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SEGMENTAL AND/OR SUBSEGMENTAL ANATOMY OF THE ANTERIOR SECTOR IN HUMAN LIVER

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ABSTRACT

Background. New concepts of liver functional anatomy were proposed. Based on the further subdivision of the second-order portal branches the segments were subdivided into 6 to 8 cone shaped units. The anterior sector segments were subdivided into ventral and dorsal areas. **Methods.** On 27/30 portobiliary casts, obtained post-mortem from adult liver specimens, the anterior sector portal vein ramification and functional subdivision were observed. **Results.** The anterior portal vein branch presented four different models of ramification: termination into segment 5, termination into segment 8, common termination into both, segments 8 and 5 and mixed model of separately and common ramification into both segments. Based on the grouping of collaterals and terminal branches of anterior portal vein branch into segments 5 and 8 the ventral and dorsal subunits were determined. Different types of subdivision were found: a subdivision of both segments into ventral and dorsal subunits in 51.85%, then only segment 5 subdivided in 25.93% of casts, only segment 8 subdivided in 11.11%, then not subdivided both segments in one case only with ventral subunits and in the other one only with dorsal segment 8 and ventral segment 5 subunits in 7.41% and in the last one 3.70% with dorsal and ventral segment 8 subunits and two dorsal and one ventral segment 5 subunits. **Conclusions.** Anterior sector of the liver was divided into segments 8 and 5. Based on the terminal and collateral ramification of anterior portal vein branch into these segments a further subdivision into ventral and dorsal subunits was noted.

KEYWORDS: liver, anterior sector, subsegmental anatomy, portal vein, injection-corrosive casts.

INTRODUCTION

Many investigators worldwide have accepted Couinaud`s [1] concept of liver segmental division based on the intrahepatic ramification of portal and hepatic veins. In accordance with the requirements of transplantation, resective and interventional hepatobiliary surgery important variations of portal venous anatomy have been illustrated. But, the variations were followed only to the II-nd (sectorial) and to the III-rd (segmental) order of ramification as Covey et al. [2], Chen et al.[3] reported, then Gupta et al.[4] used another terminology, as well as hepatic venous segmentation reported by Gupta et al.[5], Hata et al.[6-7]

Despite these reports, some authors investigated further liver subdivision and determined another portal venous arrangement of the anterior sector liver segments.

According to portal and venous distributions, Kanemura et al. [8] using 3D CT established that anterior segment was divided into ventral and dorsal units. The ventral unit was drained by the middle hepatic vein and the dorsal by the right hepatic vein.

Kogure et al.[9], with an aim to confirm Hjortsjo`s[10] concept of segmental anatomy analyzed 65 cadaveric livers and found that the third-order portal branches of the anterior segment were divided into 2 groups, from which the first nourished the upper three quarters, and the second lower quarter area. The territories of both groups were further subdivided into ventral and dorsal areas with a vertical fissure.

According to Fasel`s [11] study about portal venous territories within the human liver the number of second-order vessels was between 9 and 44 (20 on average). Later, Fasel and Schenk [12] reported a concept of liver subunits and concerning its clinical application suggested the following terms for portal venous liver subdivisions : lobes, hemilivers, sectors, segments and subunits 2, 3, 4, 5 etc.

Using MDCT data Kaneko et al. [13] found more difficult to identify hepatic anatomy in Ryu`s [14] segmentation than in Couinaud`s. In the Ryu`s method the right posterior sector was regarded as 1 segment, and the right anterior sector was subdivided into the antero-ventral and

antero-dorsal segments (AVS, ADS), which were demarcated by the anterior fissure vein.

MATERIAL AND METHODS

On thirty, post-mortem obtained, adult liver specimens the injection-corrosive method was performed. In the portal trunk uncoloured and in the bile duct coloured odontolite acrylate was injected. After corrosion in the concentrated HCl acid under magnifying lens portobiliary casts were analyzed. Among them 27 casts were with filling of proper quality and on this material were determined:

1. Intrahepatic branching patterns of portal vein
2. Segmental biliary anatomy of each specimen
3. Segmental division of liver based on the portal vein ramification
4. In the frame of anterior sector (AS)-

a) Models of branching of Anterior Portal Vein Branch (APVB) according to its terminal and collateral ramification were analyzed

b) Grouping of collaterals and terminal branches of APVB into subunits i.e. territories of segments 5 and 8 of anterior sector

