



# Challenging Orthodoxy: beyond the Critical View of Safety

Alexander Ostapenko<sup>1,2</sup> · Daniel Kleiner<sup>1,2</sup>

Received: 10 August 2022 / Accepted: 21 October 2022 / Published online: 7 November 2022  
© The Society for Surgery of the Alimentary Tract 2022

## Abstract

**Background** The critical view of safety (CVS) is the gold standard for performing safe cholecystectomies and minimizing common bile duct (CBD) injuries. It requires three criteria: complete clearance of the hepatocystic triangle, partial separation of the gallbladder from the cystic plate, and two structures alone entering the gallbladder. However, biliary anatomy varies widely, with frequent aberrant arterial supplies, which can mislead or disorient those attempting to acquire the CVS. This study was designed to examine the nature and frequency of cystic artery anatomic anomalies.

**Methods** We conducted a prospective observational study from 2018 to 2020, compiling photos of the critical view of safety of 100 consecutive elective cholecystectomies performed at our institution. Gallbladders were dissected up to the parallel portion of the cystic plate to achieve a critical view of safety. All tubular structures were preserved and clipped. Operative reports were examined for mention of posterior cystic arteries or aberrant arterial supplies. Photos were reviewed for an adequate critical view of the safety and presence of aberrant arterial supplies. The rate of aberrant arterial supply was determined and photos were reviewed for patterns of common abnormalities.

**Results** There were 121 patients who underwent an elective cholecystectomy; 21 lacked intraoperative pictures and were excluded from the study. Of the 100 patients included, 57 (57%) had an aberrant arterial supply with more than one cystic artery; seven had three concurrent arteries. Of those with more than one cystic artery, 21% had a recurrent cystic artery, 21% had a posterior dominant cystic artery, and 12% had a low-branching anterior cystic artery.

**Conclusion** Even with appropriate dissection for the CVS, surgeons can expect to frequently visualize more than two structures entering the gallbladder when a posterior cystic artery is present. It is, therefore, integral to distinguish this aberrant anatomy to prevent inadvertent injury to the CBD.

**Keywords** Critical view of safety · Gallbladder · Cholecystectomy · Common bile duct

## Introduction

Although the advent of laparoscopic techniques greatly decreased the morbidity of gallbladder surgery, the shift away from open cholecystectomy has been accompanied by an increase in the incidence of bile duct injuries. This prompted an upsurge in research into the development of protocols to reduce such injuries. The result of this work

was the development and widespread incorporation of the use of the critical view of safety.<sup>1</sup> In order to optimize the proper identification of the cystic duct and artery, the triangle of Calot must be dissected free of fat and tissue in order to visualize two and only two tubular structures entering the gallbladder, the cystic duct, and the cystic artery. In order to achieve this view, the gallbladder must be dissected partially off of the cystic plate. Consequently, the incidence of bile duct injuries has significantly decreased. As laparoscopic techniques improved, surgeons identified aberrant arterial anatomy in up to 25% of cases, with inadequate identification potentially leading to inadvertent hemorrhage.<sup>2,3</sup> In our experience, we have observed that the dissection of the gallbladder up to the parallel portion of the cystic plate often reveals an aberrant arterial supply. We, therefore, conducted a prospective study to delineate the anatomy of the gallbladder vasculature and determine the incidence of a posterior

✉ Alexander Ostapenko  
alexander.ostapenko@nuvancehealth.org

<sup>1</sup> Department of General Surgery, Nuvance Health, Danbury, CT, USA

<sup>2</sup> Department of Surgery, Larner College of Medicine, University of Vermont, Burlington, VT, USA

cystic artery in properly performed critical views of safety and identify the most common patterns.

