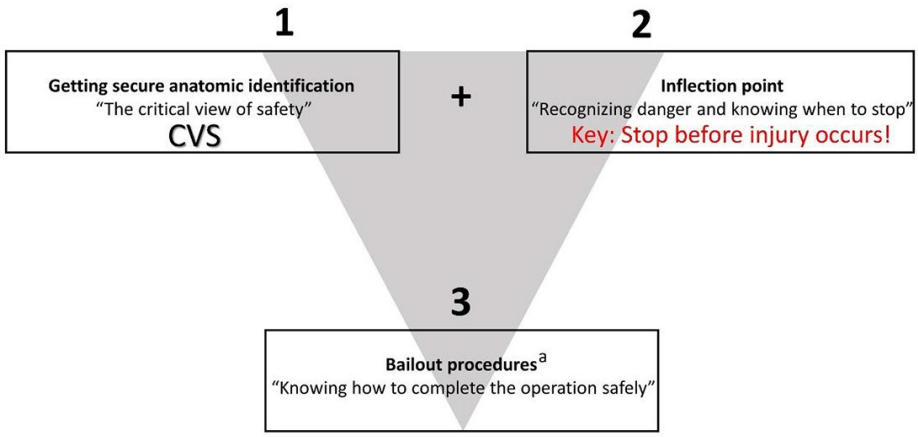
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INTRODUCTION

Laparoscopic cholecystectomy (LC) was introduced several decades ago, with favorable outcomes compared to an open approach[1]. However, a notable number of cases of bile duct injury (BDI) still occur worldwide[2], despite preventive strategies including: the fundus first technique, subtotal cholecystectomy and the critical view of safety (CVS)[3,4], which is the most accepted method. CVS is the method for identification of the cystic duct (CD) and the cystic artery (CA), which is virtually safe for when CVS can be achieved[5]. CVS has been recommended by many society guidelines[4,6] to prevent BDI. Nonetheless, injuries have occurred while surgeons were looking for the cystic duct that resulted in misinterpreting the common bile duct (CBD) as the CD. This phenomenon is called "motivated perception" which has been studied in psychological research[7]. Motivated perception is when the motivational factor (wish to see) has top-down influence over perception. In such cases, surgeons become biased towards seeing what they want to see. Therefore, the CBD is usually misinterpreted as the CD. Moreover, it is unclear regarding decision-making of when to stop attempting total cholecystectomy and choose bail-out procedures in patients in whom CVS is impossible to be achieved.

The rate of BDI in patients with successful attainment of CVS is close to zero[5]. However, a study reported that acute cholecystitis, fibrosis, impacted gallstone, empyema gallbladder, and Mirizzi syndrome are significant predictive factors in failure to achieve CVS in difficult gallbladder surgery. Of those, the rate of unattainable CVS ranged from 28.3% to 78.6%[8]. The group of patients with unattainable CVS are recognized as high risk for BDI. Accordingly, awareness of the difficulty should be emphasized. In 2019, Strasberg et al. proposed a three-step conceptual roadmap (Figure 1) as part of performing a safe cholecystectomy. The first step is anatomic identification, in particular the CVS. The second step is the inflection point, which is the point when a surgeon cannot safely achieve CVS, and should stop attempting total cholecystectomy, in other words: "when to stop." The third step is to finish the procedure safely with an alternative approach (e.g., subtotal cholecystectomy)[9]. The core concept of the second step is to stop before injury occurs. However, there is no acceptable standard of when to stop attempting either total cholecystectomy



[a]Subtotal cholecystectomy, cholecystostomy, fundus-first technique, open conversion; abort the operation

Figure 1 A three-step conceptual roadmap proposed by Strasberg[9] that emphasizes a decision should be made to halt the attempt of total cholecystectomy before any injuries occur, so as to complete the procedure with bail-out procedures

or dissection to obtain CVS. The Delphi consensus statements and a recent study of laparoscopic subtotal cholecystectomy (LSC) encouraged surgeons to stop attempting total cholecystectomy when there are impacted gallstones, severe fibrosis; scarring in the Calot's triangle, or marked inflammation in the hepatocystic triangle[10,11]. Notably, some factors are subjective and depend on the surgeon's experience. As a result, data showed that BDI is significantly associated with the experience of surgeons[12]. To prevent BDI, an objective criterion of when and where to stop is needed. Using direct anatomical landmarks of the bile duct (BD) as a guide would increase both recognition and awareness; hence, increasing the safety of LC. The purpose of this article is to incorporate the critical line of safety (CLS) into the decision-making for when to use the bail-out procedure (i.e., subtotal cholecystectomy).

