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Original Article

Anatomy Section

The Morphological Aberrations of Cystic Duct and its Clinical Significance: A Gross Anatomical Study

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ABSTRACT

Introduction: The Cystic Duct (CD) serves as a thorough fare for transport of bile to and away from the gallbladder. It is about 2-4 cm in length and 1-5 mm in diameter, and joins the Common Hepatic Duct (CHD) at its right lateral aspect, in the middle third to form the Common Bile Duct (CBD). A large number of variations are seen in its anatomy which is either due to aberrations during its developmental process or a result of underlying pathology.

Aim: To study the length, diameter, course, site and level of insertion of the CD. Presence of any other anomaly was also looked into.

Materials and Methods: This study was undertaken on one hundred specimens of liver along with entire extra hepatic biliary apparatus, in the Department of Anatomy, Jawaharlal Nehru Medical College, Sawangi (Meghe), Wardha, and Subharti Medical College, between 2008 to 2013. Total 100 cadavers considered for the study. The morphology of CD was studied with respect to its length, mid length diameter, course, site and level of insertion and the presence of other anomalies

Results: In 99 (99%) specimens the CD joined the CHD and in one (1%) it joined the Right Hepatic Duct (RHD). The length of the CD was found between 0.2 cm to 6.2 cm. The mid-length diameter of the CD ranged from 0.2 cm-0.8 cm. The course of CD was angular in 53 (53%), parallel in 23 (23%), spiral in 24 (24%) specimens. The site of insertion in 76 (76%) specimens, was right lateral, in 4 (4 %) it was anterior, in 15 (15%) it was posterior and in 5 (5%) was left medial. A tubular channel was seen arising from the wall of the gallbladder and draining into CHD above the opening of the usual one.

Conclusion: Important variations were found which are significant from the surgical point of view, especially as there is a surge in laparoscopic cholecystectomies and other minimally invasive procedures in the recent era.

Keywords: Angular, Parallel, Spiral, Tubular

INTRODUCTION

The Cystic Duct (CD) connects the gallbladder to the extra hepatic bile duct usually the CHD. It serves as a thorough fare for transport of bile to and away from the gallbladder. Classically, it is about 2-4 cm in length and 1-5 mm in diameter [1-3] and has a tortuous course. It joins the CHD at its right lateral side, in the middle third of the combined lengths of extrahepatic bile ducts (CHD+CBD) to form the CBD, but the junction might occur anywhere between the porta hepatis and the ampulla of Vater. The CD forms one of the boundaries of the cystohepatic triangle of Calot, a very important surgical landmark with respect to cholecystectomy, wherein the cystic artery and CD are ligated along with the removal of gallbladder [4]. Its endoluminal surface shows numerous mucosal projections known as the spiral valves of Heister, which are typical of the CD. Usually, the normal CD is not seen during ultrasonography or axial computed tomography [5,6]. However, with advanced techniques, it may be seen as an anechoic tubular channel between the gallbladder and bile duct [1].

Variations of the CD anatomy are found occurring in 18-23% of cases [1,7-10]. These variations are usually of little consequence, but a surgeon needs to be aware of them in lieu of the numerous invasive procedures performed in this region. The CD is also involved in many disease processes, such as the calculus disease, Mirizzi syndrome, duodenal fistula, biliary obstruction, primary sclerosing cholangitis, neoplasia, metastatic invasions from adjacent malignancies etc., [1].

MATERIALS AND METHODS

This prospective observational study was carried out in Department of Anatomy at Jawaharlal Nehru Medical College, Sawangi (Meghe), Wardha and Subharti Medical College, Meerut, India, during the five year period i.e., 2008-2013, with the aim to ascertain the anatomy of the CD, with respect to

its length, mid length diameter, course, the site and the level of its insertion and presence of other anomalies. Necessary permission was obtained from the institutional ethical committee before the commencement of the study. Cadavers with a history of abdominal surgery and crush injury to the abdomen were excluded from the study.

