Comparative Study on Portobiliary Elements of Right Hemiliver Posterior Sector

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ABSTRACT

Introduction: Intrahepatic anatomy of the liver is very complex to understand. This study was aimed at contributing to hepatobiliary practice, which means liver transplantation, resection or intervent right hemiliver surgery, portal vein ligation or embolization.

Material and Methods: Using injection-corrosive method 27 portobiliary casts out of 30 cadaveric liver specimens were made and analyzed. Under magnifying lens the portal vein branching patterns and biliary ducts merging patterns were analyzed and then compared at the level of right hemiliver posterior sector.

Results: The comparison has shown incomparable prevalence of portal and biliary anatomy as follows: main portal vein bifurcation in 88.89% and trifurcation in 11.11% of cases, in contrast to right hepatic duct present in 55.55% and absent in 44.44% of cases. Right portal vein branch conventional anatomy was observed in 59.26% of casts, and among them posterior portal vein branch conventional anatomy was observed in 29.63%. The plurality of the branches supplying segment 6 was found in a high percent of 51.85%. Comparison of ramification patterns of the posterior portal vein branch with merging patterns of the segmental ducts into posterior sector duct showed coincidence in 13/19 (68.42%) casts with modal type of merging into posterior sector duct and among the cases with different modalities of merging only in 2/8 (25%). In all levels of portobiliary branching there was only one specimen 1/27 (3.70%) with conventional anatomy in the right hemiliver.

Conclusion: Normal and variant portal vein anatomy may be accompanied with comparable or variant biliary anatomy.

Keywords: anatomy, biliary duct, liver, portal vein, right hemiliver posterior sector

INTRODUCTION

Intrahepatic anatomy of the liver according to the ramification patterns of inflow and/or outflow vasculobiliary elements was investigated by the eminent anatomists Couinaud[1-3], Gupta et al.[4-7] and as an integral part of the hepatopancreatobiliary clinical practice. Literature related to investigation of the functional anatomy of the liver and new knowledge of anatomical variations during modern diagnostic-therapeutic methods was used.[8-15] This applicable aspect of the liver anatomy was the leading motive to conduct this comparative study on portobiliary anatomy of the right hemiliver posterior sector.

MATERIAL AND METHODS

A total of 30 cadaveric liver specimens were analyzed. After careful dissection of hilar area the injection–corrosive method was performed. The portal vein as a basic element of liver functional subdivision with uncoloured odontolitic acrylate was injected and then colored acrylate was injected into common hepatic duct. Such injected specimens were placed in concentrated HCl acid under corrosion for 5-7 days. The obtained portobiliary casts under magnifying lens were analyzed.

On 27/30 casts of proper quality the following was determined:

I a) Presence or absence and branching patterns for: Main Portal Vein (MPV), Right Portal Vein Branch (RPVB) and Posterior Portal Vein Branch (PPVB)
b) Frequency and origin of segment 7 and 6 portal branches

II a) Biliary ducts-merging patterns
b) Comparison of PPVB branching patterns and Posterior Sector Duct (PSD) merging patterns
c) The site of junction of segmental ducts into PSD

RESULTS

I a) MPV: Present in 27/27 cases.

MPV Branching Patterns:

Bifurcation into: LPVB and RPVB *in 24/27 cases (88.89%)*; Cases marked as I, II, III, IV, V, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVIII, XX, XXI, XXII, XXIII, XXV, XXVI, XXVII and XXVIII.

Trifurcation_into: a) LPVB, APVB and PPVB *in 2/27 cases (7.41%)*; Cases marked as XXIV and XXIX, b) LPVB, APVB and Sg 7 PB *in 1/27 cases (3.70%)*; Case marked as XXX.

b) RPVB: present in 24/27 cases (88.89%); absent in 3/27 cases (11.11%).

RPVB Branching Patterns:

Bifurcation into: a) APVB and PPVB *in 16/27 cases (59.26%)*; Cases marked as I, II, V, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XX, XXII, XXVI and XXVII, b) APVB and Sg 7 PB *in 2/27 cases (7.41%)*; Cases marked as XXV

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How to cite this article: Dragica Jurkovikj. Comparative study on portobiliary elements of right hemiliver posterior sector. International Journal of Contemporary Medical Research 2016;3(2):546-550.

and XXVIII, c) Posterosuperior branch and Anteroinferior branch *in 1/27 case (3.70%)*; Case marked as XXI.
Trifurcation into: APVB, Sg 7 PB and Sg 6 PB *in 3/27 cases (11.11%)*; Cases marked as VII, XVIII and XXIII.
RPVB with arch-like appearance continue as APVB *in 2/27 cases (7.41%)*; Cases marked as III and IV.