Application of the critical line of safety

The majority of BDI cases are caused by perception bias that results from misidentification of the bile duct as the cystic duct. Therefore, the key to understanding how to prevent BDI during cholecystectomy is to look for the bile duct: not the cystic duct.

To our knowledge, there is only one direct anatomical landmark of the bile duct reported in the literature. According to a photographic analysis of BDI[13], and experience in treating such patients[14], the author proposes the CLS. The CLS is an anatomical landmark of the bile duct, which runs in the caudocranial direction along the lateral edge of the hepatoduodenal ligament (HDL), beginning at the duodenum and running up to the cystic-hilar plate junction (Figure 2). During the cholecystectomy procedure, before any dissection is attempted, the CLS should be marked.

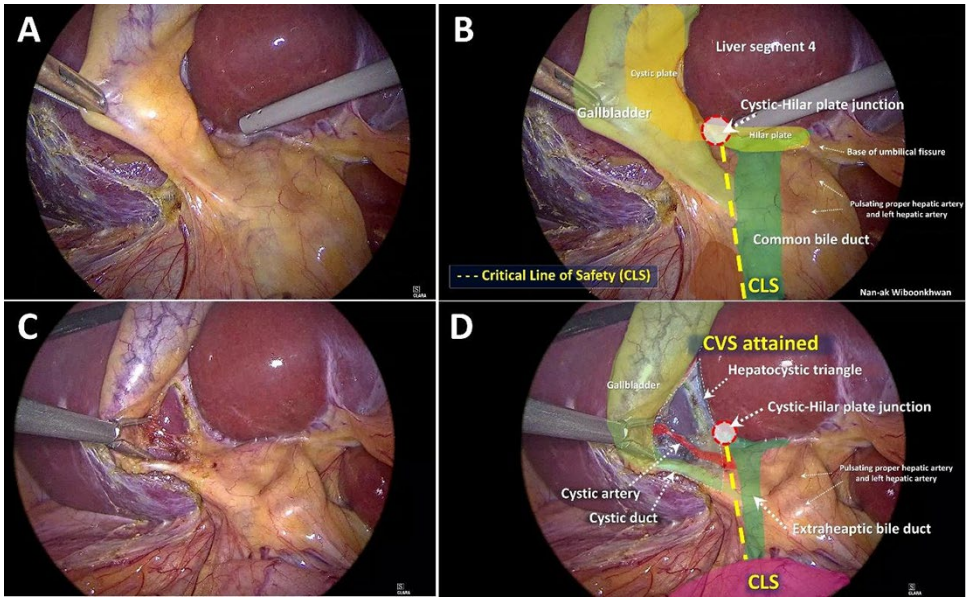


Figure 2 Critical line of safety (CLS) before and after dissection of the hepatocystic triangle. A) and B) before dissection: A) setting the exposure to identify the anatomic structures by retracting the gallbladder fundus in the anterocranial direction, the infundibulum in the lateral direction, and upward retraction of segment 4; B) visualized anatomic landmarks; including the cystic-hilar plate junction, red-dot circle and the CLS that is represented by the yellow dotted line. C), and D) after dissection: C) critical view of safety (CVS); D) CVS is attained and all structures medially beyond the CLS are intact.

The first rule is that no structures beyond the CLS in the medial compartment (i.e., in the HDL) can be resected during LC. The second rule is dissection beyond the CLS should be avoided; however, if necessary, thermal injury should be kept in mind (Table 1). Structures in the medial compartment beyond the CLS include: the extrahepatic bile duct, hepatic artery and main portal vein. Thermal injury of those structures can result in serious operative complications[15,16].

CLS-guided decision-making of: "when to stop" is any circumstance in which resection of structures beyond the CLS is needed to complete total cholecystectomy. This situation violates the first rule; therefore, this is the time to stop and complete the operation with subtotal cholecystectomy (Figure 3). When the decision is made, the procedure can be straightforward with LSC. In the case of no cystic duct opening, reconstituting subtype is necessary (Supplementary Video 1) https://drive.google.com/file/d/1f8jbRUfIY55N0lAq52hJjt2Pm8Z0sGdQ/view?usp=sharing.

