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# Variations in extra-hepatic biliary tree morphology and morphometry: a narrative review of literature with focus on cystohepatic triangle

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*The morphometry and morphology of the components of extrahepatic biliary tree show extensive variations. A beforehand recognition of these variations is very crucial to prevent unintended complications while performing surgeries in this region. This study was conducted to analyse the configuration of the extrahepatic biliary tree and its possible variations, as well as measure the components that limit the cystohepatic triangle. Articles were searched in major online indexed databases (Medline and PubMed, Scopus, Embase, CINAHL Plus, Web of Science and Google Scholar) using relevant key words. A total of 73 articles matched the search criteria of which 55 articles were identified for data extraction. The length of left and right hepatic duct in majority of studies was found to be > 10 mm. A wide range of diameters of hepatic ducts were observed between 5 and 43 mm. The average length of cystic duct is around 20 mm. The length and diameter of the common bile duct are 50–150 mm and 3–9 mm, respectively. The most frequently observed pattern of insertion of cystic duct into common hepatic duct is right lateral, rarely anterior, or posterior spiral insertion can present. The results of this study will provide a standard reference range which instead will help to differentiate the normal and pathological conditions.* (Folia Morphol 2023; 82, 3: 498–506)

**Key words: extrahepatic biliary tree, cystic duct, morphometry, morphology, cystohepatic triangle**

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## INTRODUCTION

The formation of extrahepatic bile duct is at the hepatic hilum (in proximity with the right end of porta hepatis) by union of left and right hepatic duct, to form common hepatic duct (Fig. 1). The normal length/diameter of left, right, and common hepatic duct is approximately 40 mm/4 mm, 30–40 mm/ /3–4 mm, and 60–80 mm/6 mm, respectively [21, 31]. Further, the lower end of cystic duct joins the right margin of common hepatic duct at an acute angle to form common bile duct (CBD; also known as Choledochal duct). The cystic duct usually measures 20 to 40 mm in length and the diameter of the cystic duct ranging from 1 to 5 mm [47, 52, 55]. Likewise, the length and diameter of CBD is generally varying between, 60 to 80 mm. The average external diameter is 9 mm (range 5–13 mm) and average internal diameter is 8 mm (range 4–12.5 mm) [56].

The evaluation of metrics of these ducts had begun in early 90's. At that point, the measurements were performed manually on autopsy specimens [15, 26]. In the course of time, several reports have attempted to measure these parameters by various techniques such as in cholangiograms [11, 32], vasculobiliary casts [12], sonographically [28], on computed tomography images [41], and recently magnetic resonance cholangiopancreatography (MRCP) [1, 14, 40] is being frequently used for these measurements. Eventually, it has been perceived that the dimensions of these ducts are highly variable as per available literature [1, 4, 7, 8, 11, 12, 14, 15, 26, 28, 31, 32, 40, 43, 44, 46, 48, 54, 57].

In addition, the union of cystic duct into common hepatic duct may have different configuration. The union can be right lateral, anterior spiral, posterior spiral, proximal, distal medial, distal lateral, or into the right hepatic duct. Based on this view, it has been classified [52]. This article attempts to review the existing literature on the variations of extrahepatic part of biliary tree to comprehend the possible cause and risk of post-operative complications of this region. According to the published studies the length and diameter of the extra hepatic biliary ducts may be correlated to the formation of bile duct stones, Mirizzi's syndrome, and bile duct cancer. This narrative review was undertaken to analyse the configuration of the extrahepatic biliary tree and its possible variations (morphological component), as well as collate the quantitative data regarding the components that limit the cystohepatic triangle (morphometric component).