## Materials and Methods

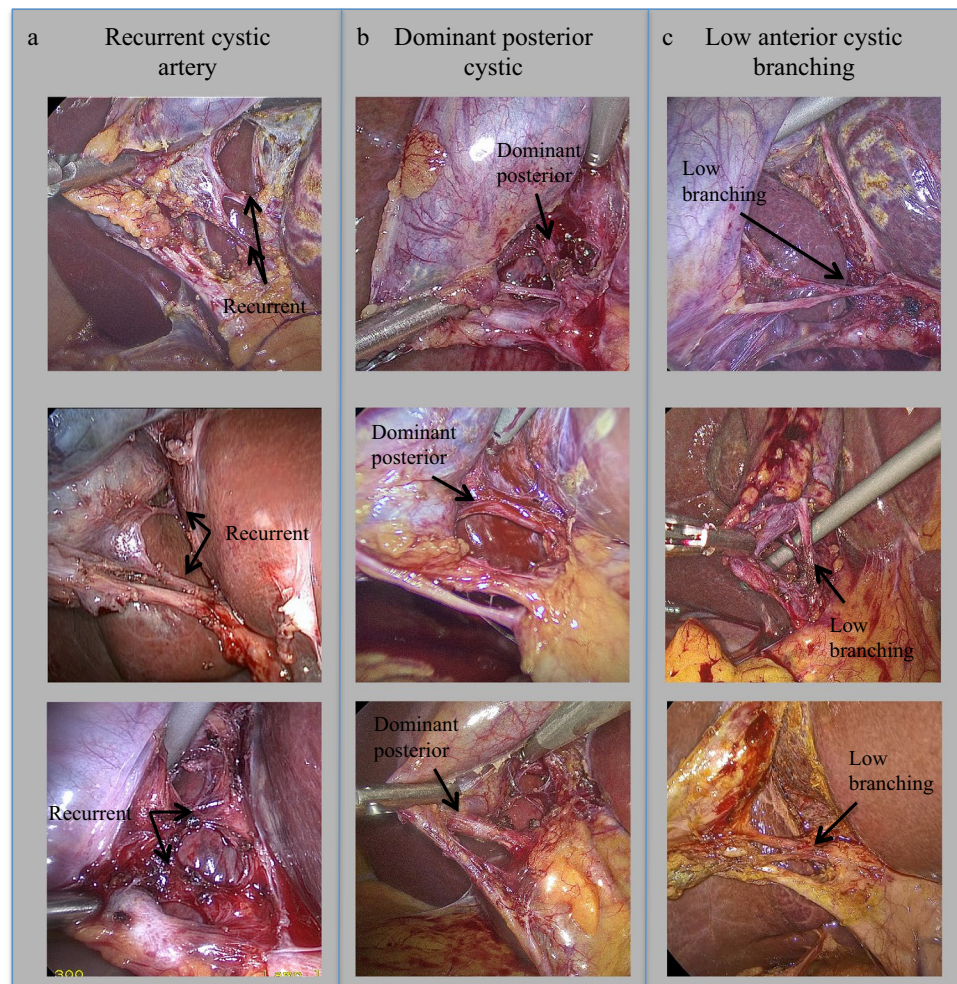
We conducted a prospective observational study from 2018 to 2020, compiling photos of the critical view of safety of 100 consecutive elective cholecystectomies performed at our institution. We continued the study until we were able to collect adequate photos for 100 cases. During each procedure, the gallbladder was dissected up to the parallel portion of the cystic plate in order to achieve the critical view of safety. All tubular structures were carefully preserved and clipped. The operative reports were examined for mention of a posterior cystic artery or an aberrant arterial supply. Similarly, photos of all cholecystectomies were reviewed for an adequate critical view of safety and the presence of an aberrant arterial supply. The rate of aberrant arterial supply was determined and photos were reviewed for patterns of common abnormalities. Our Institutional Review Board deemed this

study exempt (IRB# 18–08–322–337) and waived the need for participant consent.

## Results

We included 100 patients in the study that had intraoperative photos of the critical view of safety. There were 121 patients who underwent an elective cholecystectomy; 21 lacked intraoperative pictures and were excluded from the study (six were subtotal cholecystectomies, one was converted to open, and fourteen had missing photos). There were no bile leaks or bile duct injuries. One patient had a retained stone requiring an ERCP, and one patient had a fatal myocardial infarction within 30 days. Of the 100 patients included, 57 (57%) had an aberrant arterial supply with more than one cystic artery, and 7 had three concurrent arteries. All intraoperative photographs were reviewed, and the most common patterns of multiple vessels were identified. Examples of the most common variations are displayed in Fig. 1. Of those with more than one cystic artery, 21% had a recurrent cystic

**Fig. 1** Representative pictures of aberrant cystic arterial supply. The most frequent patterns of arterial supply when more than one artery was encountered were recurrent cystic artery (a), dominant posterior cystic artery (b), and low anterior cystic branching (c)



artery, 21% had a posterior dominant cystic artery, and 12% had a low-branching anterior cystic artery.

