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## Anatomical variations of the cystic duct assessed by magnetic resonance cholangiopancreatography (MRCP): a cross-sectional study at tertiary center of Nepal

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### Abstract

**Introduction:** The cystic duct is a crucial structure that allows bile to flow from the gallbladder to the Common Bile Duct (CBD). Magnetic Resonance Cholangiopancreatography (MRCP) can accurately depict the cystic duct anatomy and its variants which can help surgeons and interventional radiologists tailor their approach to each patient's unique anatomy and reduce the risk of inadvertent bile duct injury. The aim of this study was to evaluate variations of cystic ducts in patients undergoing MRCP.

**Method:** This cross-sectional, prospective study was done in Department of Radiology, Patan Hospital. MRCP of 252 patients done between 1<sup>st</sup> September 2023 to February 2024 were analysed. The three-dimensional MRCP images were visually analysed and categorized as per the study done by Sarawagi et al. Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences)20.

**Result:** MRCP of patient were evaluated out of which were 99(39.29%) were males and 153(60.71%) were females. The most common type was right lateral insertion seen in 120(47.62%) patients and rest of patients having other anatomical variants. Posterior insertion in 36(14.29%) was most commonly seen variant followed by high insertion in 25(9.92%). Right posterior sectoral hepatic duct draining into the cystic duct was the least common.

**Conclusion:** Typical lateral insertion was found in a 47.62% patients and common other variations were also noted in our study. Variations in the cystic duct are not uncommon. This study reinforces the importance of considering anatomical variations of the cystic duct whenever performing surgical, endoscopic and percutaneous procedures.

**Keywords:** Anatomy; Cystic Duct; Magnetic Resonance Cholangiopancreatography; Variation



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## Introduction

The biliary tract consists of intrahepatic and extrahepatic components. The common hepatic duct (CHD) is formed by the union of right and left hepatic ducts at hilar region. Cystic duct is 3–4 cm long with a mean diameter of 4.0 mm, runs posteroinferiorly and to the left to join the right border of lower end of CHD to form the common biliary duct (CBD).<sup>1-4</sup> The biliary system is known for its anatomical variability and are frequently unrecognized.<sup>5,6</sup>

Since laparoscopic cholecystectomy, hepato-biliary surgery, and transcholecystic biliary interventions have become more common, surgeons and interventional radiologists rely on accurate imaging and assessment of the cystic duct.<sup>7</sup> Non-invasive imaging technique that can delineate the cystic duct anatomy prior to any surgery and intervention procedure could be of great clinical significance.<sup>8</sup> Ultrasonography (USG) is a commonly used imaging technique to evaluate the biliary system. However, visualizing the non-dilated cystic duct can be challenging due to its small calibre or being obscured by surrounding structures. To overcome these limitations, MRCP (Magnetic Resonance Cholangiopancreatography) is the preferred imaging technique.<sup>8</sup> Multiple MRCP studies have been carried out for prevalence of normal branching of cystic duct ranging from 22 to 51%.<sup>9</sup> In one of the studies done by Sarawagi et al. in 198 cases, normal branching pattern of cystic duct was seen in 51% cases, whereas 49% cases showed multiple anatomic variations.<sup>9,10</sup> The aim of this study was to find out prevalence of different types of anatomical variation of cystic duct and find out gender specific prevalence of different variants.

## Method

This observational prospective study was conducted in Department of Radiology, Patan Hospital from 1st September 2023 to February 2024 after ethical clearance of the Institutional Review Committee (IRC) of PAHS (Patan Academy of Health Sciences) (Ref: drs2111261581). Total of 252 patients were included in the study based on inclusion and exclusion criteria using convenient sampling technique. Informed consent was taken from the patients before including them in the study. Patients who previously underwent major abdominal surgery altering normal anatomy of cystic duct (e.g. Whipple's surgery, liver transplantation, cholecystectomy) were excluded from the study. Similarly, suboptimal MRI (Magnetic Resonance Imaging) study (such as motion artefacts, inadequate contrast of cystic duct)

were also excluded from the study.

Sample size was calculated based on Cochran's formula at 95% level of significance and allowable error (e) at 5%. The tabulated value of Z at 95% level of significance is 1.96,  $Z^2=(1.96)^2=3.84$ ; prevalence(p)= 0.23<sup>10</sup>, q=100-p=77; e<sup>2</sup>=25. The calculated sample size was 252.