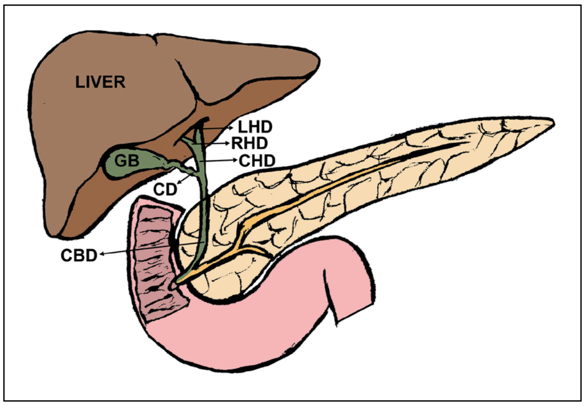


**Figure 1.** Illustration showing normal anatomical configuration of the components of extra-hepatic biliary tree; LHD — left hepatic duct; RHD — right hepatic duct; CHD — common hepatic duct; CD — cystic duct; CBD — common bile duct; GB — gall bladder.

**Table 1.** Inclusion and exclusion criteria used for literature search for the narrative review

| **Inclusion criteria** |
|---|
| 1. Full length original articles (peer reviewed and published) pertaining to morphology and morphometry of extrahepatic biliary tree |
| 2. Studies reporting observational data relevant to the topic of study |
| 3. Articles with information relevant to the study pertaining to any defined population |
| 4. Articles published any time after inception of a database till conduction of literature search |
| 5. Articles in English |
| 6. Articles not in English but with available translations in English |
| **Exclusion criteria** |
| 1. Pre-prints and non-peer-reviewed contents* |
| 2. Case reports and short communications |
| 3. Articles with limited information pertaining to the topic of study |
| 4. Articles not in English and translation in English not available |

*These were excluded as there could be possible changes in the data and the analysis thereof by the time it is published. This can have a confounding influence on data available from peer reviewed contents.

## MATERIALS AND METHODS

Regarding the present study, narrative review was the preferred method as this approach was deemed as ideal to address the diverse aspects of the topic in terms of core concepts, published data, scientific resources and existing knowledge gaps [22]. Moreover, narrative review was found to be suitable in view of the fact that diverse methodologies were followed and taking into consideration the essentially descriptive nature of selected studies [18]. The literature search undertaken for this study was based on inclusion and exclusion criteria that were set after deciding the topic but before conducting literature search (Table 1).

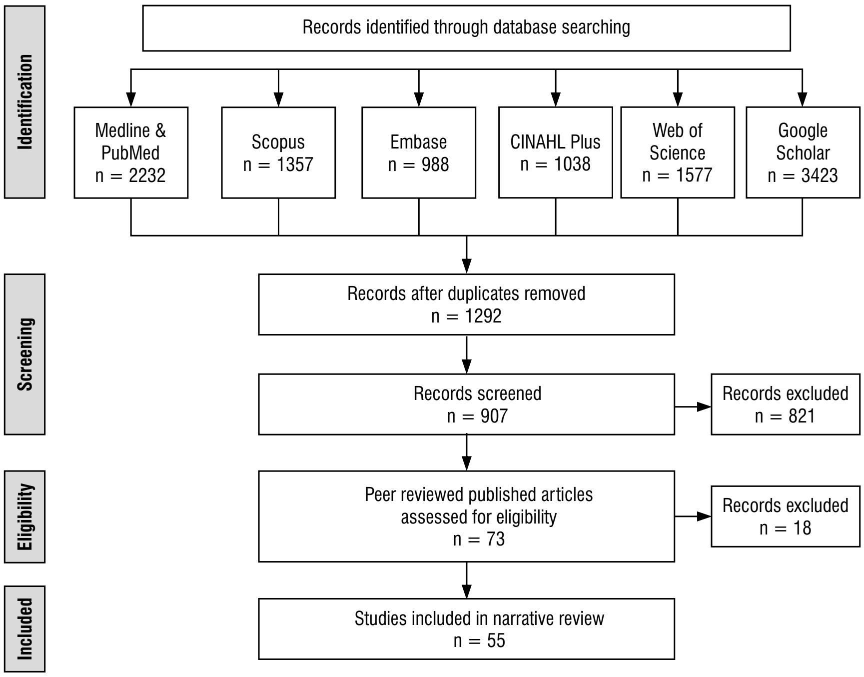


**Figure 2.** Flow chart depicting the literature search process for the present narrative review. The literature search was performed on the lines of searches for a narrative review, while incorporating the methodological rigour of a systematic review. The literature search process followed the best practice recommendations for preparing a narrative review by Ferrari [19] in order to mitigate risk of bias during selection of literature.