PPVB: present in 20/27 cases (74.1%); Cases marked as I, II, III, V, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XX, XXI, XXII, XXIV, XXVI, XXVII and XXIX, absent in 7/27 cases (25.9%); Cases marked as IV, VII, XVIII, XXIII, XXV, XXVIII and XXX.
PPVB Branching Patterns:

1. Simple bifurcation into: Sg 6 PB and Sg 7 PB *in 8/27 cases (29.63%)*; Cases marked as I, III, XI, XIII, XIV, XV, XXVI and XXVII.
2. Continue as Sg 7 PB with arch-like appearance: a) Gave origin to Sg 6 PB *in 6/27 cases (22.22%)*; Cases marked as II, V, X, XII, XX and XXIV, b) Gave origin to Sg 6 PBs and Sg 5 PBs *in 2/27 cases (7.41%)*; Cases marked as IX and XVI.
3. Trifurcation into: a) Sg 7 PB, Sg 6 intermediate PB and Sg 6 main PB *in 2/27 cases (7.41%)*; Cases marked as VIII and XXII, b) Sg 8 PB, Sg 7 PB and Sg 5 PB *in 1/27 case (3.70%)*; Case marked as XXIX.
4. PPVB originating from RPVB as Posterosuperior branch gave origin to Sg 9, Sg 1, Sg (8+5), Sg 5 PBs and continued as Sg 7 PB *in 1/27 case (3.70%)*; Case marked as XXI.

I b) Segment 7 Portal Branch-was a unique branch in all observed specimens 27/27 (100%).
It took origin from: PPVB in 21/27 cases (77.8%); RPVB in 4/27 cases (14.8%); APVB in 1/27 cases (3.70%) and MPV in 1/27 cases (3.70%).

Segment 6 Portal Branch-was present in variable number with different origin as follows:
Unique branch in 13/27 cases (48.15%); b) Two branches in 9/27 (33.33%); c) Three branches in 2/27 cases (7.41%) and d) Four branches in 3/27 cases (11.11%).
As a unique branch originating from the main portal stems the following was observed:
From PPVB in 9/13 (69.23%); from RPVB in 3/13 (23.07%) and from APVB in 1/13 cases (7.7%).
In cases with two Sg 6 PBs took origin: from PPVB in 5/9 cases (55.55%), from PPVB and RPVB in 1/9 cases (11.11%); from Sg 7 PB in 1/9 cases (11.11%); from PPVB and APVB in 1/9 cases (11.11%) and from Sg 7 PB and RPVB in 1/9 cases (11.11%).
When there were three branches, they all took origin from PPVB-1/2 (50%) except in one case when two branches took origin from APVB and one from PT-1/2 (50%).
When there were four branches, they all took origin from PPVB in 1/3 cases (33.33%), then all branches from Sg 7 PB in 1/3 cases (33.33%) and the last one with three branches originated from Sg 7 PB and one branch from APVB in 1/3 (33.33%).

II a) BILIARY DUCT-MERGING PATTERNS
From the total number of specimens in which the modal type of merging pattern of the segmental ducts (7+6) into PSD was found-19/27 (70.37%) cases marked as I, II, III, IV, V, VII, VIII, X, XII, XV, XVI, XX, XXIV, XXV, XXVI, XX-VII, XXVIII, XXIX AND XXX, only 4 specimens were with equal numeric relationship 1/1 between segmental portal and biliary elements. This is shown in Table 1.
Analysis of biliary drainage in specimens with two ducts from Sg 7 showed that it was limited to Sg 7, but in three of them (specimens marked as I, XII and XXV) the drainage area of the second duct from Sg 7 was limited to vascular area of one collateral of Sg 7 PB. The confluence of the second duct was into Sg 6 duct (cases no. I and XXV) and into PSD (case no. XII). The remaining two cases (no. X and XVI) were with two segmental ducts along Sg 7 PB but the second duct was a tributary of PSD.
Analysis of biliary drainage of Sg 6 showed that except as constituent to PSD in cases with modal type of merging **(7+6),** in specimens with two segmental ducts from Sg 6 the participation of both or one duct into the forming of PSD