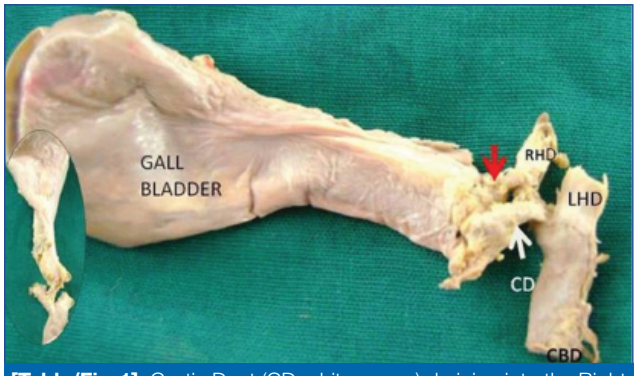
Total 100 cadavers considered for the study. The relationship of the CD with respect to the liver, gallbladder and extra hepatic bile ducts, pancreas and the duodenum were at first studied in situ and then removed en masse from the 10% formalin fixed cadavers (age 40-75 years) during routine undergraduate dissection. After washing with clean water, fine dissection was done to expose the detailed morphology of the CD in relation to the surrounding structures. The length was measured by using a measuring tape. The mid length diameter was noted using a measuring tape and callipers. The course of the CD was carefully followed from its beginning to its insertion. A magnifying lens was used to visualise the details. Photographs were taken as and when required. Observations were tabulated, interpreted and analysed and presented accordingly.

RESULTS

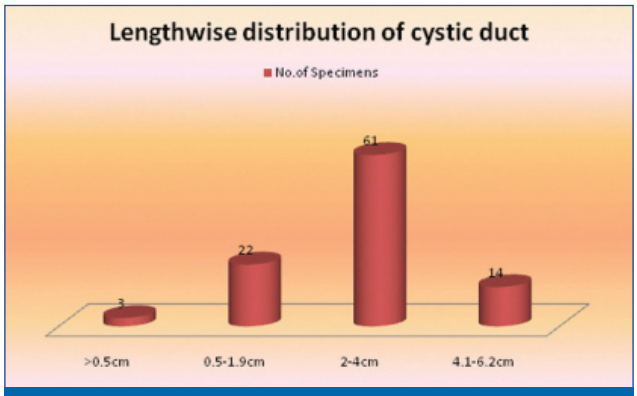
The morphology of CD was studied with respect to its length, mid length diameter, course, site and level of insertion and the presence of other anomalies. In 99 (99%) specimens the CD joined the CHD; in one (1%) it joined the Right Hepatic Duct (RHD) [Table/Fig-1]. Hence, in 99 specimens, the two of morphological parameters, course and site of insertion were studied with respect to CHD and in one with respect to RHD.

1) Length-Length of the CD was found to be ranging between 0.2cm to 6.2 cm. The shortest CD was 0.2 cm and the longest was 6.2 cm in length. The lengthwise distribution is given in [Table/Fig-2]

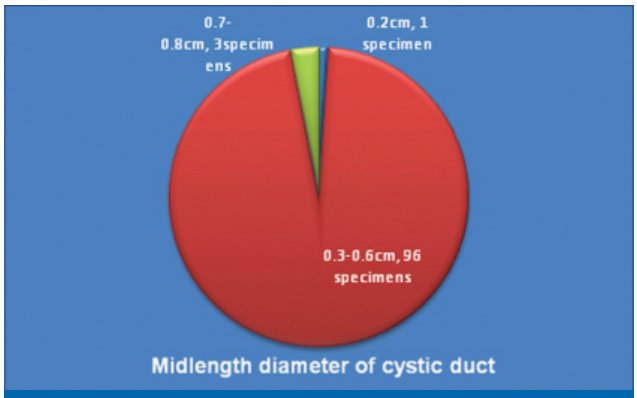
2) Mid length diameter-The mid length diameter of the CD ranged from 0.2 cm-0.8 cm and its distribution is shown in [Table/Fig-3].



[Table/Fig-1]: Cystic Duct (CD-white arrow) draining into the Right Hepatic Duct (RHD). The red arrow shows blood vessel which was parallel to CD (LHD-left hepatic duct).



[Table/Fig-2]: Lengthwise distribution.



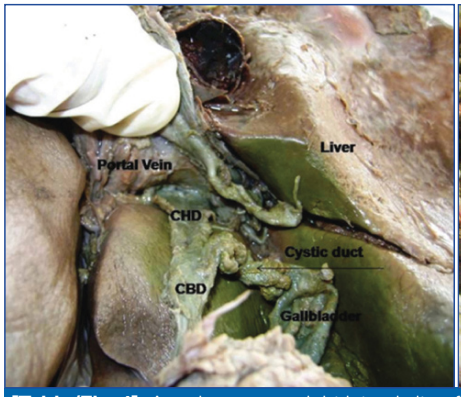
[Table/Fig-3]: Mid length diameter of cystic duct.

