WJPMR, 2025, 11(12), 287-289

Review Article

WORLD JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.wjpmr.com

Impact Factor: 6.842

ISSN (O): 2455-3301

ISSN (P): 3051-2557

Coden USA: WJPMBB

BILIARY SYSTEM ANOMALIES: A SURGICAL PRE-FLIGHT CHECKLIST

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DOI: https://doi.org/10.5281/zenodo.17802221

How to cite this Article: Dr. Lokesh Kumar Tamta1*, Prof. Dr. Ranjit Singh2, Dr. Bhoomi Soni3 (2025). Biliary System Anomalies: A Surgical Pre-Flight Checklist. World Journal of Pharmaceutical and Medical Research, 11(12), 287–289.

Article Received on 05/11/2025 **Article Revised on 25/11/2025** **Article Published on 01/12/2025**

ABSTRACT

Anatomical variations of the extrahepatic biliary system (EHBS) and its associated vasculature are common, presenting a significant hazard during upper abdominal surgery. Failure to recognize these anomalies is the leading cause of iatrogenic bile duct injury (BDI), a major determinant of patient morbidity and mortality.[1] This article reviews the clinically significant anomalies of the gallbladder, bile ducts, and related vessels, emphasizing the critical role of meticulous preoperative imaging and disciplined intraoperative dissection to ensure safe surgical outcomes.[2]

KEYWORDS: Biliary Anomalies, Extrahepatic Biliary System (EHBS), Cystic Duct Insertion, Common Hepatic Duct (CHD), **Iatrogenic Bile Duct Injury (BDI)**, Laparoscopic Cholecystectomy, Critical View of Safety (CVS), Intraoperative Cholangiography (IOC), ***Ducts of Luschka***, Vascular Variations, ***Moynihan's Hump***, MRCP, Surgical Planning.

I. INTRODUCTION: THE PERILS OF THE PORTAL TRIAD

The standard anatomical model of the biliary tree is present in only approximately 60% of the population, highlighting the necessity of an individualized approach to every patient.[3] The embryological complexity of the hepatic diverticulum's development is the basis for the high variability observed in the EHBS.

The region of the Portal Triad (containing the hepatic artery, portal vein, and bile duct) is the focus of surgical risk. Surgeons must consider these anomalies not as rarities, but as expected possibilities, demanding strict adherence to the Critical View of Safety (CVS) throughout any procedure, especially laparoscopic cholecystectomy.[4]

II. Gallbladder and Cystic Duct Variations

Variations involving the drainage of the gallbladder are the most frequent cause of iatrogenic injury.

A. Cystic Duct Insertion Anomalies

Type of Anomaly	Description	Clinical Significance
Low Parallel Insertion	The cystic duct runs sheathed in the same connective tissue as the Common Hepatic Duct (CHD) for a long distance before joining the Common Bile Duct (CBD) distally.[5]	This configuration is the highest risk for Type E BDI (ligation/transection of the CHD/CBD), as the two ducts may be mistaken for a single, broad structure.[6]
High Insertion	The cystic duct joins the CHD very close to the liver hilum, near the confluence of the right and left hepatic ducts.[7]	Limits the length of the cystic duct available for safe clipping and increases the risk of injuring the Right Hepatic Duct (RHD).
Anomalous Union	The cystic duct joins an unusual recipient, such as the RHD or the Left Hepatic Duct (LHD).	Ligation of the cystic duct in this scenario will result in an obstructive injury to the corresponding segmental or lobar duct.

B. Aberrant and Accessory Ducts

-Ducts of Luschka (Sub vesical Ducts): These are small ducts that drain bile directly from the liver bed (often Segment V) into the gallbladder or cystic duct. If cut and not secured, they are a frequent source of postoperative bile leaks.[8]

- Accessory Hepatic Ducts: An extra duct draining a liver segment (most often the right posterior sector) may join the CHD or, dangerously, the cystic duct. If mistaken for the cystic duct and ligated, it leads to segmental biliary obstruction and subsequent liver atrophy.[1]

III. Hepatic Duct and Confluence Variations

Variations in the hepatic duct confluence are critical in planning complex resections or reconstructions.

-Aberrant Right Hepatic Ducts: The most common major ductal variation. The duct draining the right posterior sector may join the LHD, the CHD, or even the cystic duct. This duct is highly vulnerable to injury during dissection in Calot's triangle or hilar lymphadenectomy.[9]

-Intrahepatic Confluence: The junction of the RHD and LHD occurs high within the liver parenchyma, shortening the extrahepatic CHD length. This provides minimal room for safe dissection.

IV. Vascular Anomalies in Calot's Triangle

Unrecognized arterial anomalies present a dual risk: massive haemorrhage and ischemic injury to the remaining bile duct.

Vascular Structure	Anomaly	Surgical Risk/Consequence
Cystic Artery (CA)	Anomalous Origin: May arise from the Common Hepatic Artery (CHA), Left Hepatic Artery (LHA), or Gastroduodenal Artery (GDA).[10]	Unexpected and rapid haemorrhage from an artery in an unusual location.
Right Hepatic Artery (RHA)	"Caterpillar Hump" **(Moynihan's Hump)**:	A tortuous RHA may dip low into Calot's triangle, running close to the cystic duct. The RHA can be mistakenly clipped or coagulated, leading to RHA thrombosis and subsequent ischemic bile duct stricture formation.[2]
Accessory/Replaced Hepatic Arteries	A replaced RHA (from the superior mesenteric artery) or a replaced LHA (from the left gastric artery) may run near the bile ducts.	Damage to a replaced RHA during common bile duct dissection can cause liver ischemia, as this vessel may provide the entire blood supply to the right lobe.[10]

V. Surgical Recommendations and Safe Practices

Given the high frequency of these anomalies, the surgeon must adhere to a rigid framework of safety.

A. Preoperative Planning

- Imaging: For all cases involving complex inflammation, prior surgery, or suspected anomalies, Magnetic Resonance Cholangiopancreatography (MRCP) is crucial for detailed mapping of both ductal and major vascular anatomy.[11]
- High Index of Suspicion: The surgeon must actively search for signs of variability, especially if the anatomy encountered appears unusual.

B. Intraoperative Strategy: Achieving the Critical View of Safety (CVS)

The CVS remains the strongest defence against BDI.[4] All structures must be cleared for clear identification before clipping.

- Clear Dissection of Calot's Triangle: All surrounding tissue must be cleared from the neck of the gallbladder.
- Two Structures Only: The surgeon must confirm that only two structures—the cystic duct and the cystic artery—are entering the gallbladder.
- Visualization of the Main Duct: A portion of the gallbladder must be dissected from the liver bed to reveal the Common Hepatic Duct (CHD) and Common Bile Duct (CBD) lying behind the cystic duct and artery, confirming they have not been pulled up or "tented".[4]
- Intraoperative Cholangiography (IOC): If the CVS cannot be achieved due to inflammation ("white-out"), IOC is mandatory. This radiographic technique visualizes the entire biliary tree, revealing the exact point of cystic duct insertion and the integrity of the main duct.[12]

CONCLUSION

The extrahepatic biliary system is an area of profound anatomical variability. The hallmark of a safe surgeon is not encyclopaedic knowledge of every rare anomaly, but the disciplined, consistent application of safety manoeuvres—particularly the CVS and IOC—to adapt to the anatomy encountered in real-time. Vigilance and the ability to recognize and manage ambiguity are the ultimate safeguards against iatrogenic injury.

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