segment	Number of portal branches/number of segmental ducts							
	1/0	**1/1**	**1/2**	**2/1**	**2/2**	**3/1**	**4/1**	**4/4**
Sg 7 No. of cases	XXVI	II, III, IV, V, VII, VIII, XV, XX, XXIV, XXVII, XXVIII, XXIX, XXX	I, X, XII, XVI, XXV	Nil	Nil	Nil	Nil	Nil
Sg 6 No. of cases	Nil	I, II, III, VII, X, XXV, XXVI, XXVII	Nil	V, VIII	IV, XV, XVI, XXIV, XXX	XX	XXIX	XII, XX-VIII
Total	1	21	5	2	5	1	1	2

Table-1: Quantitative relationship of segmental portal and biliary elements destined to segments 7 and 6

was determined. The second duct was either the tributary of PSD or of ASD.
In the specimens with four ducts from Sg 6 the participation of all ducts in the forming of PSD was found or only one was a constituent duct and the remaining three were tributaries of PSD.

II b) Concerning the analyses of PPVB branching patterns and of PSD merging patterns for the mentioned 19 specimens the coincidence in the majority of them 13/19 (68.42%) was found on contrary to the cases with absent PPVB and present PSD 6/19 (31.58%).
For specimens with different modalities of merging of the segmental ducts into **PSD** the implication of more than two constituent ducts was found, especially when they came from drainage area of the neighboring segment, as follows:

- 7+(6+5) in specimen no. IX with comparable terminal ramification of PPVB
- 7+(7+6) in specimen no. XI with two ducts from Sg 7 and simple bifurcation of PPVB
- (7+7)+6 in specimen no. XIII with three Sg 7 ducts from which the last one was a tributary of PSD while PPVB simply divided into Sg 7 and 6 branches
- (7+6+5) in specimen no. XIV with second duct from Sg 7 which was a tributary of PSD and a simple bifurcation of PPVB
- (6+6) in specimen no. XVIII with one Sg 7 duct which was a tributary of PSD. On the contrary to the RPVB trifurcation into APVB, Sg 7 PB and Sg 6 PB a separate confluence of PSD and ASD on the opposite side was observed
- 7+[(7+6)+5] in specimen no. XXIII with absent PPVB
- Prolongation of Sg 7 duct into PSD in specimen no. XXII with magistral way of confluence of 7, 9d, 6, 9b, 1 right portion with caudate process and 1 left portion with 9b segmental ducts. Contrary to the presence of RPVB and PPVB a separate confluence of PSD and ASD on the opposite side was observed
- Prolongation of Sg 7 duct into PSD and consequently into RHD in specimen no. XXI with magistral way of confluence of 7, 6, 5, 9, 1, 8+5 and 4b segmental ducts. The RPVB ending was comparable.

II c) Also, the site of junction of segmental ducts into PSD was determined and it was found to lay at these different levels:

1. **At the level of PPVB: a)** At the middle of anterior surface in specimens marked as I, V and XX; b) At the anterior surface of terminal bifurcation in specimens marked as IX, XII, XIV and XVI; c) At the anterior surface of terminal part in specimen marked as XXIV and d) Above the initial part of posterior border in specimen marked as XXVII.
2. **At the level of Sg 7 PB-**anterior surface of the initial part in specimens marked as II, III, VII, VIII, X, XIII, XV, XXII, XXIII, XXV, XXVI, XXVIII, XXIX and XXX.
3. **At the level of Sg 6 PB-**anterior surface of the initial part in specimens marked as IV and XVIII.
4. **At the level of APVB-**posterior surface of the beginning part in specimen marked as XI.
5. **At the level of anteroinferior terminal branch of RPVB**-anterior surface of the initial part in specimen marked as XXI.