The study was conducted between May 2021 and January 2022. An extensive literature search was undertaken for this study from the following indexed databases:
- Medline and PubMed (United States National Library of Medicine, Bethesda, MD);
- Scopus (Elsevier, Amsterdam, The Netherlands);
- Embase (Ovid Technologies, Inc., New York, NY);
- CINAHL Plus (EBSCO Information Services, Ipswich, MA);
- Web of Science (Clarivate Analytics, Philadelphia, PA);
- Google Scholar (Google, Inc., Mountain View, CA).

The above databases were explored as all of them are multidisciplinary databases and provide access to a large volume of peer-reviewed scholarly research.

The literature search was based on key terms which were essentially key words from individual studies and mentioned at the time of indexation of particular research article. The key terms used for the present study were finalised during the course of literature search for finding articles relevant to the topic of present study. Accordingly, the following terms were used during literature search: "morphology of biliary tree"; "morphometry of biliary tree"; "morphology of extra-hepatic biliary tree"; "variations in anatomy of extra-hepatic biliary tree"; "morphology of bile duct"; "morphology of hepatic duct" and "morphology of cystic duct". Although the present study is a narrative review, but in order to mitigate the risk of bias in inclusion process, methodological rigour of a systematic review was incorporated in the literature search process. This was undertaken in accordance with the best practice recommendations for the preparation of a narrative review in clinical research [19]. A total of 55 published articles were identified as appropriate with regards to the topic of the present study (Fig. 2). After completion of literature search, the findings were compiled and final observations were prepared.

## RESULTS

The anatomical variations of extrahepatic biliary duct have been documented since 3000 BC [36]. The surgical anatomy of this region gained importance with the emergence of cholecystectomy in 1882. In no area of the human body are the relationships as described in the text books of anatomy more misleading as to constancy than the region encompassing the extra-hepatic biliary ducts [25].

The variations in the morphometric components and configuration of extrahepatic biliary tree were analysed from available literature. The anatomy of the extrahepatic biliary tree is characterised with frequent aberrations [24]. In the present review it was noted with

**Table 2.** A chronological representation of variations in the morphometry of extrahepatic biliary tree in terms of length and diameter of left (LHD), right (RHD), and common (CHD) hepatic duct as reported in published literature

| Authors [reference] | Sample size | Type of sample | Length [mm] | | | Diameter [mm] | | |
|---|---|---|---|---|---|---|---|---|
| | | | LHD | RHD | CHD | LHD | RHD | CHD |
| Healey and Shroy [26] | 100 | Adult human livers | – | 9 | – | – | – | – |
| Dowdy et al. [15] | 100 | Autopsy specimens | 10 | 8 | 20 | 3.4 | 4 | 8 |
| Counaud [12] | 110 | Vasculobiliary casts | 13.47 | 9 | – | – | – | – |
| Kim et al. [32] | 8194 | Cholangiograms | – | – | – | – | – | Maximal diameter: 6.1<br>Mid-portion diameter: 5.3 |
| Choi et al. [11] | 300 | Cholangiograms | – | 12.8 | – | – | – | – |
| Ayuso et al. [4] | 25 | Live liver specimens | – | < 10 | – | 3–4 | | – |
| Cachoeira et al. [8] | 41 | Cadaver | – | – | 21.76 | – | – | – |
| Deka et al. [14] | 299 | MRCP | 7.83* | 10.06* | 22.05^ | 2.92* | 2.59* | 4.14^ |
| Eftekhar et al. [16] | 150 | Cadaver | 14.75 | 17.15 | 19.91 | 6.61 | 8.63 | 9.75 |
| Awazli [3] | 50 | Human livers | – | – | 25 | – | – | – |
| Khatiwada et al. [31] | 32 | Liver specimens | 20.77 | 10.48 | – | ED = 2.54<br>ID = 1.37 | ED = 3.37<br>ID = 2.1 | – |
| Tellez et al. [54] | 33 | Blocks | 12.6 | 10.3 | 28.6 | 3.1 | 4 | 4.6 |
| Babu and Sharma [5] | 100 | Cadaver | 15 | 13 | 29 | 15 | 16 | 43 |