## Discussion

The culture of safety in cholecystectomy is a broad concept that fosters safe practices in cholecystectomy, temporally spanning preoperative evaluation, intraoperative decision-making, and postoperative practices. The aims of the program are to promote safe practices and increase the quality of care through various mechanisms, from specific safety checks and utilization of distinct imaging modalities to bailout procedures. With this goal in mind, a task force was formed in 2014 to develop multi-society consensus guidelines aimed at reducing biliary injuries.<sup>4</sup> A key portion of these guidelines sought to address which surgical method is best to identify the cystic duct and artery, specifically comparing CVS to other techniques such as infundibular, fundus first (top-down), and routine cholangiography. Although there were no direct comparative studies between these techniques, the CVS was deemed the optimal method for delineating biliary and arterial anatomy.<sup>5</sup>

The education and incorporation of the CVS in surgical practice have decreased rates of biliary injuries in laparoscopic cholecystectomy, with a current estimated incidence between 0.1 and 0.3%<sup>6–8</sup> This is crucial, as major bile duct injuries significantly increase morbidity and mortality, and inability to confidently identify anatomy as well as aberrant anatomy is one of the most commonly cited reasons for such biliary injuries.<sup>9</sup> It is for this reason that variations in biliary drainage, as well as vascular anatomy, have been extensively studied and described. Extant vascular studies have focused on describing the origin of the cystic artery and its relation to the common hepatic duct and cystic duct.<sup>9</sup> Most commonly, the cystic artery originates from the right hepatic artery and makes a sharp turn within the hepatocystic triangle. Once the CVS is obtained during laparoscopic surgery, the cystic artery is most commonly identified as superior and deep to the cystic duct. Once it reaches the gallbladder, it splays into a superficial/anterior branch running within the serosal layer of the gallbladder and a deep/posterior branch along the gallbladder fossa.

The incidence of multiple cystic arteries entering the gallbladder ranges in the literature between 1 and 19%.<sup>10–12</sup> Within this anatomic variation, most authors describe visualization of two arteries within the triangle of Calot; however, some do describe a single cystic artery within the triangle with “accessory” arteries arising from either below the cystic duct, entering the gallbladder bed, or along the cystic duct. In our study, we demonstrate that when the dissection of the triangle of Calot is carried up

to the parallel portion of the cystic plate, the incidence of multiple vessels is significantly higher than previously reported. This finding could be in part due to the higher resolution and quality of laparoscopes as well as a more detailed dissection. Other studies, which report a lower incidence of anomalous arterial supply, do not disclose the degree of inflammation or acuity of the cases.<sup>10–12</sup> In a higher acuity or more inflamed setting, we may anticipate a falsely lower incidence of anomalous arterial supply, given surgeons may be less inclined to continue dissecting the cystic artery once it was sufficiently identified for the critical view of safety. In this study, we demonstrate that a more meticulous dissection can lead to the discovery of more vascular structures that can confuse inexperienced surgeons attempting to meticulously achieve a CVS. As a result, we argue for recognition that the CVS may contain more than two tubular structures when multiple arteries are identified, and the critical component is establishing recognition of a single biliary structure. This may be especially imperative in the acute setting or in challenging cases where inflammation and chronic fibrosis can distort normal anatomy or make anomalous anatomy almost unrecognizable. Consequently, a key direction for future studies may be to include both elective and acute cholecystectomies.

Vascular and biliary variations can distort anatomy, prolong surgery, and lead to higher rates of inadvertent injury. Injuries to the cystic duct and artery consequently lead to more frequent conversion to open surgery.<sup>3,13</sup> Although accessory arteries are typically small and can have inconsequential bleeding with proper electrocauterization, it is important for surgeons to be familiar with anomalous arterial anatomy. Appropriate identification prior to transection can ensure that a vessel is properly clipped and bleeding is minimized. Strict adherence to visualizing only two tubular structures for the CVS may result in inadvertent bleeding if an aberrant artery is not properly identified during the dissection.

Our study contributes to the body of literature that supports the culture of safety in cholecystectomy. Evidence shows us that the critical view of safety has greatly improved outcomes in laparoscopic gallbladder surgeries—and while we need to continue cultivating this practice and the culture of safety, we must not grow complacent in our awareness of the variability in human anatomy. Guidelines and protocols exist to augment our cognitive and technical processes, though not replace them. Accessory cystic arteries, or variations of an anterior or posterior cystic artery, can have different origins, be different in size and dominance, can be found in variable locations within the triangle of Calot, and vary in their relation to the cystic duct. As demonstrated by our study, up to 57% of patients can have these variations of the classic anatomy, and strict adherence to isolating only two structures as dictated by the CVS construct may result

in more harm than good in these situations. Appreciation of the most common arterial anomalies can assist surgeons in performing safer surgeries.