DISCUSSION

The French anatomist and surgeon Claude Couinaud[3] spent many years in investigation of the liver anatomy. He said that if the order of branches (ducts) was higher the anatomical varieties were numerous. Also, at the level of first order of portal, arterial and biliary elements he had established that arterial and biliary duplications were more frequent in relation to the portal ones.
In the present study MPV in all analyzed cases (27/27) was observed. In the literature absent portal vein bifurcation and a single intrahepatic portal venous arch as a rare variant were described by Couinaud[3] and Sahoo et al.[16]
A conventional anatomy of portal ramification in the right hemiliver was presented in a very high percentage i.e. portal vein bifurcation into the left and right branches, and trifurcating was rare, which was in agreement with the results (88% and respective 12%) presented by Gupta et al.[6]
Comparison of portobiliary elements of the hepatic order showed that: RPVB in 24/27 cases (88.89%) was present and in 3/27 cases (11.11%) was absent contrary to RHD found in 15/27 cases (55.55%) and in 12/27 cases (44.44) was absent (replaced by two sectoral ducts with confluence on the opposite site). Also, the comparison of specimens without portobiliary elements of the hepatic order showed discrepancy as follows: RPVB in specimens marked as XXIV, XXIX and XXX was absent, while RHD among those specimens was absent only in the specimen marked as XXIV. So, the absence of RPVB/RHD was in relation 3/1.
Similar to the found variations in the branching patterns of RPVB was the variant portovenous anatomy detected in 35% on the CT portographies by Covey et al.[17] They also noted that branches to segments VII and VI were separate branches originating from right portal vein and finding of trifurcation into APVB, Sg 6 and Sg 7 PBs. However, according to these authors' opinion conventional arterioportography was limited in determining segmental branch patterns.
Atasoy and Ozyurek[18] investigated the prevalence of variant main and right portal vein ramification with MDCT and among patients with conventional MPV branching (65.5%) variant right portal vein branching was found in 16.8%.
Van Leeuwen et al.[19] in their in vivo study illustrated that right hemiliver was divided into an anterosuperior sector and a posteroinferior sector. Additionally, a total of 15 accessory portal sectors were present, each arising directly from the portal bifurcation or the right portal trunk. The same year van Leeuwen et al.[20] found a conventional branching pattern in 2 of 10 volunteers, wherein no portal branches crossed the segmental boundaries. As they stated, the studies based on corrosion specimens, described a large number of variations

in ductal branching patterns and segmental anatomy.
In support to the above-mentioned statement are the results of our study about ramification patterns of PPVB. They are in agreement with the investigated aspects of the vascular morphology in the posterior sector by Hata et al.[21] Using the dissection they described four major patterns of branching of the posterior sectorial trunk of the portal vein system: group A (32%) an arch-like pattern sending multiple branches to Sg 6 and Sg 7; group B (27.9%) bifurcation into branches to Sg 6 and Sg 7 that allowed to identify segments 6 and 7 based on the portal vein system; group C (6.6%) trifurcation into branches to Sg 6, Sg 7, and an intermediate branch, which supplied both segments or a gray zone between them and group D (33.5%) included variations of the anterior segmental branches, and in specimens of this group, the anteromedial border of the sector was difficult to identify. They pointed out the difficulty in discriminating the intermediate branch from a branch to Sg 7.
Analysing the branching patterns of RPVB and
PPVB and origin of Sg 6 and Sg 7 PBs it was noted that these segmental branches can have a total or partial origin from the APVB or can form trifurcation with this branch. This finding is in agreement with Couinaud's[22] investigation on injection-corrosion casts.
The observed plurality of the branches supplying Sg 6 may be a cause of postoperative complications but on the other hand this feature may be of positive surgical sentence when one accessory portal branch, on contrary to the main segmental portal branch, supplies the affected area.
The new surgical technique for a precise tailoring of the area of hepatic resection using inflow and outflow modulation was described by Donadon et al.[23]
At the level of right hemiliver posterior sector only PPVB as variable was observed while PSD was present in all observed cases. Comparison of ramification patterns of the PPVB with merging patterns of the segmental ducts into PSD encountered very different relationships.
Among the cases with modal type of merging into PSD in 13/19 (68.42) coincidence was found, contrary to 6/19 (31.58%) cases with absent PPVB and present PSD. Also, among the cases with different modalities of merging of the segmental ducts into PSD 8/27 (25.9 %) only in 2/8 (25%) cases coincidence was found. Even among the cases with modal type of merging into PSD there was a case with very significant differences of portobiliary anatomy, for e. g. No. XXX with absent RPVB and PPVB but present RHD and PSD, (Figure 1 and 2).
In the Greek cadavers atypical branching patterns of the RHD were found in 34.25% of cases, of which in 4.11% drainage of the right posterior hepatic duct into the left hepatic was found.[24] Using the intraoperative cholangiograms of 300 consecutive LDLT donors Choi et al.[25] noted typical anatomy of the intrahepatic ducts in 63% and as the most common anatomic variant drainage of the PSD into LHD in 11% of donors.
The current trend of using MR cholangiography as modality of choice in the evaluation of biliary diseases and the increasing complexity of hepatic surgical procedures and biliary interventions, however, necessitate a more widespread and appropriate knowledge of these anatomic variations.[26]
On the basis of MDCT angiography and MDCT cholangiography the second order portal venous variants in 10 (18%) and biliary branch variants in 23 (41%) of 56 patients were seen by Chen et al.[27] They found that concordance between second-order portal venous and biliary tract anatomies was statistically significant. According to Macdonald et al.[28] on the preoperative hepatic CT scans and intraoperative cholangiograms portal venous and hepatic arterial branching patterns did not correlate well with biliary anatomic variants. Biliary anomalies in 15 (38%) of 39 patients were present. Of 23 patients with anomalous vascular anatomy, 7 (30%) had biliary anomalies. Of 16 patients with conventional vascular anatomy, 8 (50%) had biliary anomalies.
Variant PV anatomy in 52 (13%) of 386 transplants using right lobe grafts associated with a high (54%) incidence of biliary variations was seen by Guler et al.[29] Similar report on this subject was given by Ozsoy et al.[30] about vascular and biliary variations in Turkish liver donors. The relationship between the bile ducts and portal vein variants showed high probability of coinciding variations of bile ducts in subjects