*Length and diameter measured in 290 out of 299 samples only; ^ Length and diameter measured in 296 out of 299 samples only; MRCP — magnetic resonance cholangiopancreatography; ED — external diameter; ID — internal diameter

**Table 3.** A chronological representation of variations in the morphometry of extrahepatic biliary tree in terms of length and diameter of cystic duct as reported in published literature

| Authors [reference] | Sample size | Type of sample | Cystic duct | |
|---|---|---|---|---|
| | | | Length [mm] | Diameter [mm] |
| Dowdy et al. [15] | 100 | Autopsy specimens | 22 | 3 |
| Cachoeira et al. [8] | 41 | Cadaver | 19.11 | – |
| Eftekhar et al. [16] | 150 | Cadaver | 20.55 | 8.91 |
| Rajguru and Dave [43] | 100 | Cadaver | 2–62 | 2–8 |
| Tellez et al. [54] | 33 | Blocks | 27.8 | 3.3 |
| Sangameswaran [46] | 50 | Cadaver | 29 | – |

interest that there are significant variations in the range of length and diameter of hepatic, cystic, and CBD.

Furthermore, high frequency of aberration in the morphology (branching pattern) of the cystic duct was observed in published literature. Few authors have also classified it into various types based on the mode of insertion of the cystic duct into the common hepatic duct [6, 9, 23, 26, 37, 47].

**Variations in morphometry of extrahepatic biliary ducts**

***Left, right, and common hepatic duct***

The length and diameter of the right and left hepatic ducts constantly fluctuate. Frequently, the right hepatic duct is short, wide and more vertically aligned than the left hepatic duct [15, 31]. The morphometry of hepatic ducts measured and evaluated in the previous studies has been tabulated (Table 2) [3–5, 8, 11, 12, 14–16, 26, 31, 32, 34].

***Cystic duct***

Few authors have found the cystic duct to be as short as 10 mm [38]. In, contrast to that the length of the cystic duct was observed to be > 40 mm in almost 25% cases [34]. The variances in length and diameter of cystic ducts are presented in (Table 3) [8, 15, 16, 34, 43, 46].

***Common bile duct***

Earlier, the deviation in size of CBD has been witnessed in different sample or imaging modalities as represented in (Table 4) [1, 2, 7, 12, 14, 15, 27, 28, 32–35,