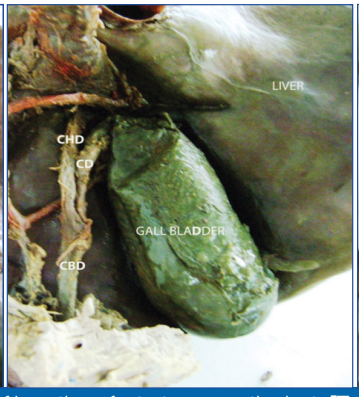
3) Course-Course of the CD was found to be either angular [Table/Fig-4], parallel [Table/Fig-5], or spiral [Table/Fig-6]. The observations are tabulated in [Table/Fig-7]. Out of the 23 specimens where the course was parallel, in four the CD and CHD were encased by a fibrous sheath. In another two specimens with the spiral course, the CD first spiraled backwards and then ran parallel to the CHD before draining into it.

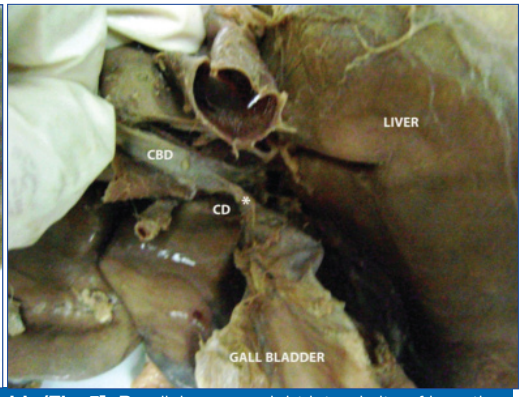
4) Site of insertion-The site of insertion of the CD was right lateral [Table/Fig-4 and 5] as found in 76 specimens, anterior [Table/Fig-6] in 4 specimens, posterior [Table/Fig-8] in 15 specimens and left medial [Table/Fig-9] in 5 specimens. The distribution is shown in [Table/Fig-10].

5) Level of insertion-The level of insertion of the CD was studied with respect to the first part of the duodenum and divided into three categories, i.e., supraduodenal, retroduodenal (behind the first part of duodenum) or infraduodenal. The correlation of site of insertion with the level of insertion [Table/Fig-11].

Out of 72 supraduodenal specimens with right lateral as the site of insertion, 34 had angular and 19 had a parallel course. All the four retroduodenal and infraduonenal specimens with the right lateral site of insertion had a parallel course with respect to CHD. Out of the seven specimens where the CD joined the CHD below the duodenum, three had their confluence inside the substance of the pancreas i.e. intrapancreatic [Table/Fig-



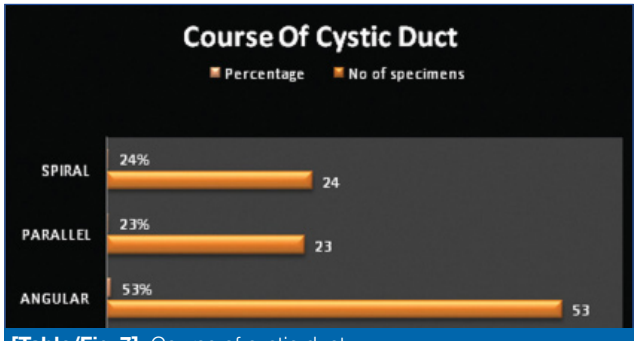




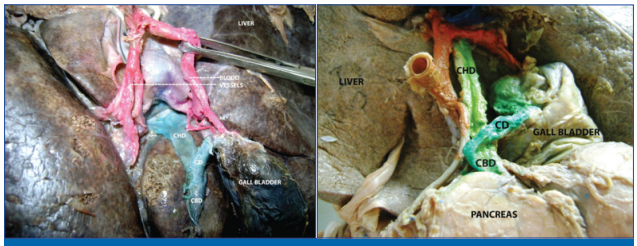
[Table/Fig-4]: Angular course, right lateral site of insertion of a tortuous cystic duct. **[Table/Fig-5]:** Parallel course, right lateral site of insertion of cystic duct. **[Table/Fig-6]:** Spiral course anterior insertion of the cystic duct.

