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Review Article

Biliary Merging Patterns of the Caudate Lobe: A Review Report

Dragica Jurkovikj*, Niki Matveeva
Institute of Anatomy, Medical Faculty, University "Ss. Cyril and Methodius'', Skopje, Republic of Macedonia

***Corresponding author**
Dragica Jurkovik
Email: dragica.jurkovik@gmail.com

Abstract: Concerning the previous anatomical knowledge and requirements of current hepato-pancreato-biliary practice it was our aim to enhance the anatomy knowledge of the caudate lobe biliary drainage. Using the injection-corrosion method we made 27 acrylic porto-biliary casts of proper quality from 30 post-mortem, adult human liver specimens. During the observation under a magnifying glass a portal vascular segmentation was determined along with intrahepatic merging patterns of biliary ducts. In segment 1, the biliary drainage appeared as a confluence of segmental ducts from two distinct portions, left and right. According to their merging patterns we found a separate confluence of both portions in 16/27 casts, their common confluence in 7/27 casts, and a combined confluence in 4/27 casts. The total number of ducts, based on their ending manner of confluence, was 1 in 11 cases, 2 in 9 cases, and 3 in 4 cases. The confluence of both portion ducts was most frequently into the same collecting duct (11/27), then into different collecting ducts (9/27), and rarely it was a combined confluence (3/27), on contrary to the confluence only from one portion, left or right (4/27). Drainage into ducts of different order was also observed: the first (left and right hepatic duct), the second (posterior and anterior right sectoral ducts, left lateral sectoral duct), and the third order (segment 2 duct). These anatomical data addressing the key elements in the liver hilum are important when performing caudate lobectomies or when performing it in combination with major liver resection.
Keywords: Liver, Caudate lobe, Bile duct, Intrahepatic, Anatomy .

INTRODUCTION

It was discovered many years ago that caudate lobe is an independent liver lobe designated as segment 1. Its outflow veins directly enter the retrohepatic portion of the inferior vena cava. The inflow elements, grouped into Glisson's pedicles, into variable number from 2-4, originate from both hemilivers, but predominantly from the left one. Biliary ducts are mainly presented with the same number of ducts as are the portal veins, but most often two ducts form one common stem prior to their confluence into the left hepatic duct [1].

Goldsmith & Woodburne [2] described the caudate lobe as an individual area. If compared to both branches that arise from the right and left branch of the portal vein towards this area, arteries and duct can also have bilateral origin.

Based on the discoveries and division of the caudate lobe given by Kumon [3], and in addition to the requirements of the surgical anatomy of this lobe Sasada *et al.* [4] defined the complete caudate lobectomy as complete resection of Spiegelian lobe, paracaval portion and caudate process. According to their opinion, there are 3 ways how to approach and resect the caudate lobe: isolated caudal lobectomy, combined resection of the liver and caudate lobe and transhepatic anterior approach by splitting parenchyma of the liver.

Having in mind these former and recent anatomic discoveries presented by Kogure *et al.* [5], Craina *et al.* [6], and Lee *et al.* [7], as well as the current hepato-pancreatic-biliary practice, it was our aim to give a review survey of caudate lobe biliary drainage and to enhance the complex and variable anatomy of this liver lobe.

MATERIALS AND METHODS

Intrahepatic biliary drainage along with portal vascular ramification were investigated on a series of 30 post-mortem adult human liver specimens. Injection-corrosion method was used to make acrylic portobiliary casts. The obtained casts were observed under a magnifying glass in order to determine portal segmentation of each specimen and to analyze biliary drainage. The modalities of portal and biliary ramifications were illustrated with diagrams. Of the total number of obtained specimens, the larger number (27/30) were of proper quality and only these specimens were further analyzed.

Biliary drainage of segment 1 was examined through segmental collecting ducts from its left and right portion. Ducts were differentiated into superficial and profound according to their location in relation to external area of the caudate lobe and the liver itself.