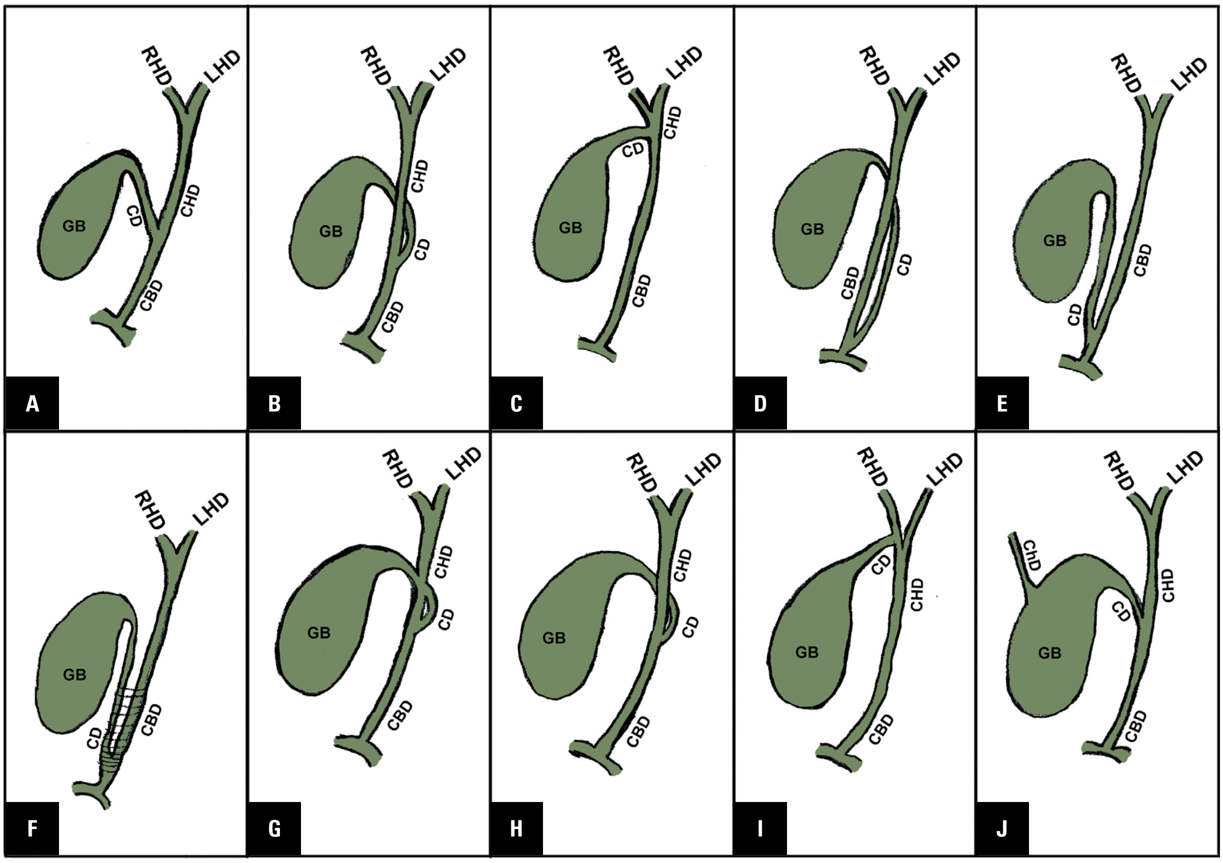


**Figure 3.** Illustration showing variations in the pattern of insertion of cystic duct as reported in available literature; **A.** Right lateral; **B**. Medial; **C**. Proximal; **D**. Low medial; **E**. Low lateral; **F**. Low lateral with common fibrous sheath; **G**. Anterior spiral; **H**. Posterior spiral; **I**. Into left hepatic duct; **J**. Cholecystohepatic duct; LHD — left hepatic duct; RHD — right hepatic duct; CHD — common hepatic duct; CD — cystic duct; CBD — common bile duct; GB — gall bladder.

40, 41, 44, 48, 57]. Additionally, the diameter of the CBD can range as high as 17 mm (average 8.85 mm) [20].

### Classification of the morphology of cystic duct branching pattern

The entry of the cystic duct into the common hepatic duct has an inconsistent pattern. This pattern has been classified in different ways by various authors [6, 9, 23, 47, 52]. Cao et al. [9], 2019 gave a slightly unique classification in which the cystic duct represented three types of patterns (type I: right and angled up, type II: right and angled down, type III: angled up and left). Type I pattern was found to have great variation and could be further divided into three subtypes based on their mode of insertion: linear type, s type (s1, not surrounding CBD; s2, surrounding CBD), and $\alpha$ type ($\alpha$1, forward $\alpha$; $\alpha$2, reverse $\alpha$) by doing retrospective analysis of endoscopic trans papillary cannulation of the gallbladder. The schematic representation of various patterns of cystic duct insertion is shown in Figure 3.

## DISCUSSION

The extra-hepatic biliary tract develops from the hepatic diverticulum (of foregut) at 4 weeks of intra-uterine life. Further, this diverticulum gives rise to pars hepatica and pars cystica. Hepatic ducts develop from pars hepatica and cystic duct develop from pars cystica. The stalk between the hepatic diverticulum and the foregut becomes the bile duct; its Y shaped bifurcation continues as right and left hepatic duct. Alteration in this normal phenomenon leads to developmental (morphological and morphometric) variants.

### Morphometry of extrahepatic bile duct

The standard morphometric range plays significant role in differentiating between normal and pathological conditions. However, the exact morphometry of extrahepatic bile duct is still undetermined pertaining to the excessively varying dimensions observed by researchers in past.

