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COMPARATIVE STUDY OF THE SEGMENTAL PORTOBILIARY ANATOMY OF ANTERIOR LIVER SECTOR

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ABSTRACT

Background: The current advance in liver anatomy and surgery is based on the new concept of subdivision. The area fed by each tertiary branch was cone-shaped unit and the cone unit resection indicated resection on segments smaller than Couinaud's segments. **Material and methods:** Portobiliary casts were obtained from 27 out of 30 cadaveric liver specimens, using injection-corrosive method. Under magnifying lens they were investigated. **Results:** Numerical relation between segmental portal branches and biliary ducts into segment 8 was predominantly equal on contrary to different relation with predominant biliary ducts or portal branches. Into segment 5 predominant different relation with more numerous portal branches on contrary to different relation with more numerous biliary ducts or equal relation was found. Three types of biliary drainage were observed: classical with drainage of area supplied by one segmental portal branch through one segmental duct, then second type with additional drainage of more different portal branches through one segmental duct and the third one with additional drainage of one portal branch through more segmental ducts. Segments 8 and 5 ducts mainly appeared as constituent ducts to the anterior sector duct without or with collateral confluence into lower-order ducts. Rarely these ducts were constituent or only collateral ducts to the other lower-order ducts. Only in segment 5 confluence through accessory ducts was observed. **Conclusion:** The preoperative assessment of portobiliary anatomy at the level up to the second-order Glissonean pedicles is imperative necessary for safe realization of liver resection at that level.

KEYWORDS: liver, anterior sector, portal vein, bile duct, comparative anatomy.

INTRODUCTION

The current trend in liver resection is based on the new concept of functional liver subdivision. The area fed by each tertiary branch was cone-shaped, and was termed a "cone unit". The use of combination of the Glissonean pedicle approach and ultrasound-guided dye injection allowed removing tumors with a cone-shaped resection. This approach was introduced to increase the rate of survival since in patients with liver cirrhosis and poor hepatic function the surgical method was among other factors that affected survival.[1] The concept of cone unit resection indicated anatomical resection based on segments that are smaller than Couinaud's segments.[2-3]

In the literature total or partial anatomical resection of segment 8 (S8) was reported using the ultrasound-guided finger compression technique.[4] Another method staining the portal unit (S3 and S8) by indigo carmine dye was performed by Yoshida et al.[5] This segmentectomy technique was also effective for anatomical liver resection of less than one segment. Precise anatomical resection only of the ventral part of S8 was reported by Xiang et al.[6] According to Fujimoto et al.[7] the right paramedian (anterior) sector can be divided vertically into ventral and dorsal area on the basis of ramification of the third-order of the portal veins. They described an approach for the ventral and dorsal portal pedicles and six kinds of surgical procedures including the Right Paramedian Sector (RPS): resection of the ventral area of the RPS, resection of the dorsal area of RPS, resection of S8 ventral area, resection of left liver with ventral area of RPS, resection of Right Lateral Sector (RLS) with dorsal area of RPS and resection of RLS (S6+S7), right caudal paramedian sector (S5), and cranio-dorsal paramedian sector (S8-dorsal).

This study was performed as a contribution to this advancement in liver anatomy and surgery at the segmental level of the anterior liver sector.

MATERIAL AND METHODS

The study material consisted of acrylic casts from the intrahepatic portal and biliary ramifications. They were made from the 30 adult cadaveric liver specimens using injection-corrosive method. Yellow coloured odontolite acrylate was injected into biliary ducts. Hence, the biliary ducts will be different from the uncoloured portal branches. Specimens numbered as VI, XVII and XIX were excluded from the investigation because of incomplete filling. Twenty-seven out of 30 specimens were investigated under magnifying lens and were determined:

Numerical relation between portal segmental branches and segmental biliary ducts into each separate segment, 8 and 5, of anterior liver sector.
1. Patterns of biliary drainage through segmental ducts separately for each segment.
2. Confluence of segmental ducts into ducts of lower-order.
3. Site of origin of portal branches destined to segments 8 and 5.