The analysis of biliary merging patterns of the caudate lobe was made by determining the following paragraphs:

- into ducts of which the functional hemiliver is the confluence of ducts from both portions of segment 1
- ending manner of confluence of the left and right portion caudate lobe segmental ducts
- differentiating of collecting ducts
- total number of merging ducts
- order of collecting ducts.

RESULTS

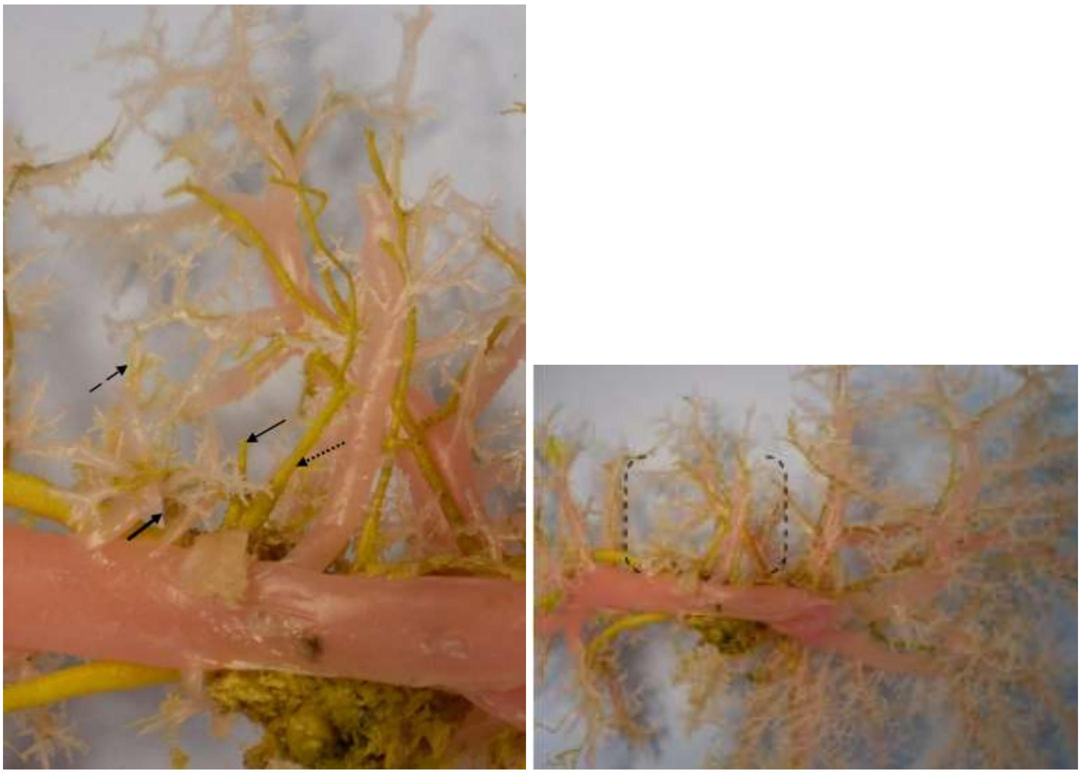
The obtained findings are illustrated in Table-1.

Table 1: Caudate lobe-merging patterns of left (1LP) and right (1RP) portions ducts of Segment 1 s-superficial duct; p-profound duct; stem (s+p); Sg-segment; cp-caudate process; pp-papillary process