RESULTS

Based on determined portal and biliary anatomy on 27/30 casts the functional division of liver into Couinaud`s [1] I-IX segments was established. Then models of branching of APVB and grouping of its collaterals and terminal branches into ventral (v) and dorsal (d) subunits of segment (Sg) 5 and 8-Sg 5v, Sg 5d, Sg 8v and Sg 8d of AS were determined as follows:

1. APVB terminated into segment 5 through one or two terminal branches giving previously collaterals to Sg 5 and one collateral to Sg 8

Specimen no. I **AS = Sg 8v + Sg 5v + Sg 5d**
Sg 8v-supplied by one collateral of APVB; Sg 5v-supplied by left terminal branch of APVB and its collaterals and collaterals of APVB; Sg 5d-supplied by right terminal branch of APVB
Specimen no. II **AS = Sg 8d + Sg 5d + Sg 5v**

Sg 8d-supplied by one collateral of APVB; Sg 5d-supplied by collaterals of APVB;
Sg 5v- supplied by terminal branch and collateral of APVB
Specimen no. XVIII **AS = Sg 8d + Sg 5d + Sg 5v**

Sg 8d-supplied by one collateral of APVB; Sg 5d-supplied by one collateral of APVB;
Sg 5v- supplied by terminal branch and collaterals of APVB

2. APVB terminated into segment 8 through one, two or three terminal branches giving previously collaterals to Sg 8 in some cases and collaterals to Sg 5

Specimen no. VIII **AS = Sg 8d + Sg 8v + Sg 5v**
Sg 8d- supplied by right terminal branch of APVB; Sg 8v- supplied by left terminal branch of APVB; Sg 5v-supplied by collaterals of APVB
Specimen no. XVI **AS = Sg 8d + Sg 8v + Sg 5v + Sg 5d**

Sg 8d- supplied by right terminal branch of APVB; Sg 8v- supplied by left terminal branch of APVB; Sg 5v-supplied by collaterals of APVB; Sg 5d- supplied by collateral of Posterior Portal Vein Branch (PPVB)
Specimen no. XX **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by right terminal branch and collateral of APVB; Sg 8v-supplied by left terminal branch of APVB; Sg 5d- supplied by collaterals of APVB; Sg 5v- supplied by collaterals of APVB
Specimen no. XXVIII **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by right terminal branch and collateral of APVB; Sg 8v-supplied by left terminal branch and collateral of APVB; Sg 5d- supplied by collaterals of APVB; Sg 5v- supplied by collateral of APVB
Specimen no. XXX **AS = Sg 8d + Sg 8v + Sg 5v**

Sg 8d-supplied by right terminal branch and collateral of APVB; Sg 8v-supplied by left terminal branch of APVB and its collateral; Sg 5v- supplied by collaterals of APVB
Specimen no. VII **AS = Sg 8v + Sg 5v + Sg 5d**

Sg 8v-supplied by three terminal branches of APVB; Sg 5v- supplied by collaterals of APVB; Sg 5d- supplied by collateral of APVB
Specimen no. XIII **AS = Sg 8v + Sg 5v**

Sg 8v-supplied by left, right and descendant terminal branches and collaterals of APVB; Sg 5v- supplied by collaterals of APVB;
Specimen no. XV **AS = Sg 8d + Sg 8v + Sg 5d**

Sg 8d-supplied by collaterals of APVB; Sg 8v-supplied by terminal branch and collaterals of APVB; Sg 5d-supplied by collaterals of APVB
Specimen no. XXIV **AS = Sg 8v + Sg 8d + Sg 5d + Sg5v**

Sg 8v-supplied by terminal branch and collaterals of APVB; Sg 8d-supplied by collaterals of APVB; Sg 5d-supplied by collaterals of APVB; Sg 5v- supplied by collaterals of APVB
Specimen no. XXII **AS = Sg 8d + Sg5v**

Sg 8d-supplied by terminal branch and collateral of APVB; Sg 5v- supplied by collaterals of APVB and collaterals of Sg 6 Portal Branch (PB)
Specimen no. XXVI **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by collateral of APVB; Sg 8v-supplied by terminal branch and collaterals of APVB; Sg 5d-

supplied by collateral of APVB; Sg 5v- supplied by collateral of APVB
Specimen no. XXVII **AS = Sg 8v + Sg 8d + Sg 5d + Sg 5v**
Sg 8v-supplied by terminal branch and collaterals of APVB; Sg 8d-supplied by collateral of APVB; Sg 5d-supplied by collateral of APVB; Sg 5v- supplied by collateral of APVB, collaterals of Right Portal Vein Branch (RPVB) and collateral of PPVB