Patients undergoing MRCP of abdomen were scanned with Philips Ingenia 1.5 T MRI in Department of Radiology in coronal, axial and sagittal planes as per the standard protocol. Heavy T2 weighted sequences in multi planar reconstruction was used for the evaluation. The patients were thoroughly screened as per department guidelines for any ferromagnetic material. Freshly crushed pineapple juice was given to the patients prior to the examination. Respiratory triggered T2 SPAIR axial and T2 coronal sequence with slice thickness 5mm including liver and region were obtained. Two dimensional and three dimensional MRCP images using breath-hold thick-slab heavily T2-weighted fat saturated single shot fast spin-echo images centred at CBD covering entire pancreatico-hepaticobiliary system were obtained. Thin collimation axial and coronal images were evaluated for visualization of the extrahepatic ducts. Acquired raw data were processed in workstation and images were evaluated for anatomy of cystic duct in Philips Portal software version 11.

The course, and insertion of cystic duct were documented as described in a previous study.<sup>9</sup> The cystic duct insertion into the CHD is categorized as high or low insertion. High insertion occurs when the cystic duct joins the CHD at its upper third, while low insertion occurs when it joins the CHD at its lower third. The point of insertion can be further described as lateral (to the right of CHD), anterior, posterior, or medial (to the left of CHD). Additionally, a short cystic duct is defined as having a length of less than 5 mm. On the other hand, a long parallel insertion is characterized by a parallel course of the cystic duct with the CHD for a minimum of 2 cm. Variant anatomy that did not match the above types were grouped as other. Prevalence of different variant anatomy and gender wise distribution were calculated with Statistical Package for Social Science software.

## Result

A total of 252 patients were selected. Among 252 patients, 99(39.29%) were males and 153(60.71%) were females. Among these 252 patients, normal lateral insertion of cystic duct (Type I) at middle third

**Table 1. Distribution of different anatomical variant of cystic duct in study population. (N=252)**

Cystic duct and its anatomical variants <sup>9</sup>	Male (%)	Female (%)	Total
I (Right lateral insertion)	51(20.24%)	69(27.38%)	120(47.62%)
II (Spiral course with medial insertion)	6(2.38%)	5(1.98%)	11(4.37%)
III (Low medial insertion)	9(3.57%)	14(5.56%)	23(9.13%)
IV (High insertion)	12(4.76%)	13(5.16%)	25(9.92%)
V (Anterior insertion)	2(0.79%)	16(6.35%)	18(7.14%)
VI (Posterior insertion)	12(4.76%)	24(9.52%)	36(14.29%)
VII (Parallel course of cystic duct)	5(1.98%)	4(1.59%)	9(3.57%)
VIII (Short cystic duct)	0(0.00%)	4(1.59%)	4(1.59%)
IX (Cystic duct draining into the right hepatic duct)	0(0.00%)	2(0.79%)	2(0.79%)
X (Right posterior sectoral hepatic duct draining into the cystic duct)	1(0.40%)	0(0.00%)	1(0.40%)
XI (Others)	1(0.40%)	2(0.79%)	3(1.19%)
Total	99(39.29%)	153(60.71%)	252(100.00%)

of CHD was seen in 120(47.62%) cases out of which 69(27.38%) were female and 51(20.24%) were male. Posterior insertion was seen in 36(14.29%) cases. Low insertion of cystic duct was noted in 23(9.13%) cases. Spiral course with medial insertion (type II) was seen in 11(4.37%) patients. Low medial insertion (Type III) was seen in 23(9.13%) cases. High insertion (Type IV) was one of the common variants seen in current study that included total of 25(9.92%) patients. Type V variant (anterior insertion of cystic duct) was present in 18(7.14%) patients out of which were 16 were females and 2 were males. Total of 36(14.3%) patients had this posterior insertion. Parallel course of cystic duct (Type VII) was present in 9(3.57%) cases. Short cystic duct (Type VIII) was seen in 4(1.59%) patients. In 2(0.79%) of our cases, cystic duct was draining into the Right hepatic duct. Aberrant right posterior sectoral bile duct (Type X) draining into cystic duct was noted in 1(0.40%) case.

There were 3(1.19%) patients had different anatomic variation that were not included by Saragawi, et al.<sup>9</sup> Among the three patients, one patient had fusiform dilatation of cystic duct associated with choledochal cyst and two patients had cystic duct draining directly into the duodenum, Table 1.