12], whereas four specimens had their confluence posterior to the pancreas, below the first part of the duodenum.

6) Other anomalies-In one specimen a narrow tubular structure [Table/Fig-13] was seen rising near the neck of the gallbladder and draining into the CHD, the opening of which was 2 cm above than that of the normally draining CD. This tubular patent channel was 3.2 cm in length, 0.3 cm in diameter and did not have any spiral valves. Its opening on the interior of the gallbladder wall could not be made out, Whereas, that on the



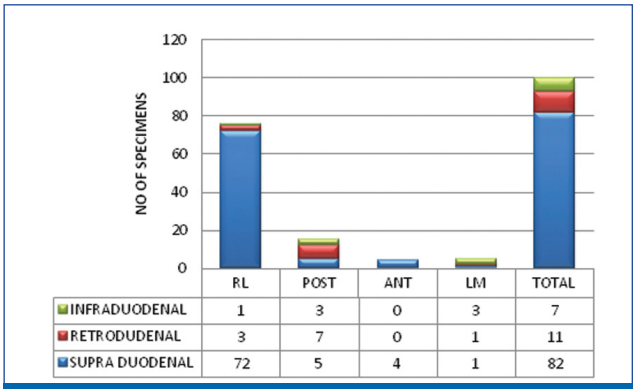
[Table/Fig-7]: Course of cystic duct.



[Table/Fig-8]: Spiral course, posterior insertion of cystic duct. **[Table/Fig-9]:** Spiral course -left medial insertion of cystic duct.

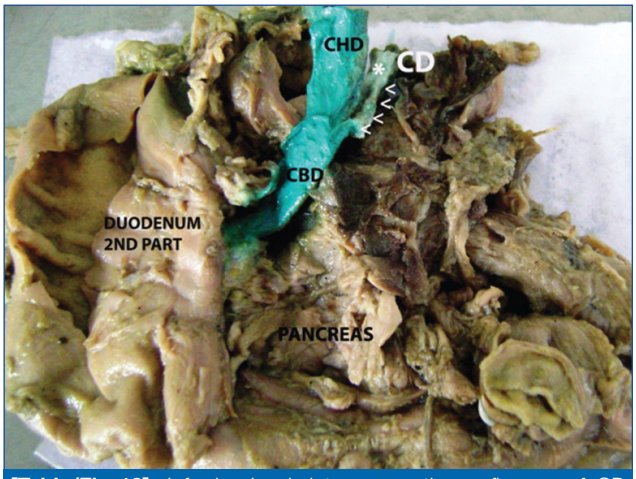
Site of Insertion	No. of Specimens	Course
Right Lateral	76	53 Angular+23 Parallel
Anterior	4	Spiral
Posterior	15	Spiral
Medial	5	Spiral

[Table/Fig-10]: Site of insertion with respect to course of cystic duct.



	RL	POST	ANT	LM	TOTAL
INFRADUODENAL	1	3	0	3	7
RETRODUDENAL	3	7	0	1	11
SUPRA DUODENAL	72	5	4	1	82

[Table/Fig-11]: Correlation of site of insertion with level of insertion of cystic duct.

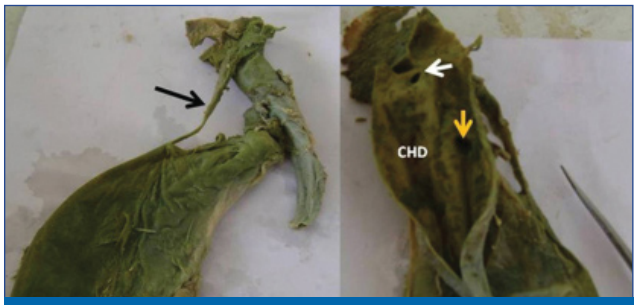


[Table/Fig-12]: Infraduodenal, intrapancreatic confluence of CD and CHD.

CHD was patent. The interior of the gallbladder did not show any septations. CD draining into the RHD has already been mentioned.