Specimen no. XXIX **AS = Sg 8v + Sg 8d + Sg 5d + Sg 5v**

Sg 8v-supplied by terminal branch and collaterals of APVB; Sg 8d-supplied by branch to Sg 8 originating from trifurcation of PPVB into branches to Sg 8, Sg 7 and Sg 5; Sg 5d- supplied by branch to Sg 5 originating from trifurcation of PPVB into branches to Sg 8, Sg 7 and Sg 5; Sg 5v- supplied by collaterals of APVB

3. APVB terminated into segments 8 and 5 separately giving previously collaterals to Sg 8 and to Sg 5

Specimen no. X **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by collateral of APVB; Sg 8v-supplied by terminal branch of APVB; Sg 5d- supplied by two terminal branches of APVB; Sg 5v- supplied by one terminal branch and collaterals of APVB

Specimen no. XI **AS = Sg 8v + Sg 5d + Sg 5v**

Sg 8v-supplied by terminal branch and collaterals of APVB; Sg 5d- supplied by collaterals and one terminal branch of APVB; Sg 5v- supplied by terminal branch of APVB

Specimen no. XIV **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by collateral of APVB; Sg 8v-supplied by right terminal branch and collaterals of APVB; Sg 5d-supplied by collaterals of APVB; Sg 5v- supplied by left terminal branch and collaterals of APVB

4. Mixed model of separately and common ramification of APVB into Sg 8 and Sg 5 through common collateral and/or common terminal branches.

Specimen no. IX **AS = Sg 8d + Sg 8v + Sg $5d_1$ + Sg $5d_2$ + Sg 5v**

Sg 8d-supplied by common branch to Sg 8 and Sg 5 originating from APVB; Sg 8v-supplied by terminal branch and collateral of APVB; Sg $5d_1$- supplied by common branch to Sg 8 and Sg 5 originating from APVB; Sg $5d_2$-supplied by collateral of PPVB; Sg 5v-supplied by collaterals of APVB
Specimen no. XII **AS = Sg 8d + Sg 5d + Sg 5v**

Sg 8d-supplied by terminal branch and collaterals of APVB; Sg 5d- supplied by collateral branch originating from terminal branch to Sg 8 and collaterals of APVB; Sg 5v- supplied by collateral of APVB ramified into Sg 5 as APVB duplex
Specimen no. XXV **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by collateral of APVB; Sg 8v-supplied by terminal branch of APVB; Sg 5d- supplied by collateral of APVB; Sg 5v-supplied by collateral branch originating from terminal branch to Sg 8 and collaterals of APVB

Specimen no. XXIII **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by collaterals of APVB; Sg 8v-supplied by left and right terminal branches of APVB; Sg 5d-supplied by collaterals of APVB; Sg 5v-supplied by collateral branch originating from left terminal branch to Sg 8 and collateral of APVB

Specimen no. III **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by right terminal branch of APVB; Sg 8v-supplied by collateral of APVB; Sg 5d- supplied by collaterals of right terminal branch of APVB; Sg 5v-supplied by left terminal branch of APVB and its collaterals and collaterals of APVB
Specimen no. IV **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

Sg 8d-supplied by collaterals of APVB; Sg 8v-supplied by terminal branch to Sg 8 of APVB; Sg 5d-supplied by collaterals of branch to Sg 8 originating from APVB; Sg 5v-supplied by collaterals of terminal branch to Sg 8, terminal branch to Sg 5 and collaterals of APVB
Specimen no. XXI **AS = Sg 8d + Sg 8v + Sg 5d + Sg 5v**

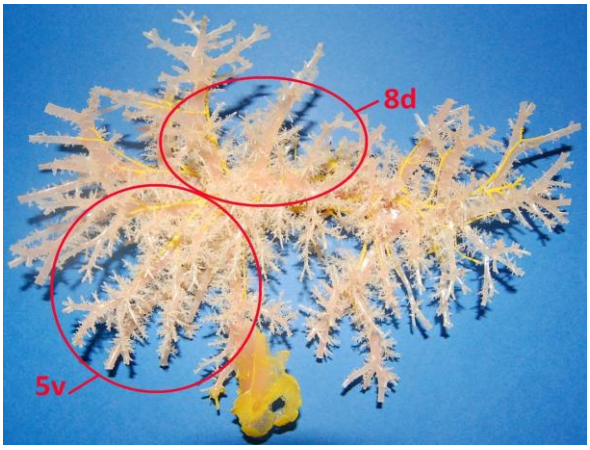
Sg 8d-supplied by collaterals of Posterosuperior Portal Vein Branch (PSPVB) and branch to Sg 8 originating from common branch to Sg 8 and Sg 5 which was collateral of PSPVB; Sg 8v-supplied by common branch to Sg 8 and Sg 5 originating from PSPVB; Sg 5d-supplied by branch to Sg 5 originating from common branch to Sg 8 and Sg 5 which was collateral of PSPVB and collateral of PSPVB; Sg 5v-supplied by collateral of common branch to Sg 8 and Sg 5 originating from PSPVB and collaterals of PSPVB