Table 1 Critical line of safety (CLS) guided decision-making for the inflection point

Rule	Description	Leading to inflection point
No.1	Required resection of any structures beyond the CLS to complete total cholecystectomy	Absolute
No.2	Dissection beyond the CLS in the medial compartment is required to complete total cholecystectomy or to achieve critical view of safety	Relative

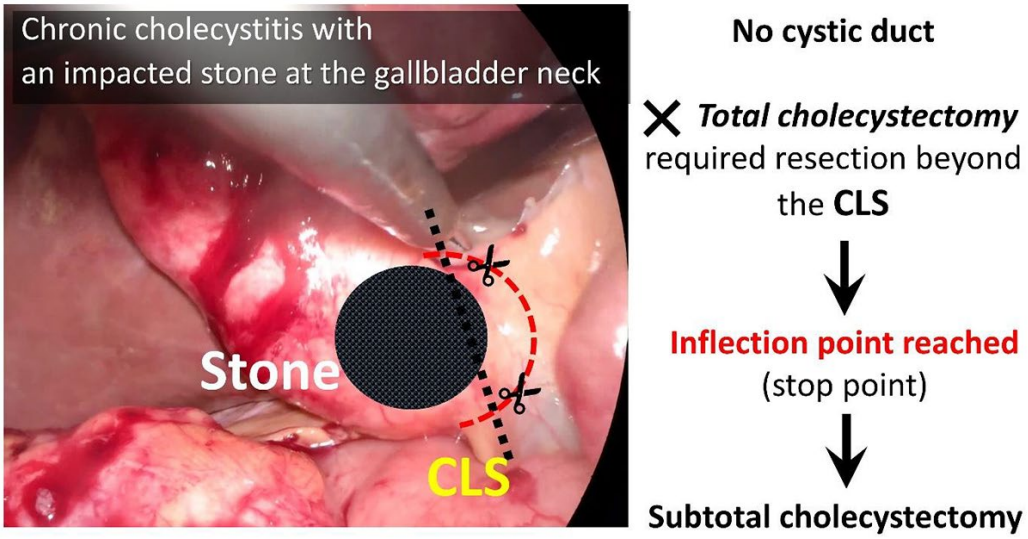


Figure 3 An impacted stone at the neck of the gallbladder without a cystic duct: the straight dotted line represents the critical line of safety (CLS). When a total cholecystectomy resection is needed beyond the CLS, the inflection point has been reached. This is when and where to stop any attempt at total cholecystectomy. The operation should be finished by subtotal cholecystectomy.

According to the second rule, dissection should be carried out lateral to the CLS to avoid injury to vital structures. Even with careful dissection in the case of dense fibrous scaring at the hepatocystic triangle, the possibility of biliary injury is high. In this situation, the surgeon should take a step back, make an assessment, and reassure that no structures beyond the CLS are injured. Taking rule number one into consideration, the decision to halt the attempt of total cholecystectomy should be made if resection beyond the CLS is required to complete the procedure. In such cases, the CLS is where the surgeon should stop (Figure 4). In addition, this objective criterion guided decision making for the inflection point can result in shortening the dissection time and turn a complex procedure into a simple one (Supplementary Video 2) https://drive.google.com/file/d/1c7fQ1DnSjsfm4G-a-d4pgmqDq9hprSms/view?usp=sharing.

Surgical technique for laparoscopic subtotal cholecystectomy

The operative field is initially prepared using surgical gauze placed under the liver to prevent contamination. The retrieval bag is also prepared. Changing one of the working ports to 12 mm can also facilitate exchanging surgical instruments. Following full exposure to the gallbladder, it is opened anterosuperiorly. Any stones should be gradually removed and placed into the retrieval bag. Caution should be taken not to drop the stones. Once the stones are removed, the anterior wall of the gallbladder is excised. Resection of the gallbladder wall must be restricted laterally to the CLS, which leaves approximately 1 cm of gallbladder cuff. The next step is to evaluate the internal orifice of the cystic duct and remove any cystic duct stones; if present. If the internal orifice can be identified, suture closure of the orifice (i.e., fenestrating subtype) is preferred over