DISCUSSION

The complexities in the anatomy of the CD like alterations in length, diameter, course, site of insertion, drainage, etc., are associated with resistance of bile flow from the gallbladder. It



[Table/Fig-13]: Tubular channel connecting the gallbladder to CHD (Black arrow), white arrow opening of tubular channel, yellow arrow - opening of usual CD in lumen of CHD.

predisposes the CD and the gallbladder to lithogenesis, and clinically presents as abdominal pain, which is a component of the CD syndrome [11]. These variations, irrespective of whether they are congenital or acquired, make the CD and other ducts and vessels susceptible to injuries. The congenital anomalies of the CD could be attributed to the aberrations or arrest in the development process during prenatal life.

The liver, gallbladder and the biliary ductal system develop from the endodermal hepatic diverticulum of the foregut, in the fourth week of development. The rapidly proliferating endodermal cells invaginate the septum transversum, and divide into two parts-the cranial one i.e., pars hepatica, the primordium of the liver and bile ducts, and the caudal part i.e., pars cystica, the primordium of the gallbladder. The pedicle of pars cystica becomes the CD. The stalk between the hepatic diverticulum and the foregut becomes the bile duct; its Y shaped bifurcation continues as right and left hepatic duct. Initially, it was thought that the biliary ducts were patent in the early prenatal life, becoming solid thereafter with subsequent recanalisation [12]. Recent studies reveal it to be patent and in continuity with the developing liver from the very beginning. Notch, Wnt, sonic hedgehog and transforming growth factor β3 cell signalling pathways play an important role in the development of the liver and biliary apparatus [12]. *Lgr4* gene has been found to be particularly responsible for the development of the gallbladder and CD [13] in hypomorphic mice.

The comparison between the findings of eminent researchers can be ascertained from [Table/Fig-14]. Variations in the lengths of the CD have been reported in literature ranging from absent CD [8,10,22] to short [3, 10,14,16,17,20-22] to long CDs [3,10,11,14,16,17,20-22]. The length of the CD is directly related to its level of the confluence with CHD [4,19]. Short CD i.e., length less than 0.5 cm or absent CD is a rare occurrence, resulting from delay or arrest of development of the proximal part of the pars cystica [8,23]. It needs extra attention at surgery, as it may lead to the tenting of CBD or CHD, while visualising the gallbladder [3]. Both the variants are liable to get easily injured in surgery [3,24]. Cystic hypertrophy is said to be there when the diameter exceeds 5 mm [2]. Longer and narrower CDs are more likely to develop calculus disease [11]. The CD may undergo secondary dilatation due to the passage of gallstone/calculus as seen in "Mirizzi syndrome" [8] conversely dilated CDs assists in instrumentation during various minimally invasive procedures [25]. The instances of increased diameter as seen in this study were probably due to the associated loss of tone in the tissues seen after death, as no calculi were found in any of the specimens in any part of the biliary tree.

The course of the CD with the CHD is possibly related to the rotation of the duodenum and development of the head of the pancreas during the prenatal life [23,26]. The angular/oblique course has been found to be the most common one seen across the globe as shown in [Table/Fig-15]. Parallel CD is one that runs parallel to the CHD for a minimum of a 2 cm segment of its length [2,3]. Long parallel CDs covered by a fibrous sheath [1,3,5,6,27,28] may lead to mis-identification of the ducts and vessels during imaging studies, thereby resulting in iatrogenic injuries during laparoscopic cholecystectomies. A case of a long parallel CD with a malpositioned biliary stent has been cited in the literature [29]. The CD is usually inserted in the right lateral aspect of CHD (junction) after an angle or parallel course, as found in most studies [1,3,5,20,23]. Spiral CDs [3,5,7,20,30] especially the low medial ones are considered ominous as they often complicate the therapeutic procedures due to confusing imaging interpretations. A spiral CD is more often than not superimposed on the extrahepatic bile duct and calculi in it could be mistaken for that in the CBD. Such a case often makes it difficult to cannulate during invasive procedures [1].

In the present study most of the CDs (82%) joined the CHD above the first part of duodenum i.e., at supraduodenal level. Very high CD insertion was observed in three cases out of which in one it had an anterior spiral insertion, in the other it joined the CHD just below the confluence of the right and left hepatic ducts and in the third it drained into the RHD. CD draining into the RHD can lead to inadvertent ligation of CHD during cholecystectomies and subsequent development of strictures [2]. There is also a possibility of mistaking the RHD or a blood vessel for the CD and therefore dividing and ligating the former during the process [4]. In a study in Ethiopia [19] supraduodenal level of insertion was seen in 44 % and infraduodenal at 52% and in three cases it drained directly into the duodenum.