**Table 4.** A chronological representation of variations in the morphometry of extrahepatic biliary tree in terms of length and diameter of common bile duct (CBD) as reported in published literature

| Authors [reference] | Sample size | Type of sample | Common bile duct | |
|---|---|---|---|---|
| | | | Length [mm] | Diameter [mm] |
| Dowdy et al. [15] | 100 | Autopsy specimens | 50 | 6.6 |
| Couinand [12] | | | 80–100 | 5–6 |
| Mahour et al. [35] | | | – | 6.21–8.39 |
| Leslie [33] | | | 9–58 | 5–17 |
| Hollinshead [27] | | | 90 | – |
| Anson and McVay [2] | | | 50–150 | 6–8 |
| Horrow et al. [28] | 258 | Sonographic images | – | 3.5 |
| Kim et al. [32] | 8194 | Cholangiograms | – | Maximal diameter: 6.4<br>Mid-portion diameter: 5.5 |
| Blidaru et al. [7] | 172 | Adults cadavers and human fetuses | 72 | 5.25 |
| Senturk et al. [48] | 604 | Patients | – | 4.16 |
| Deka et al. [14] | 299 | MRCP | 5.1* | Diameter of CBD at upper end: 4.61<br>Diameter of CBD at lower end: 2.88 |
| Peng et al. [40] | 862 | MRCP | – | 4.13 |
| Piyawong and Lekhavat [41] | 277 | CT images | – | 4.65 |
| Tellez et al. [54] | 33 | Blocks | CBD (supra duodenal): 15.5<br>CBD (retro duodenal): 29.3<br>CBD (intra pancreatic): 18.5 | 5.6 |
| Worku et al. [57] | 206 | Sonographic images | – | 3.64 |
| Aljiffry et al. [1] | 325 | MRCP | – | 7.57 |
| Sah et al. [44] | 30 | Cadaver | 46.92 | 6.50 |

*Length measured in 243 samples only, rest 56 was not measurable; CT — computed tomography; MRCP — magnetic resonance cholangiopancreatography

***Left, right, and common hepatic ducts***

The average length of the left and right hepatic duct is 17 mm and 9 mm [5], conforming to which, the length of left and right hepatic duct in majority of studies was found to be > 10 mm (Table 2). The length of common hepatic duct has been measured in various ways using cadavers, magnetic resonance imaging and MRCP. The length of common hepatic duct was seen to range from 19.1 to 36 mm [34]. The length of common hepatic duct was significantly long, i.e. 43 mm [14].

***Cystic duct***

The length of cystic duct often fluctuates from 10 to 50 mm (Table 3). An unusually long cystic duct [13, 30] may be associated with inflammatory changes and formation of calculi, resulting in persistent or recurrent biliary symptoms in affected patients. Too short cystic [3, 30, 34, 42, 47, 50] duct poses difficulty in clip occlusion during laparoscopic cholecystectomy.

***Common bile duct***

The size of the CBD helps to speculate about chances of biliary obstruction. With regard to this, an accurate CBD size reference range should exist [10]. A large number of published studies present the normal size of the CBD. However, an accurate range for CBD size is uncertain till date; therefore, a precise reference range for CBD size would help to distinguish obstructive from non-obstructive causes of jaundice [17]. The diameter of the CBD changes in response to various factors, such as, age, post-cholecystectomy, location of measurement, phase of respiration, and basal metabolic index. After analysing various studies we found the most common range of length was 50–100 mm and diameter to be 5–8 mm (Table 4).

**Morphology of cystic duct**

***Pattern of cystic duct insertion into common hepatic duct***

Cystic duct anatomy was first described in 1654 by Francis Glisson. The mode of insertion of the cystic duct