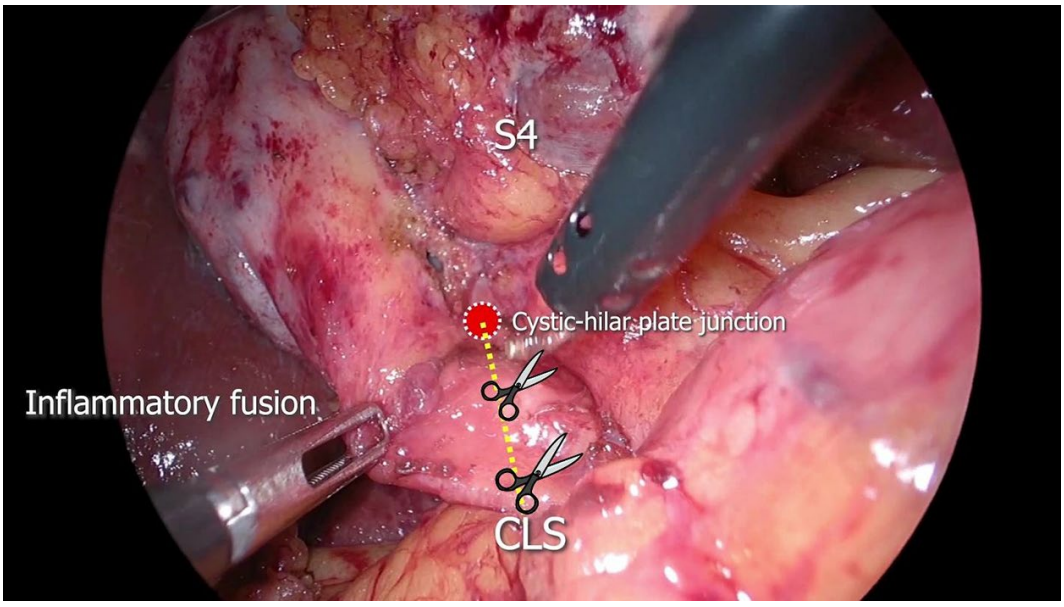


Figure 4 Chronic cholecystitis with inflammatory biliary fusion of the cystic duct to the common hepatic duct (arrow head): the red circle is the cystic-hilar plate junction. The yellow dotted line represents the critical line of safety (CLS). To complete a total cholecystectomy in this case, resection beyond the CLS to the medial compartment is needed; therefore, the inflection point has been reached.

closure of the gallbladder cuff (i.e., reconstituting subtype). Fenestrating subtype avoids a neogallbladder formation; thus, theoretically preventing recurrent gallstones. The step-by-step procedure is shown in Figure 5.

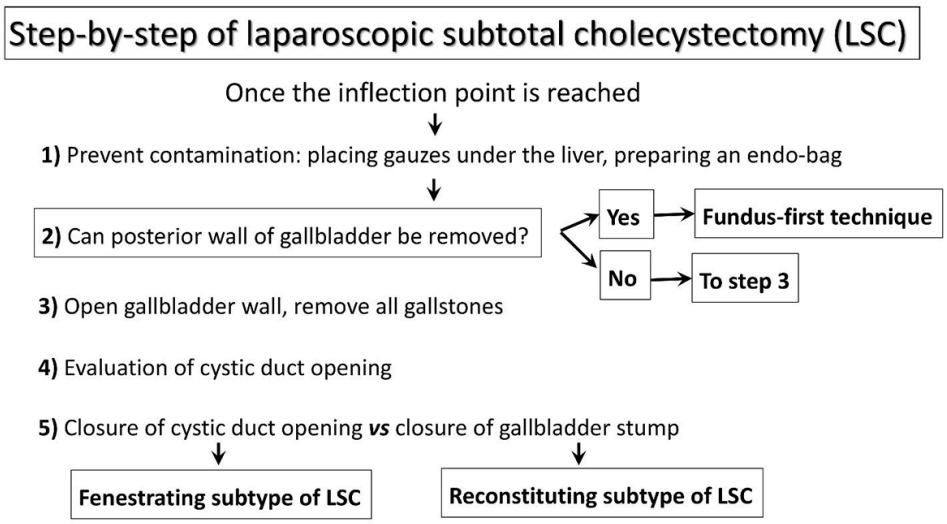


Figure 5 The step-by-step procedure for performing laparoscopic subtotal cholecystectomy

CONCLUSION

CLS-guided decision-making would add to when and where a surgeon should stop attempting total cholecystectomy, and when to finish the procedure with subtotal cholecystectomy. It should be incorporated into routine practice, as it increases awareness and prevents misinterpretation that would otherwise lead to a BDI. Further study to validate this concept is warranted.

Author contributions

The author contributed solely to the article.

Availability of data and materials

Not applicable

Ethical approval and consent to participate

Not applicable

Consent for publication

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CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

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