The results obtained were tabulated and documented with drafts. The segmental biliary ducts were numbered according to Couinaud's segmentation[3] from 1 to 9 with Arabic numerals, then segment 1 left portion as 1LP, segment 1 right portion as 1RP, p-profound, s-superficial, cp-caudate process, pp-papillar process, h-hilar, dc-cystic duct.

RESULTS

Comparatively to the intrahepatic portal ramification, the patterns of segmental biliary drainage for each investigated case were determined. Accorded to the consequent biliary duct confluence the ducts were ranged into ducts from Ist to IVth-order concerning the right and left hepatic ducts from Ist-order, sectorial (on the right posterior and anterior, and on the left lateral and medial) from IInd-order, segmental from 1 to 9 from IIIrd-order and beginning ducts of segmental ducts from IVth-order.

In accordance with this manner of ranging on the acrylic casts firstly the segmental ducts were observed and then their total number was determined and compared with the total number of segmental portal branches which is shown in Tables 1-2.

Table 1: A, B and C: Numerical relation between portal segmental branches-p and segmental biliary ducts-b into segment 8.

Equal relation (p=b)	**1/1**	**2/2**	**3/3**	**4/4**	**5/5**	**6/6**	**7/7**	**Total**
Number of pecimens	I, II	III, VIII, X, XVI, XXII, XXV	IX	XXI, XXIX	V, XXIII	XXVI	XIII, XXX	
Total	2	6	1	2	2	1	2	16

A: p=b

Different relation (p>b)	**3/2**	**5/2**	**9/6**	**15/6**	**Total**
Number of specimens	VII	XI	XXIV	XV	
Total	1	1	1	1	4

B: p>b

Different relation (p<b)	**1/4**	**3/4**	**4/5**	**3/6**	**5/6**	**Total**
Number of specimens	XVIII	XX	XXVII	IV, XII, XXVIII	XIV	
Total	1	1	1	3	1	7

C: p<b

Table 2: A, B and C: Numerical relation between portal segmental branches-p and segmental biliary ducts-b into segment 5.

Equal relation (p=b)	2/2	5/5	8/8	Total
Number of specimens	XXVI	XXIII	XXX	
Total	1	1	1	3

A: p=b

Different relation (p>b)	Number of specimens	Total
4/1	VIII	1
4/3	II, XI	2
5/1	X	1
5/2	VII	1
5/3	IX, XIII, XXIV, XXVII	4
6/3	XV, XXII	2
6/4	XVI	1
6/5	I	1
7/3	XXIX	1
7/5	XXV	1
7/6	III	1
9/3	V	1
9/7	IV	1
10/5	XX	1
10/7	XIV	1
Total		20

B: p>b

Different relation (p<b)	4/5	5/9	6/8	6/14	Total
Number of specimens	XVIII	XXVIII	XXI	XII	
Total	1	1	1	1	4

C: p<b

Patterns of segmental biliary drainage into segments 8 and 5

Classical pattern of segmental biliary drainage was observed on the examined material showing drainage of area supplied by one segmental portal branch through one segmental duct. Also, additionally to the classical pattern, there were some different patterns of biliary drainage in the same specimen.

Segment 8

1. *Classical pattern:* in specimens no. I, II, III, VIII, IX, X, XVI, XXI, XXII and XXV; 10/27 (37.037%), "Fig.1A and 1B".
2. Additionally to the classical pattern the *drainage of different portal branches through the trunk and collaterals of one duct* as follows:

a) One duct/two portal branches: in specimens no. V, XIV, XXVI, XXIX and XXX; 5/27 (18.18%).
b) One duct/three portal branches: in specimens no. XI and XV; 2/27 (7.41%).
c) One duct/eight portal branches: in specimen no. XV; 1/27 (3.70%).