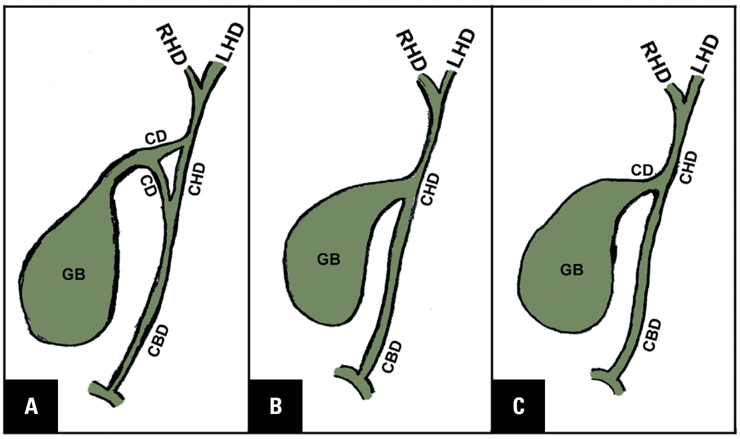


**Figure 4.** Illustration showing variations in the morphology of cystic duct other than its pattern of insertion as reported in available literature; **A**. Bifurcation of cystic duct; **B**. Absent cystic duct; **C**. Short cystic duct; LHD — left hepatic duct; RHD — right hepatic duct; CHD — common hepatic duct; CD — cystic duct; CBD — common bile duct; GB — gall bladder.

in the common hepatic duct varies greatly. The pattern has been classified into several types: right lateral, medial, proximal, low medial, low lateral, low lateral with common fibrous sheath, anterior spiral, posterior spiral, into left hepatic duct (Fig. 3). The most common pattern observed is right lateral insertion [46, 50]. The proximal union of cystic duct with common hepatic duct resulting in short cystic duct [47]. Overlap of the cystic duct on the distal part of CBD is frequently seen with the low medial insertion [39, 55].

A cystic duct has parallel course (in cases of low medial or low lateral insertion). This long, parallel course sometimes is enclosed within a common fibrous sheath around the distal part of cystic duct and common hepatic duct. Therefore, it can be tricky during ligating the cystic duct in close proximity of common hepatic duct as there is risk of stricture formation in the latter post-cholecystectomy. The anterior and posterior spiral insertion may cause misperception during radiographic intervention such as MRCP. In rare situation, cystic duct enters into left hepatic duct [49, 50, 58]. Less commonly, cystic duct may drain into either ampulla of Vater or intraduodenally [46, 49, 55]. Cholecystohepatic duct (Fig. 3) can lead to post cholecystectomy biliary leak if unidentified pre-operatively.

### *Other variants of extrahepatic biliary duct*

Accessory hepatic ducts, especially those arising from the right lobe, may join the common hepatic duct at its junction with the cystic duct or directly into the cystic duct (Fig. 4). Variable numbers of accessory hepatic ducts have been detected [51, 53]. There is high accidental probability of transection of this duct near its insertion into the cystic duct during cholecystectomy [55]. Additionally, few other rare variants can be present such as bifurcation of cystic duct [45] before draining into common hepatic duct or absence of cystic duct [37, 50].

### Limitations of the study

We concede that the present study is a narrative review and therefore has its limitations. Though we have tried to present a comprehensive data on this research topic, but we would imply on further evidence based meta-analysis which would be beneficial clinically.

## CONCLUSIONS

Long cystic duct may be quiet baffling in cross-sectional imaging, which represents the parallel cystic duct and common hepatic duct as a septate cystic structure. Also, it can be cause of displacement of biliary stent. The usual diameter of cystic duct so as to differentiate it from pathological conditions such as dilatation due to passage of gall stone (as in Mirizzi syndrome). Calculus in the low medially inserting cystic duct at the ampulla of Vater may be confused for stones in the distal part of bile duct. Likewise, the other variant pattern should be known beforehand in order to prevent unmanageable unintended injury while operating. The bifurcation of cystic duct is often associated with morphological aberrations elsewhere and the condition is commonly referred to as VACTERL (vertebral defects, anal atresia, cardiac defects, tracheoesophageal fistula, renal anomalies, and limb abnormalities). Looking at the surge in laparoscopic cholecystectomies these variations in the extrahepatic biliary ducts can be dicey if the surgeons are not acquainted well before.

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The authors would like to mention that the studies included in this review are based on findings from dissection of precious human tissues. Therefore, we as authors of this review article are equally grateful to those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase mankind's overall knowledge that can then improve patient care. Therefore, these donors and their families deserve our highest gratitude [29].

**Conflict of interest:** None declared

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