## Discussion

The anatomy of the cystic duct is characterised with frequent aberrations and it has also been seen in our current study. During the first four weeks of embryogenesis, the hepatic diverticulum gives rise to the pars cystica and pars hepatica that forms extra hepatic biliary tract which ultimately forms cystic and hepatic ducts respectively. The bile duct emerges from the stalk connecting the hepatic diverticulum to the foregut as the left and

right hepatic ducts take on a Y shape. Variations in development can occur due to changes in this process.<sup>11</sup>

Various study involving both cadaveric and radiological study in different population have shown different frequency of anatomical variant of cystic duct.<sup>8,12</sup> Current study reveals a higher proportion of females compared to males. This distribution was similar to the study done by Karki et al. in Dhulikhel Hospital and suggested this might be because of the high incidence of cholelithiasis and choledocholithiasis among the middle-aged female.<sup>12</sup> There is a lack of uniformity and standardization in the classification of cystic duct variation among different populations. Study done by Sarawagi et al. among 198 patients with MRCP showed normal anatomy in 51.5% and variant anatomy in 48.5 %. Among the variant posterior insertion was the most common type seen in 20.2% of cases and low insertion seen in 9% which was similar to our study. Low parallel insertion was seen in 7.5% cases whereas high insertion, short cystic duct and cystic duct draining into right hepatic duct were least common seen in 6%, 1% and 0.5% of cases respectively.<sup>9</sup> In contrast to our study, the prevalence of spiral course with medial insertion was seen in higher number of cases (16.1%)

Another MRCP study done in Turkey by Taştemur et al. among 930 patients, showed most common variation was lateral insertion in 372(40%), medial insertion in 226 (24.3%), and high insertion in 137(14.7%).<sup>13</sup> The main difference was in cases of medial insertion, with a prevalence of 24.3% compared to 4.37% in our study. Onder et al. studied biliary tract variations in 590 patients. Among them, 239 (39%) had variations, including medial insertion

of the cystic duct (9.8%), distal medial insertion (6.8%), short cystic duct (1.7%) and duplicate anatomic variations (7.2%) which was similar to our study.<sup>14</sup> However, no cases of duplication were seen in our study. Another retrospective study done by Al-Muhanna et al. among 150 patients showed normal anatomy in 72% of population which was higher than our study.<sup>15</sup> In contrary to our study, retrospective MRCP study done by Swain et al. among 1038 cases showed posterior insertion (42.8%) was more common than right lateral insertion (39.3%).<sup>16</sup>

Dating back to 3000 BC, there are historical records available that detail the anatomical variation within the extrahepatic biliary channel. Francis Glisson's publication in 1654 AD marked an important milestone as it provided the first comprehensive description of the anatomy of the cystic duct. The significance of this area's surgical anatomy grew with the rising popularity of cholecystectomy in 1882 AD.<sup>17</sup> With increase in laparoscopic cholecystectomies it becomes crucial for surgeons to have a good understanding of variations in the extrahepatic biliary ducts beforehand. Although cystic duct variations do not contraindicate cholecystectomy, accurate pre-operative identification is crucial to prevent bile duct injury and post-surgical complications.<sup>18</sup> Percutaneous biliary interventions through the cystic duct have gained significant attention in recent times. Failure to correctly identify the ductal anatomy, especially in the presence of anatomical variant, is a major contributing factor to bile duct injuries. Having prior knowledge about the morphology and variations of the cystic duct would greatly aid in planning and minimizing complications during surgical, endoscopic and percutaneous procedures.<sup>19</sup>

The three most common and clinically significant variants are low medial insertion, parallel course of the cystic duct and short cystic duct.<sup>20</sup> In previous studies, it has been reported that 8 to 11% of cases exhibit a low medial insertion of the cystic duct, where it joins the extrahepatic bile duct from the medial aspect near the ampulla of Vater. Among our cases, 9.1% showed this low medial insertion. The presence of a low insertion of the cystic duct has been associated with a higher rate of formation and recurrence of CBD stone. It is important to note that failure to detect this variant may lead to unintentional cannulation into the cystic duct instead of the common bile duct during ERCP. Similarly, confusion between cystic duct stones and stones in the distal bile duct can occur in patients presenting with distal CBD obstruction or gallstone pancreatitis. Failure to identify this variant during

ERCP could lead to confusion with common bile duct or pancreatic duct.<sup>21</sup> Dissecting the medial cystic duct up to its end is considered risky, so leaving a long remnant is advisable during surgery.<sup>22</sup>

Long, parallel course has been observed in 1.2-25% of the population, with the ducts showing a parallel course for at least 2 cm and surrounded by a common fibrous sheath.<sup>2</sup> In our study, this variation was noted in 3.57% of patients. When a patient has a long parallel cystic duct and medial insertion, the cystic duct is often left behind after cholecystectomy. However, this can lead to complications such as inflammatory changes and calculus formation, resulting in post cholecystectomy syndrome. If this variant is not recognized, there is a risk of mistaking the extrahepatic bile duct for the cystic duct, increasing the risk of accidental ligation or injury and also increases risk of strictures. Additionally, it can cause displacement of a biliary stent.<sup>23</sup>