## Conclusion

In this study, we highlight the high frequency of cystic artery anomalies in elective cholecystectomies and provide examples of the most common abnormalities. Surgeons should be familiar with this variability and the possibility of multiple cystic arteries while attempting to establish the CVS. Meticulous dissection up to the parallel portion of the cystic plate results in the visualization of additional vascular vessels 57% of the time, posing a challenge to the CVS and its requirement of identification of two and only two tubular structures. With this variability in aberrant arterial anatomy, isolating two structures should not be the only factor in determining a CVS, but a definitive identification of a single biliary structure entering the gallbladder should be the critical step in preventing biliary injury. This study adds to the growing body of literature promoting a culture of safety in cholecystectomy.

## Declarations

**Conflict of Interest** The authors declare no competing interests.

## References

1. Avgerinos C, Kelgiorgi D, Touloumis Z, Baltatzi L, Dervenis C. One thousand laparoscopic cholecystectomies in a single surgical unit using the “critical view of safety” technique. *Journal of Gastrointestinal Surgery*. 2009;13(3):498-503.
2. Connor SJ, Perry W, Nathanson L, Hugh TB, Hugh TJ. Using a standardized method for laparoscopic cholecystectomy to create a concept operation-specific checklist. *HPB*. 2014;16(5):422-429.
3. Ding Y-M, Wang B, Wang W-X, Wang P, Yan J-S. New classification of the anatomic variations of cystic artery during laparoscopic cholecystectomy. *World journal of gastroenterology: WJG*. 2007;13(42):5629.
4. Pucher PH, Brunt LM, Fanelli RD, Asbun HJ, Aggarwal R. SAGES expert Delphi consensus: critical factors for safe surgical practice in laparoscopic cholecystectomy. *Surgical endoscopy*. 2015;29(11):3074-3085.
5. Michael Brunt L, Deziel DJ, Telem DA, et al. Safe cholecystectomy multi-society practice guideline and state-of-the-art consensus conference on prevention of bile duct injury during cholecystectomy. *Surgical Endoscopy*. 2020;34(7):2827-2855.
6. Barrett M, Asbun HJ, Chien H-L, Brunt LM, Telem DA. Bile duct injury and morbidity following cholecystectomy: a need for improvement. *Surgical endoscopy*. 2018;32(4):1683-1688.
7. Fong ZV, Pitt HA, Strasberg SM, et al. Diminished survival in patients with bile leak and ductal injury: management strategy and outcomes. *Journal of the American College of Surgeons*. 2018;226(4):568-576. e561.
8. Strasberg SM, Eagon CJ, Drebin JA. The “hidden cystic duct” syndrome and the infundibular technique of laparoscopic cholecystectomy—the danger of the false infundibulum. *Journal of the American College of Surgeons*. 2000;191(6):661-667.
9. Andall R, Matusz P, Du Plessis M, Ward R, Tubbs R, Loukas M. The clinical anatomy of cystic artery variations: a review of over 9800 cases. *Surgical and Radiologic Anatomy*. 2016;38(5):529-539.
10. Wang X, Shah RP, Maybody M, et al. Cystic artery localization with a three-dimensional angiography vessel tracking system compared with conventional two-dimensional angiography. *Journal of Vascular and Interventional Radiology*. 2011;22(10):1414-1419.
11. Suzuki M, Akaishi S, Rikiyama T, Naitoh T, Rahman M, Matsuno S. Laparoscopic cholecystectomy, Calot's triangle, and variations in cystic arterial supply. *Surgical endoscopy*. 2000;14(2):141-144.
12. Sugita R, Yamazaki T, Fujita N, Naitoh T, Kobari M, Takahashi S. Cystic artery and cystic duct assessment with 64-detector row CT before laparoscopic cholecystectomy. *Radiology*. 2008;248(1):124-131.
13. Fathy O, Zeid MA, Abdallah T, et al. Laparoscopic cholecystectomy: a report on 2000 cases. *Hepato-gastroenterology*. 2003;50(52):967-971.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.