3. Additionally to the classical pattern the *drainage of trunk and collaterals of one portal branch through different segmental ducts* as follows:

a) Two ducts/one portal branch: in specimens no. V, XI, XII, XIII, XV, XX, XXIII, XXVII and XXIX; 9/27 (33.33%).
b) Three ducts/one portal branch: in specimens no. XII and XIV; 2/27 (7.41%).
c) Four ducts/one portal branch: in specimens no. IV and XVIII; 2/27 (7.41%)
d) Five ducts/three portal branch: in specimen no. XXVIII; 1/27 (3.70%).

4. *Presence of portal branches not accompanied by biliary ducts:* in specimens no. V, VII, XV and XXIV; 4/27 (14.81%).

Segment 5

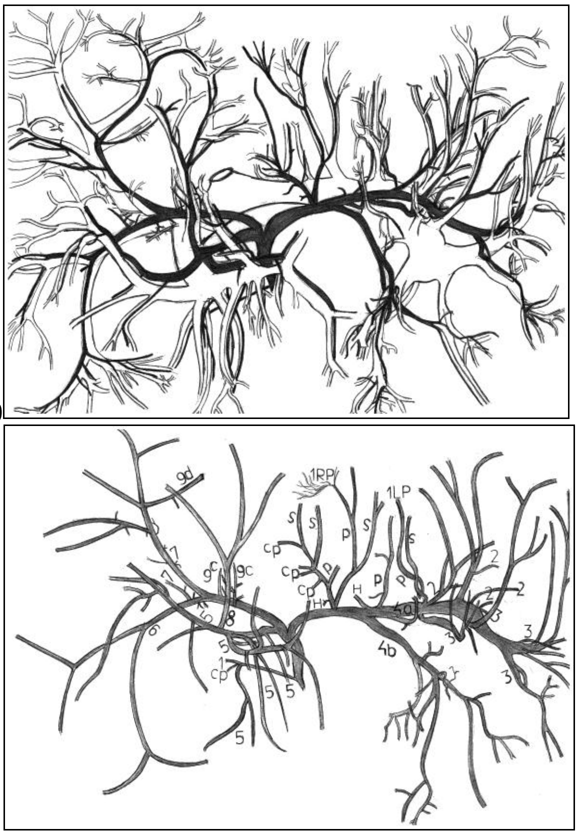
1. *Classical pattern:* in specimens no. XXIII and XXVI; 2/27 (7.41%).
2. Additionally to the classical pattern the *drainage of different portal branches through the trunk and collaterals of one duct* as follows:

a) One duct/two portal branches: in specimens no. I, IV, VII, VIII, XI, XIII, XIV, XVI, XX, XXV, XXVIII and XXIX; 12/27 (44.44%).
b) One duct/three portal branches: in specimens no. I, V, VII and XXIX; 4/27 (14.81%).
c) One duct/four portal branches: in specimens no. XIV and XV; 2/27 (7.41%).
d) One duct/five portal branches: in specimens no. X and XX; 2/27 (7.41%).
e) One duct/six portal branches: in specimens no. XXX; 1/27 (3.70%).
f) Two ducts/three portal branches: in specimens no. II and XVI; 2/27 (7.41%).

3. Additionally to the classical pattern the *drainage of trunk and collaterals of one portal branch through different segmental ducts* as follows:

a) One duct/four S6 portal branch collaterals: in specimen no. XXII; 1/27 (3.70%).
b) Two ducts/one portal branch: in specimens no. IX, XIII, XIV, XVI and XVIII; 5/27 (18.52%).
c) Three ducts/one portal branch: in specimens no. III and XXI; 2/27 (7.41%).
d) Four ducts/one portal branch: in specimens no. XXVIII; 1/27 (3.70%).
e) Five ducts/one portal branch: in specimen no. XII; 1/27 (3.70%).
f) Seven ducts/one portal branch: in specimen no. XII; 1/27 (3.70%).

4. *Presence of portal branches not accompanied by biliary ducts:* in specimens no. II, III, V, VIII, IX, XIII, XX, XXIV, XXV XXVII; 10/27 (37.037%).