Ordinal number of specimen	Ducts which drain caudate lobe left portion	Ducts which drain caudate lobe right portion
I	I(1) 1LP (s+p) + Sg2 duct = common stem into Left Lateral Sectoral Duct I(2) 1LP (p) into Left Lateral Sectoral Duct	I(1) 1RP (s+p) into Left Hepatic Duct
II	II(0)	II(1) into Right Posterior Sectoral Duct
III	III(1) 1LP (p) into Left Hepatic Duct	III(1) 1RP (p) into Left Hepatic Duct III(2) 1RP (s+p) into Right Posterior Sectoral Duct
IV	IV(1) 1LP (s) into Left Hepatic Duct IV(2) 1LP (s+p) into Right Hepatic Duct	IV(1) 1RP (s) into IV(2) 1LP (s+p) IV(2) 1RP (p) + Sg9c duct = common stem into IV(2) 1LP (s+p) IV(3) 1RP (p) into Right Anterior Sectoral Duct
V	V(1) 1LP (s) into Sg2 duct V(2) 1LP (s) into Left Lateral Sectoral Duct	V(1) 1RP (s) + Sg9b duct = common stem into Right Posterior Sectoral Duct
VII	VII(1) 1LP (s) into Left Lateral Sectoral Duct VII(2) 1LP (p) into Left Lateral Sectoral Duct	VII(0)
VIII	VIII(1) 1LP (s) + 1RP (p) = common stem into Left Hepatic Duct	VIII(1) 1RP (p) + 1LP (s) = common stem into Left Hepatic Duct VIII(2) 1RP (p) + VIII(3) 1RP (p) = common stem into common stem of 1LP + 1RP
IX	IX(1) 1LP (s+p) + Sg9b duct = common stem into Left Hepatic Duct	IX(0)
X	X(1) 1LP (s) into Sg2 duct X(2) 1LP (s+p) + Sg9b duct = common stem into Left Hepatic Duct	X(0)
XI	XI(1) 1LP (s) into Sg2 duct	XI(1) 1RP (s) + cp duct = common stem into Left Lateral Sectoral Duct
XII	XII(1) 1LP (p) + XII(2) 1LP (s) = common stem into Left Hepatic Duct XII(3) 1LP (p) into common stem	XII(1) 1RP (p) + XII(2) 1RP (s) = common stem into common stem of 1LP XII(3) 1RP (s) + XII(4) 1RP (p) + cp duct = common stem + Sg9b duct = common stem into Right Posterior Sectoral Duct
XIII	XIII(1) 1LP (p) + XIII(2) 1LP (s) + XIII(3) 1LP (s) = common stem into Left Lateral Sectoral Duct XIII(4) 1LP (p) into Left Lateral Sectoral Duct XIII(5) 1LP (s) + XIII(6) 1LP (s) = common stem into Left Hepatic Duct	XIII(1) 1RP (p) + cp duct = common stem into Right Posterior Sectoral Duct