Specimen no. V **AS = Sg 8d + Sg 8v + Sg 5v**

Sg 8d-supplied by collaterals of APVB; Sg 8v-supplied by right and left terminal branches of APVB; Sg 5v-supplied by collaterals of branch to Sg 8 originating from APVB and collaterals of APVB

When the results were summarized there the types of subdivision were determined as follows:
1. AS = Sg 8v + Sg 5v in specimen no. XIII

2. AS = Sg 8d + Sg 5v in specimen no. XXII, ”Fig. 1A”
3. AS = Sg 8v + (Sg 5v + Sg 5d) in specimens no. I, VII and XI, ”Fig. 1B”
4. AS = Sg 8d + (Sg 5d + Sg 5v) in specimens no. II, XII, XV and XVIII
5. AS = (Sg 8d + Sg 8v) + Sg 5v in specimens no. V, VIII and XXX
6. AS = (Sg 8d + Sg 8v) + (Sg 5d + Sg 5v) in specimens no. III, IV, X, XIV, XVI, XX, XXI, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII and XXIX, ”Fig. 1C”
7. AS = (Sg 8d + Sg 8v) + (Sg $5d_1$ + Sg $5d_2$ + Sg 5v) in specimen no. IX



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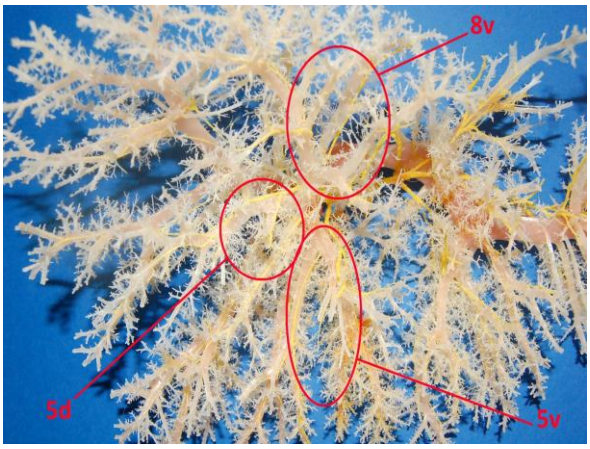

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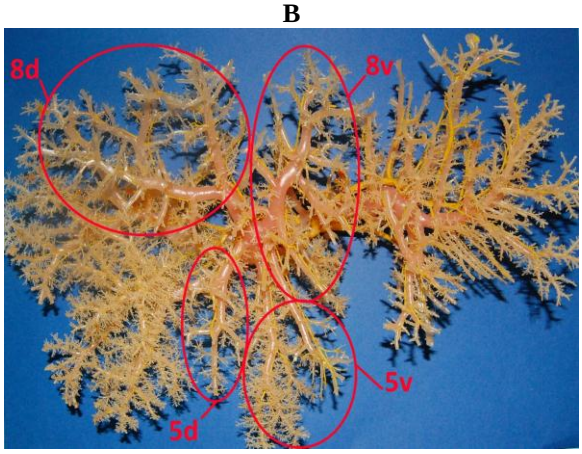

C

Figure 1. On portobiliary casts anterior view some different types of anterior sector segments subdivision are presented. The portal branches for subunits 8d, 8v, 5d and 5v are marked in red. A- specimen no. XXII with type 2 subdivision; B- specimen no. XI with type 3 subdivision; C- specimen no. XXV with type 6 subdivision

DISCUSSION

The study results confirmed Couinaud`s [1] concept of liver segmental anatomy i.e. functional division of liver into I-IX segments. The anterior sector of right hemiliver on each specimen was divided into segment 8 and segment 5. But, concerning the other investigators`s findings the further subdivision was analyzed.