(A)

(B)

Figure 1: Classical pattern of biliary drainage into S8; A-scheme of specimen no. I portobiliary cast as it is seen on the diaphragmatic surface (portal vein in white, biliary ducts in black); B-scheme of biliary tree with numbered segmental ducts.

Confluence of segments 8 and 5 ducts into ducts of lower-order

Segment 8

In 8 out of 10 specimens with segment 8 ducts in range from 1 to 2 they contributed only to the constituence of Anterior Sector Duct (ASD): in specimens no. I, II, VII, VIII, X, XI, XVI and XXV; 8/27 (29.63%).

Additionally to the constituent ducts to the ASD there were ducts with collateral confluence:

a) Into ASD in specimens no. IV, V, IX, XIII, XXI, XXII, XXIV and XXX; 8/27 (29,63%).
b) Into Posterior Sector Duct (PSD) in specimens no. XV, XVIII, XX and XXVI; 4/27 (14.81%).
c) Into both, ASD and PSD in specimens no. XIV, XXVII and XXIX; 3/27 (11.11%).

In 2 out of 27 specimens (7.41%) these ducts contributed to the constituence of Right Hepatic Duct (RHD). So, these cases were with no ASD, in specimens no. XII and XV.

Also, in 2 out of 27 specimens (7.41%) there was a magistral way of confluence of both segment ducts into ASD, in specimens no. III and XXVIII.

Segment 5

In this segment biliary ducts slowly contributed only to the constituence of ASD: in specimens no. VII, VIII, X and XVIII; 4/27 (14.81).

Additionally to the constituent ducts to the ASD there were ducts with collateral confluence:

a) Into ASD in specimens no. I, V, XI, XXII, XXV and XXVI; 6/27 (22.22%).
b) Into both, ASD and PSD in specimens no. IV and XXIX; 2/27 (7.41%).
c) Into RHD in specimen no. II; 1/27 (3.70%).

In 3 out of 27 specimens (11.11%) segment 5 ducts contributed to the constituence of PSD, but additionally the following was found: collateral confluence into PSD and constituent duct to the ASD in specimen no. IX “Fig. 2A and 2B”; collateral confluence into PSD and constituent and collateral ducts to the ASD in specimen no. XIV; only collaterals into ASD in specimen no. XXIII.

In 2 out of 27 specimens (7.41%) segment 5 ducts contributed to the constituence of RHD in specimen no. XV and with additional collaterals into RHD in specimen no. XII.

In the remaining 7/27 (25.92%) of specimens only collateral confluence of segment 5 ducts into different ducts was found:

a) Into ASD in specimens no. XIII, XXIV and XXX; 3/27 (11.11%).
b) Into both, ASD and PSD in specimen no. XVI; 1/27 (3.70%).
c) Into RHD in specimen no. XX and XXVII; 2/27 (7.41%).
d) Into ASD and RHD in specimen no. XXI; 1/27 (3.70%).

To the magistral way of confluence of both segment ducts into ASD, in specimens no. III and XXVIII; 2/27 (7.41%) was above mentioned.

Drainage through accessory ducts as additional way of confluence was found into: ASD in specimen no. XIII; PSD in specimen no. IV; RHD in specimen no. XXX; Common Hepatic Duct (CHD) in specimens no. I and XV; cystic duct in specimen no. XIII.