XIV	XIV(1) 1LP (p) + XIV(2) 1LP (s) = common stem + XIV(1) 1RP (s) = common stem into Left Hepatic Duct	XIV(1) 1RP (s) + common stem of 1LP = common stem into Left Hepatic Duct
XV	XV(1) 1LP (p) into common stem of XV(2) 1LP (s) + XV(1) 1RP (s) which drains into Left Hepatic Duct	XV(1) 1RP (s) + XV(2) 1LP (s) = common stem into Left Hepatic Duct XV(2) 1RP (p) into common stem XV(3) 1RP (p) into common stem XV(4) 1RP (p) into common stem
XVI	XVI(1) 1LP (s) into Left Lateral Sectoral Duct XVI(2) 1LP (s) into Right Anterior Sectoral Duct	XVI(1) 1RP (s) into Right Posterior Sectoral Duct
XVIII	XVIII(1) 1LP (p) + XVIII(1) 1LP (s) = common stem into Left Lateral Sectoral Duct	XVIII(1) 1RP (p) into common stem of 1LP
XX	XX(1) 1LP (p) into Sg2 duct	XX(1) 1RP (s) into Right Posterior Sectoral Duct
XXI	XXI(1) 1LP (s) + XXI(1) 1RP (s) = common stem into Right Hepatic Duct XXI(2) 1LP (s) way and ductule + XXI(2) 1RP (s) way = newly formed stem into old common stem	XXI(1) 1RP (s) + XXI(1) 1LP (s) = common stem into Right Hepatic Duct XXI(2) 1RP (s) way + XXI(2) 1LP (s) way and ductule = newly formed stem into old common stem
XXII	XXII(1) 1LP (s) into Right Posterior Sectoral Duct	XXII(1) 1RP (s) into Right Posterior Sectoral Duct
XXIII	XXIII(1) 1LP (s) into Sg2 duct	XXIII(1) 1RP (s) + XXIII(2) 1RP (s) = common stem into 1LP duct formed by pp duct + cp duct draining into 1LP (s) XXIII(3) 1RP (s) into 1LP (s)
XXIV	XXIV(1) 1LP (p) into Left Hepatic Duct XXIV(2) 1LP (p) into Left Hepatic Duct XXIV(3) 1LP (s) + XXIV(1) 1RP (s) = common stem + XXIV(2) 1RP (p) = common stem into Left Hepatic Duct	XXIV(1) 1RP (s) + XXIV(3) 1LP (s) = common stem + XXIV(2) 1RP (p) = common stem into Left Hepatic Duct
XXV	XXV(1) 1LP (s) into common stem of XXV(1) 1RP (s) + XXV(2) 1RP (p) which drains into Left Hepatic Duct XXV(2) 1LP (p) into Left Hepatic Duct	XXV(1) 1RP (s) + XXV(2) 1RP (p) = common stem into Left Hepatic Duct
XXVI	One duct of Sg1 by magistral way both, left and right portions, drains into Right Posterior Sectoral Duct as follows: XXVI(1) 1LP (s) XXVI(1) 1RP (p) XXVI(2) 1RP (s) XXVI(3) 1RP (p) XXVI(2) 1LP (s) XXVI(4) 1RP (s) cp duct	
XXVII	XXVII(1) 1LP (s) into Left Hepatic Duct	XXVII(1) 1RP (s) into Right Hepatic Duct
XXVIII	XXVIII(1) 1LP (p) + XXVIII(1) 1LP (s) = common stem into Left Lateral Sectoral Duct	XXVIII(1) 1RP (p) + XXVIII 1RP (p) = common stem + Sg9b duct = common stem into Left Hepatic Duct
XXIX	XXIX(1) 1LP (s) + pp duct = common stem + Sg2 duct = Left Lateral Sectoral Duct (triple) into Left Hepatic Duct	XXIX(1) 1RP (s) + XXIX(2) 1RP (s) = common stem into Right Posterior Sectoral Duct
XXX	XXX(1) 1LP (s) into Right Posterior Sectoral Duct	XXX(1) 1 RP (s) into Right Posterior Sectoral Duct

Biliary segmental ducts of each specimen are numbered with Arabic numerals into brackets.



A **B**

C **D** **E**

Fig. 1: Presents a case with confluence of both left and right portions into duct that drained left hemiliver as combined confluence (common confluence by collateral flow of 1lP duct into stem of 1RP ducts and separately by proper duct of 1LP) into the same collecting duct i.e. into the left hepatic duct. (A) Visceral view of the caudate area selected from under B. Arrows: dotty arrow-1RP superficial duct; thin arrow-1RP profound duct; thick arrow-1LP superficial duct; long dash arrow-1LP profound duct; (B) Visceral view of the specimen XXV portobiliary cast; (C) Schematic drawing of the visceral appearance of caudate area selected from under D, (D) Schematic drawing of the visceral appearance of specimen XXV portobiliary cast; (E) Scheme to the anterior (diaphragmatic) appearance of the biliary tree from this case. Segmental ducts are numbered from 1 to 9 (b, c and d) with Arabic numerals.

DISCUSSION

Generally in the literature the most common types of vascular biliary anatomy of caudate lobe are presented as well as its classification in different morphological types.

According to Kogure *et al*. [5] many combinations of portal branches were found in the caudate lobe but the patterns of portal branching were classified into two types. In the first one the territories of the first-order portal branches were clearly divided into two areas distinctly separated by the intersegmental plane (67.4%), and the second one (32.6%) in which one of the first-order portal branches simultaneously supplied two areas. Both types were related to the Spiegel lobe and the paracaval portion.