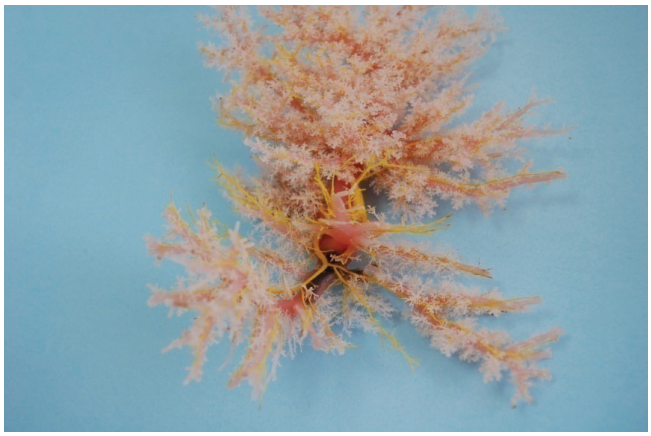

Figure-1: Right-anterior view of the portobiliary cast from specimen no.XXX. Posterior sector duct formed by segment VII and VI ducts vaults above the APVB arch.

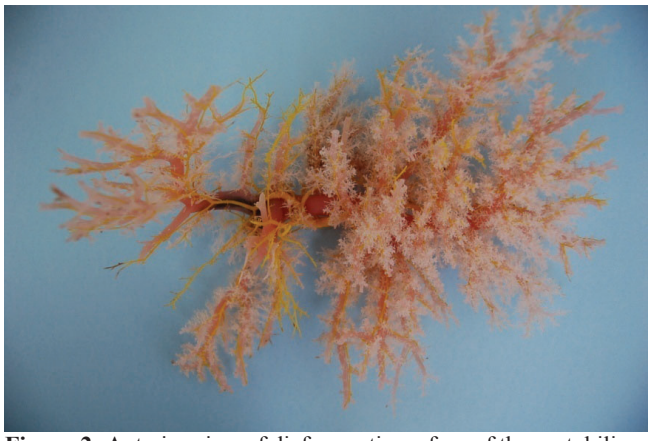

Figure-2: Anterior view of diafragmatic surface of the portobiliary cast from specimen no. XXX. PSD and ASD merge into short RHD anterior and below to the transverse part of the LPVB.

with portal vein variants.
Concerning the all levels of portobiliary branching in the present study only one specimen (no. III) was with conventional anatomy in the right hemiliver.

CONCLUSION

Normal portal vein anatomy may be accompanied with comparable or variant biliary anatomy as well as variant portal vein anatomy may be accompanied with comparable variant or normal biliary anatomy.

ABBREVIATIONS

Left Portal Vein Branch (LPVB); Anterior Portal Vein Branch (APVB); Segment (Sg); Portal branch (PB); Portal branches (PBs); Portal Trunk (PT); Anterior Sector Duct (ASD); Right Hepatic Duct (RHD); Portal Vein (PV); Left Hepatic Duct (LHD)

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Source of Support: Nil; **Conflict of Interest:** None

Submitted: 02-01-2016; **Published online**: 23-01-2016