Short cystic duct can complicate the process of clipping during laparoscopic cholecystectomy.<sup>24</sup> This uncommon but significant variation increases the risk of biliary damage, with previous research done by Sarawagi et al showing a prevalence of 1.0%.<sup>9</sup> We also observed this variant in 4 cases (1.59%). When surgeons attempt to locate the cystic duct by pulling on the gallbladder during surgery, the presence of a short cystic duct may cause the common hepatic duct or common bile duct to be tented, leading to injury or unintended clamping of these ducts.<sup>25</sup>

In addition, we identified 6 cases (total 2.38%) with rare but clinically significant variant. The anomalous drainage of the cystic duct into the right hepatic duct is a rare occurrence, with reported cases in only 0.3% to 0.4%.<sup>26</sup> We have encountered two such instances where we found the cystic duct draining into the RHD, and one case where an abnormal intrahepatic duct was draining into the cystic duct. Failing to recognize a cholecystohepatic duct before surgery can result in biliary leakage after cholecystectomy.<sup>25</sup> In rarer cases, the cystic duct might empty into the ampulla of Vater or intraduodenally which was seen in 2 of our patients. Apart from this variant anatomy described our study showed 1 case of fusiform dilatation of cystic duct. The classification by Todani et al. does not include cysts that affect the cystic duct but isolated cystic malformation and dilatation of the cystic duct have been reported in combination with other types of choledochal cysts.<sup>27,28</sup>

Specific anatomical variation may require adjustments to the surgical technique. For example, if the cystic duct empties into the left side of the common hepatic duct, it is risky to dissect it up to the left side of the common hepatic duct. Therefore,

it is recommended to leave a longer portion of the cystic duct intact.<sup>9</sup> The occurrence of two cystic ducts with a single gall bladder is extremely rare and is associated with an increased risk of complications during laparoscopic cholecystectomy. In our study, we did not encounter such variants.

Limited studies are available comparing the gender specific differences. Studies have examined cystic duct variation in different ethnic populations, but there is limited data on gender-specific differences. The discrepancy in the proportion in variant anatomy among the various studies might be because of the sample population and ethnicity. A study by Rahmat et al revealed a nearly equal distribution of normal anatomical configurations between males and females.<sup>29</sup> In our study, normal lateral insertion (Type I) and anterior insertion (Type V) was observed more in females than in males. Conversely, other variants were found to be have near equal distribution. Given the limited sample size and lack of other similar research, it is important to conduct more extensive studies with larger and varied samples to draw conclusive findings on gender specific disparities.

The region surrounding the extra-hepatic bile ducts is well-known for its intricate nature and variability in anatomy, which presents a fascinating and challenging topic in human body at same time.<sup>30</sup> Various imaging techniques like ultrasonography, Computed Tomography (CT), Endoscopic retrograde cholangiopancreatography (ERCP), percutaneous transhepatic cholangiography (PTC), T-tube cholangiography, MRCP, and cholescintigraphy can be used for evaluation of biliary system. Ultrasound (USG) is a commonly used imaging technique to evaluate the biliary system. However, visualizing the non-dilated cystic duct can be challenging due to its small calibre or being obscured by surrounding structures.<sup>31</sup> In one series involving the intra operative cholangiography (IOP) conclusive results in 57% of cases only and hence not routinely performed.<sup>32</sup> To overcome these limitations, MRCP is considered as principal imaging modality. MRCP has a reported accuracy of 94.8% % as compared to CT and USG for detecting the anatomical variants.<sup>33</sup> Research has demonstrated that preoperative MRCP plays a crucial role in providing valuable information about cystic duct anatomy in cross-section and three-dimensional reconstruction images of biliary tree and significantly enhances the safety of laparoscopic cholecystectomy and also for medico-legal purposes.<sup>8,9</sup>

One of the drawbacks of our study is the inability to compare our findings with those obtained through ERCP or intraoperative cholangiography.

Also, patients with suboptimal MRCP images or pathology distorting the cystic duct anatomy were excluded from the study although which increases the sensitivity of our findings, the specificity of the study may have been compromised. We must be careful to extrapolate it in the community since the study is a hospital-based study in a small sample size. Thus, some more studies are required to demonstrate to draw conclusive gender specific disparities.

### Conclusion

There is significant variability in the anatomy of the cystic duct and was seen in 52.38% of study population. Type I and V were seen more in females; rest of the variation was seen in almost equal distribution. MRCP is a valuable tool for assessing anatomy, variations, pathology in these systems.

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### Conflict of Interest:

None

### Authors' Contribution:

All authors contributed equally to the study.

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