The study of Craina *et al*. [6] conducted on 100 liver corrosive casts has confirmed the classic drainage of caudate lobe by 2 biliary ducts. However, the number of caudate lobe ducts was in the range of 0 to 3 and 24 morphological types were determined as follows: no biliary duct in 3% of the cases, a single duct in 13% by 2 morphological types, two ducts in 66% by 8 morphological types and three ducts in 18% by 6 morphological types.

New consideration on liver anatomy was given by Couinaud [8] presenting the anatomy of the liver dorsal sector on a series of 101 liver casts. This sector consisted of a left dorsal sector (segment 1), which means the caudate lobe and a right dorsal sector (segment 9). Left dorsal sector duct was the only one in 23 casts with confluence into the left hepatic duct, and not so often into the duct of the segment 2 and another 3 with confluence in the right lateral (posterior) duct.

Recent literature reports from clinical practice related to surgical procedures during isolated complete caudal lobectomy for liver tumors include ligation of caudate portal triad. Yang *et al*. [9] reported that three to five caudate portal triads branching from the left and right hepatic pedicle junction into the caudate lobe.

The subject of this study was biliary drainage of segment 1 or the classical caudate lobe known as Spiegel's lobe.

Of the observed 27 acrylic portobiliary casts, 23 were with evident 2 constituent portions – left and right, versus 3 cases with only left portion and 1 case with absent biliary elements from the left portion. Drainage modality of both distinct portions from segment 1 for each individual specimen is presented in Table 1, and one of them is illustrated by Fig. 1.

According to the obtained modalities it may be concluded that caudate lobe biliary drainage on the investigated material appeared mostly as confluence:

- Of both portions into ducts that drained left hemiliver forming a common stem, either via collateral flow or separately by proper ducts in 10 cases (37.037%)
- Of both portions into ducts that drained right hemiliver, also as a separate or common confluence and especially by magistral way in 4 cases (14.81%)
- Separately from each portion into ducts of corresponding hemiliver and additionally by confluence of either right or left portion into opposite hemiliver in 4 cases (14.81%)
- Of the ducts of the left portion into ducts of the left hemiliver, whereas of the ducts of the right portion into ducts of the right hemiliver in 5 cases (18.52%)
- Only of the right portion duct into the right hemiliver duct in 1 case (3.704%)
- Only of the left portion ducts into the left hemiliver ducts in 3 cases (11.11%).

Similar to our findings are the results obtained by Gupta et al. (1977), [10] in which the caudate lobe and process formed a separate subsegment on the basis of the pattern of their blood supply and biliary drainage. As segments of the caudate lobe the left and the right portion and the caudate process were drained in different percentage in the right or left ductal system.

Having in mind this subdivision of the segment 1 and practical importance of liver hilum we analyzed the ending manner of segmental ducts from both portions and it was found a separate confluence of both portions in 16/27 casts, their common confluence in 7/27 casts, and a combined confluence in 4/27 casts.

The analysis according to the confluence of both portion ducts showed that it was most frequently into the same collecting duct (11/27), then into different collecting ducts (9/27); there was a combined confluence in 3/27 and one-sided in 4 cases.

The results obtained in this study also confirmed a variable total number of collecting ducts from segment 1, of which from both portions 11 cases had 1 duct, 9 cases had 2 ducts and 4 cases had 3 ducts.

Of special importance is also the drainage distribution. In the Couinaud's series [8] it was in the left liver duct in 60/101 casts, in the upper biliary confluent in 3 casts, whereas in the right liver ducts in 67 casts, of which in 56 livers a duct from the left dorsal sector entered the right lateral (posterior) duct.

Our results are similar with the findings reported in the study of Craina *et al*. [6]. They revealed a number of 199 biliary ducts with confluence in the right hepatic duct (65/199 or 32.66%), in the superior biliary confluent (10/199 or 5.03%), and in the left hepatic duct (124/199 or 62.31%).