Intrapancreatic confluence has been rarely reported in the literature [31,32]. They stand at risk of developing the Mirrizi syndrome [31]. Long CDs with low junction have a propensity for recurrence of stone besides presenting difficulties in surgery due to the long and convoluted course [1,3].

A small channel connecting the gallbladder with the CHD was found wherein its lumen in the CHD was patent but that in the gallbladder was obliterated. It is presumably an accessory CD wherein there was a partial failure of recanalisation, subsequent

S.no.	Study	Type of study	Range of length (cm)	Short CD%	Long CD%	Confluence with CHD/RHD/ LHD/Duodenum	Absent CD
1.	Sawaragi R et al., [3]	MRCP	-	1	7.5	All CHD except RHD-0.8%	-
2.	Cachoera E et al., [4]	Cadaveric	0.7-3.9cm	-	-	All CHD except LHD-1 case	
3.	Khan AS et al., [10]	Surgery		2.3	1.7	All CHD except RHD-1.7%	1.33
4.	Deenitchin G et al., [11]	ERCP	0.9-4.8	-	6	All CHD	-
5.	Talpur KAH et al.,[14]	Surgery	-	2.67	1	All CHD	
6.	Nahar N et al., [15]	Cadaveric	2.43-2.91			All CHD	
7.	Awazli LG et al., [16]	Cadaveric		2	5.3	All CHD	
8.	Qamar N et al., [17]	Laparoscopy	Normal-85.7	6.3	3.7	All CHD	-
9.	Pina L et al., [18]	Cadaveric	0.8-3.4	-	-	All CHD	-
10.	Ambaye A et al., [19]	Cadaveric	1.3-8cm	-	-	All CHD, except 3 cases-draining to the duodenum	-
11.	Talpur KAH et al., [20]	Surgery	-	26.76	17.86	All CHD except RHD -1.78%	
12.	Koshiyara M et al., [21]			8%	3%	All CHD	
13.	Shirisha V et al., [22]	Cadaveric		3.84	11.53	All CHD except RHD-1%	1
14.	Present study	Cadaveric	0.2cm-6.2cm. 2-4cm=61%	3%	14%	All CHD except RHD-1%	-

[Table/Fig-14]: Comparison in length and drainage of cystic duct between various researchers.

S.no.	Study	Mode of study	Angular (%)	Parallel (%)	Spiral (%)
1.	Sawaragi R et al., [3]	MRCP	Rt Lat 51	7.5	Medial insertion-8.3, Anterior insertion-2, Posterior insertion-20.2
2.	Pina LN et al., [18]	Cadaveric	67.74	16.12	No spiral,Straight in 5 cases (16.12%)
3.	Talpur KAH et al., [20]	Surgery	-	Low parallel 8.93	Anterior-3.57, Posterior-8.93
4.	Koshiyara M et al., [21]	Cadaveric	97	3	-
5.	Al-Tigiani HA, [26]	Surgical, Cadaveric ,USG	75	13	6
6.	Al-Jiffry BO et al., [27]	IOC	59	10.7	11.3
7.	Present study	Cadaveric	53	23	24 Anterior-4, Posterior-15, Medial -5

[Table/Fig-15]: Comparison in course of cystic duct between various researchers.

to initial occlusion of the lumen by cells during embryonic life. Double CDs are relatively rare and a case of a neonate with VACTERL association (vertebral defects, anal atresia, cardiac defects, tracheoesophageal fistula, renal anomalies, and limb abnormalities) with double CDs has been reported recently in literature [33].

LIMITATION

The main limitation of this study was that the findings could not be corroborated clinically as this was a cadaveric study. Also, vascular variations and their relations with the aforesaid structures were not taking into account in course of the study.

CONCLUSION

Important variations were found which are significant from the surgical point of view, especially as there is a surge in laparoscopic cholecystectomies and other minimally invasive procedures in the recent era. These anomalies could be potentially risky to the unaware surgeon during any invasive procedure. Therefore, it is imperative that surgeons and radiologists keep in mind the usual and aberrant anatomy of the CD, for having a successful therapeutic intervention along with uneventful recovery during and after the convalescence period.

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