(A)

(B)

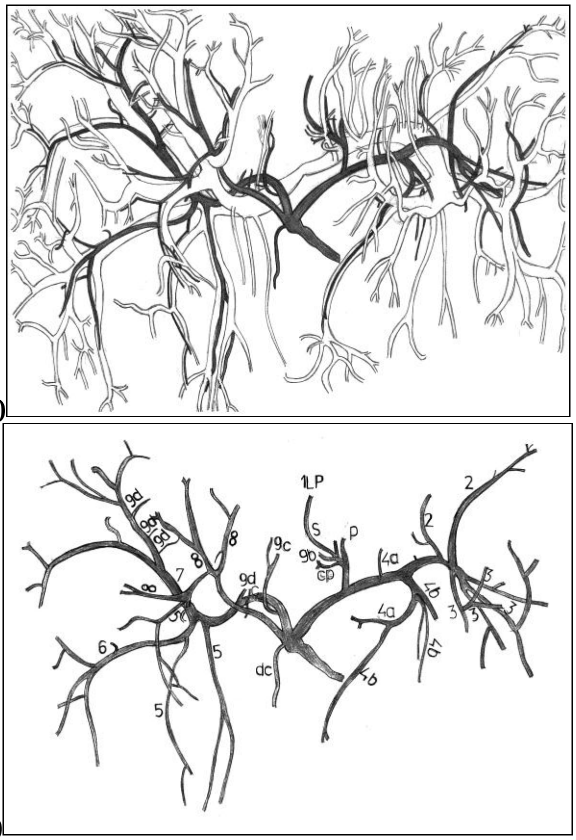


Figure 2: S5 ducts as constituent ducts to the ASD and PSD and collateral confluence into PSD; A-scheme of specimen no.IX portobiliary cast as it is seen on the diaphragmatic surface (portal vein in white, biliary ducts in black); B-scheme of biliary tree with numbered segmental ducts.

Site of origin of portal branches into segments 8 and 5

S8 portal branches as collaterals of Anterior Portal Vein Branch (APVB) originating mainly along the posterior and right side of horizontal part of APVB arch, rarely from its left side even without accompanied biliary ducts were observed. Exclusively some of branches were descendant or originated from anterior side of APVB arch. Also, they arose either as collaterals or as terminal branches of ascendant terminal part of APVB. Only once branch to S8 with branches to segments 7 and 5 formed terminal trifurcation of Posterior Portal Vein Branch (PPVB) additionally to the branches originating from the APVB.

In general, S5 portal branches took origin on every side along the horizontal part of APVB arch: the anterior inferior, right and left and exclusively posterior superior. Also, they were a part of terminal branches of ascendant terminal part of APVB as destined to S5 or with origin from the branches destined to S8. In some cases these branches took additional origin from the PPVB and Right Portal Vein Branch (RPVB).

DISCUSSION

The present study allowed to establish important variation not only in the total number of segmental portal branches but in their numerical relation with the segmental biliary ducts at the level of investigated segments 8 and 5.

The total number of portal branches destined to S8 varied from 1 to 15 while the number of biliary ducts ranged from 1 to 7. But, when comparison was made for each specimen predominantly the equal relation was found on contrary to different relation with predominant biliary ducts or portal branches, respectively.

The total number of portal branches destined to S5 varied from 2 to 10 while the number of biliary ducts ranged from 1 to 14. The comparison showed predominant different relation in which portal branches were more numerous, on contrary to different relation with more numerous biliary ducts or equal relation, respectively.

In the anatomo-clinical reports of the segmental liver anatomy no similar investigation was found about numerical relation of portobiliary elements and especially of the patterns of segmental biliary drainage.

Moreover, it is an old notion by Couinad[8] that the total number of segmental portal branches is very variable (from 1 to 3 destined to S8 and from 1 to 6 to S5). The anterior veins originating from the APVB arch and its anterior terminal branches formed S5, while the total number of posterior veins formed S8. Also, the different types of terminal ramification were presented.

The new applied liver anatomy is aimed up to the second-order Glissonean pedicles. As Fasel and Schenk[9] have noticed segments are territories that depend partly on major second-order branches. In their subunits-concept to the liver defined that territories vascularised by individual branch coming directly off the RPVB and Left Portal Vein Branch (LPVB) were subunits2 while territories depending on the individual third-order branches of the Glissonean triad were cone units.