Drainage of ducts of the segment 1 in our specimens was into ducts of all 3 orders: hepatic- left and right, sectoral – right, anterior and posterior, and left lateral, and segment order - segment 2 duct.

From surgical point of view these notions about biliary anatomy of the caudate lobe are important pre-, peri- and postoperative determinants. Different biologies requiring caudate resection led to differences in operative techniques and outcomes as reported by Philips *et al*. [11]. However, hilar chlonagiocarcinoma biliary anatomy rather than liver disease was the main focus of the evaluation. The dominant caudate bile duct generally drained to within 1 cm of the hilum, but of the described variations in caudate duct anatomy, most had involved drainage to the hilum or right posterior bile duct. Thus caudate lobectomy was usually necessary to enable complete resection of involved bile duct-Anaya *et al*. [12]. The importance of complete excision of the caudate lobe in resection of hilar cholangiocarcinoma was previously pointed out by Dinant *et al*. [13]. Tsao *et al*. [14] recommended the cholangiogram-based surgical strategy in the treatment of hilar cholangiocarcinoma and according to the cancer extent they recommended the major hepatic resections with caudate lobectomy and bile duct resection, as well as, an independent caudate lobectomy with bile duct resection and an extrahepatic bile duct resection alone.

Also, using hanging maneuver by three Glisson's pedicles and three hepatic veins during various anatomic liver resections Kim *et al*. [15] performed four major hepatectomies in combination with caudate lobectomy. Primary liver cancer in caudate lobe was successfully resected by Wen *et al*. [16] while performing an isolated caudate lobectomy either a combined partial right hepatectomy or a combined left lateral lobectomy. Mesohepatectomy was an oncologically adequate procedure for selected patients with perihilar cholangiocellular carcinoma and compromised liver function. The tumor frequently infiltrated the parenchyma of the caudate lobe or/and invaded its bile duct-Malago *et al*. [17].

In the study conducted by Sakamoto *et al*. [18] the pattern of infiltration at the proximal border of hilar bile duct carcinoma was presented. The involved layers and the routes of invasion of the carcinomas were investigated histologically. The involved layer at the proximal border of the cancer was classified as the mucosal, submucosal-intramural, or submucosal-extramural layer. The routes of invasion were categorized into four types: direct, lymphatic, venous, and perineural invasion. Continuous cancer cell invasion with fibrous stroma was defined as direct invasion.

In the study performed by Vellar on post-mortem livers the anatomy of the venous drainage of the intrahepatic and extrahepatic bile ducts was established. These marginal vessels gave branches which entered the hepatic substance superiorly: segment IV, segment V, the caudate lobe and the caudate process. Other branches joined the hilar venous plexus which then entered the caudate process or joined the caudate portal venous branches. These veins may provide a pathway for a cholangiocarcinoma to metastasize either by tumor emboli or permeation to segment 1 and 4 [19].

Historically, intrabiliary growth of metastatic liver tumors has been associated with colorectal primaries. Estrella *et al*. [20] identified two patterns of intrabiliary growth: colonization of the bile duct, with replacement of the normal biliary epithelium and growth along an intact basement membrane, and tumor "plugs" within the bile duct lumen. Intrabiliary growth was highly specific to metastatic colorectal carcinomas in 41 (3.6%) of 1144 versus 3 (0.7%) of 452 noncolorectal tumors.

Based on the presented observations from hepato-pancreatic-biliary practice as well as on the notions about dissociation among the courses of the bile duct, hepatic artery and portal vein in the human liver, as suggested by Lee *et al*. [7] treatment of these triad components during surgery has to be done independently.

CONCLUSION

The caudate lobe biliary drainage appears as a confluence of segmental ducts from two distinct portions-left and right. According to their merging patterns it may be a separate, common and combined drainage of both portions, as well as drainage into ducts of different order (first, second and even third). In number of 1 to 3 they enter the ducts only of left or right hemiliver or of both.

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