The determined types of subdivision showed that subdivision at the level of the third-order portal branches was common in a little more than one half of specimens and that there were some different types of subdivision of either one or both segments.

Moreover, these results are in agreement with the Kogure et al.[9] point of view that there were 2 portal subsegmentations in the anterior segment. Their analysis of the hepatic venous system of the anterior segment suggested that there was a vertical fissure located by an intersubsegmental hepatic vein or a branch of the middle hepatic vein or the right hepatic vein.

A similar observation was reported by Hata et al.[7] about venous tributaries in the upper region of the right lobe. They classified these tributaries into 5 types of ’’Right Superior Radicles”(RSR): anterior, posterior, lateral, medial and intersegmental from which the lateral RSR running along course was located between portal 8 dorsal (P8d) and portal 8 ventral (P8v) branches.

Also, similar to this study were the results presented by Kaneko et al. [13]. They identified the hepatic segments of Couinaud`s segmentation in all analyzed cases. But, anterior fissure vein (AFV) could be identified in 85% and in several cases it transversed from the cranial to the caudal side. Although the AFV was identified in these cases, it was difficult to determine the border between the AVS and ADS.

On contrary to the IHPBA Brisbane 2000 terminology reviewed by Strasberg [15], there is a classification in the literature based on the ramification of the secondary Glissonean pedicle. According to this classification the liver was divided into right (S6, S7), middle (S5, S8) and left (S2, S3, S4) segments and a caudate area (S1). The area supplied by each of the tertiary branches was cone-shaped-”cone unit”. Each segment was composed of 6 from 8 cone units.[16]

Yamamoto et al. [17] proposed Glissonean pedicle transection method for liver surgery and explained how to approach the tertiary branches. The tertiary branches

in the right liver close to the hepatic hilus can be approached around the secondary pedicle near the hepatic hilus. The tertiary branches that originate from the deep portions of the secondary pedicles cannot be approached from the hepatic hilus but after initially dissecting the liver parenchyma on the border between the sections. Such cone unit resection can be made when liver function is insufficient for sectionectomy.

According to the Chouillard et al.[18] experience monosegmentectomies can be used for peripheral lesions, but some tumors might require extensive liver resection and in such cases bi-right inferior bisegmentectomy (segments 5 and 6), right superior bisegmentectomy (segments 7 and 8), central anterior (segments 4b and 5) and central posterior (segments 4a and 8) and trisegmentectomy could represent an alternative to extensive hepatectomies. For surgical removal of centrally located hepatocellular carcinomas mesohepatectomy involving removal of liver segments 4, 5 and 8 was reported by Kattepur et al.[19]

A new approach which allowed selective disclosure of each subsegmental branch to segment 8 (P8v and P8d) rather than allowing complete or partial anatomical resection of segment 8 using the ultrasound-finger compression technique was reported by Torzilli et al.[20]

From clinical application aspects, it is important to comment the results of this study regarding the interrelationship between anterior sector portal vein ramification models and types of subdivision of their segments. In the first model of branching of APVB segment 8 was supplied only by one collateral of APVB and presented as either ventral or dorsal subunit that is the most suitable case for total or cone resection of segment 8. More difficult for such surgery are the cases of the second model, which dorsal, ventral or both dorsal and ventral subunits of segment 8 were supplied additionally to the terminal branches by collaterals of APVB and especially by a branch with origin other than APVB. Segment 5, subdivided or not into subunits, was supplied only by collaterals. In the third model of ramification there was a common termination of APVB into both segments and despite the presented collaterals it is more suitable for bisegmentectomies (segments 8 and 5). The fourth i.e. mixed model of ramification is very complex because of the common supply to Sg 8d and Sg 5d; Sg 8v and Sg 5v; at the same time to the ventral and to the dorsal subunits and only once to Sg 8d and Sg 5v. The common supply was through a collateral or a terminal branch.

CONCLUSIONS

Anterior sector of liver in all investigated cases was divided into segments 8 and 5. Based on the terminal and collateral ramification of APVB into these segments a further subdivision into ventral and dorsal subunits was noted. Most frequently both segments were subdivided into ventral and dorsal subunits (51.85%), then only segment 5 was subdivided in 25.93%, only segment 8 was also subdivided in 11.11%, then both segments not subdivided but in one case only with ventral subunits and in the other one only with dorsal segment 8 and ventral segment 5 subunits in 7.41% and in the last one 3.70% with dorsal and ventral segment 8 subunits and two dorsal and one ventral segment 5 subunits.

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