This point of view was supported by Kang and Ahn.[1] Based on literature data, they noticed that in most cases tertiary branches of the portal pedicle were supplied by one pedicle in a cone unit. But, in 33%-70% of cases, a single Couinaud segment was supplied by ≥2 tertiary branches arising from the same or different secondary branches, especially in segments 7 and 8.

Three types of biliary drainage were observed on the examined material, based on the variable number of third-order portal branches and differences in the ramification patterns of APVB. The drainage of area supplied by one segmental portal branch through one segmental duct was determined as a classical pattern, which was observed in a higher percent in S8 than in S5.

The second type was more complex because in spite of branches accompanied by proper segmental duct there was a drainage of more different portal branches through one segmental duct and its collateral ducts. This pattern was more frequently observed in S5 than in S8. The third type was drainage of one portal branch through more i.e. different segmental ducts, which was more frequently observed in S8 than in S5.

In contribution to the more complex S5 anatomy was the higher percent of portal branches not accompanied by biliary ducts. The presence of these branches was mainly caused by compensatory regeneration of liver and the branches appeared as newly i.e. later ramified branches. Contrary to this, some branches were not accompanied by segmental ducts due to fibroobliterative changes of biliary ducts named pruning.

Previouslly mentioned findings of segments 8 and 5 portobiliary anatomy resulted in very variable and complex merging patterns of biliary ducts. Here the merging pattern was not determined but manner of confluence i.e. does the segmental ducts constituent or collateral to the lower-order ducts? As it might be concluded from the presented results S8 ducts were not only constituent ducts to the ASD and in absence of ASD they contributed to the constituence of RHD. Also, these ducts were constituent ducts to the ASD and collateral ducts to the ASD, PSD or to both at the same time. Thus, to determine, to visualize or to find and to ligate these ducts is more difficult if they are numerous and with confluence to the other than ASD. At the level of S5 the things are more complex. Segmental ducts least only as constituent ducts to the ASD were observed because they were more frequently constituent and collateral ducts not only to the ASD but to the PSD or RHD and in high percent of 25.92%-7/27 specimens only collaterals to the lower-order ducts. Also, drainage through accessory ducts was observed only from this segment.

Similar to lack of literature reports about segmental biliary anatomy is scarce literature regarding Bile Duct Injuries (BDI) at segmental level. Buddingh et al.[10] in their review article reported different developed techniques for intraoperative assessment of bile duct anatomy to prevent early detection of BDI. BDI was a dreaded complication of cholecystectomy, often caused by misinterpretation of biliary anatomy. Strasberg et al.[11] pointed that the problem of biliary injury during laparoscopic cholecystectomy included training and experience among others risk factors for biliary injury. BDI during cholecystectomy was reported in details by Amin et al.[12]

In agreement with illustrated variations for intrahepatic portal vein ramification done by Couinaud[8] is this study concerning the site of origin of segments 8 and 5 portal branches.

Xu et al. [13] pointed to the importance of the anatomical variations of the right Glisson pedicle in liver surgery. A safe and simple Glissonean pedicle approach may be accomplished by performing the procedure at the second-order branch or at more distal branches. This point of view was based on their division of the segmental portal branches into 3 groups according to the sliding pattern of the branches of the Glisson pedicle origin. In the A (normal group) all right posterior branches originated from the right posterior portal pedicle or all right anterior branches from the right anterior portal pedicle. In the B (right posterior dominant group) several right anterior branches from the right posterior portal pedicle originated. In the C (right anterior dominant group) several right posterior branches from the anterior portal pedicle originated.

CONCLUSION

In contribution to safe realization of surgical procedures of the anterior liver sector such as demarcation of resection line or resective area, ligation of Glissonean pedicle up to the second-order is our opinion that preoperative assessment must provide knowledge-about these three main questions:

1. Does the Glissonean pedicle unique or numerous with regular or irregular origin?
2. Does the accompanied biliary ducts of equal length, either longer or shorter than the portal branches?
3. Does the segmental biliary ducts merge into sectorial-order ducts in a regular or irregular manner?

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