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Hepatic portal vein branching patterns according to different liver assessment methods and classifications of branching type

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ABSTRACT

Background: It is known that there are varying frequencies of hepatic portal vein branching patterns found in the literature. Studies use different methods and classifications to evaluate the anatomy of the portal vein, which limits accurate comparison between studies and the determination of true frequency of branching patterns in different populations. The aim of the present study was to investigate the intrahepatic branching of the portal vein in corrosive samples using different methods – somatoscopic and computed tomography (CT) and compare with similar studies as well as compare the reclassified data according to the most popular classifications used in the literature.

Methods: A total of 105 liver corrosion specimens from the 1960–1980 period (51 male and 54 female individuals; min-max age variation – 21–90 y., M=59,46 y.) were investigated. The branching patterns of the hepatic portal vein (HPV), left (HPV-LB) and right branch of hepatic portal vein (HPV-RB), and their segmental branches were examined and scanned by CT. Standard HPV ramification was considered, when HPV divided into HPV-LB and HPV-RB, HPV-RB bifurcated to the anterior and posterior branches, and further segmental ramification into the superior and inferior branches was considered standard. We compared the HPV main branch length and diameter measurements between manual and CT method. A review of the literature was performed on portal vein branching variations.

Results: The standard HPV ramification pattern was detected in 85.7% of the cases in both somatoscopic and CT evaluation. Variations related to the main branches were HPV trifurcation – 7.6%, posterior branch of right branch of hepatic portal vein from HPV – 4.8% and 5.7%, HPV quadrifurcation 1.9% and 1% respectively, in somatoscopic and CT evaluation. There was a significant difference between HPV-LB length and diameter in CT and manual measurements. According to the literature, more variations are seen using the CT method versus somatoscopic corrosion cast evaluation. The varying frequency in studies may be explained by a lack of one unanimous classification of branching patterns (some authors do not consider segmental variations as standard HPV ramification) and different evaluation methods.

Conclusion: Somatoscopic evaluation of the branching patterns of the hepatic portal vein in corroded specimens and their CT reconstructions did not differ significantly (which allows relatively accurate comparison of old specimens with newer data). However, the ability to evaluate the reconstructed 3D images of the specimens allowed a more accurate assessment of segmental branching and measurements of lengths and diameters. Standard HPV branching (according to a self-developed classification) in this study was 85.7%. Depending on the classification, the rate of standard branching in the same corrosive samples varied from 63.8% to 84.8% of all

Abbreviations: CTA, computed tomography angiography; CT, computed tomography; HPV, hepatic portal vein; HPV-LB, left branch of hepatic portal vein; MRI, magnetic resonance imaging; HPV-RB-AB, anterior branch of right branch of hepatic portal vein; HPV-RB, right branch of hepatic portal vein; HPV-RB-PB, posterior branch of right branch of hepatic portal vein; HPV-RB-PSB, posterior superior branch of right branch of hepatic portal vein; HPV-RB-PIB, posterior inferior branch of right branch of hepatic portal vein.

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cases, indicating that the lack of a unified and stable classification makes it difficult to compare the results of different studies. Deviations from standard branching are very important in surgical procedures and liver transplantation.

1. Introduction

The hepatic portal vein (HPV) is the main blood vessel transporting blood from the gastrointestinal tract (apart from the lower section of the rectum), spleen, pancreas, and gallbladder to the liver (Geller et al., 2019; Olivetti, 2015). The portal vein is formed by the confluence of the splenic and superior mesenteric veins (and sometimes by the inferior mesenteric vein, as it usually confluences to the splenic or superior mesenteric vein or to the confluence angle of both veins (Rocha, 2012; Bergman et al., 1996)) and contributes approximately 75–80% of the hepatic blood supply. The functional segmental anatomy of the liver is determined by the distribution of the portal and hepatic veins, as the well as biliary branches (Olivetti, 2015).

Normally, HPV splits at porta hepatis into the right branch of hepatic portal vein (HPV-RB) and the left branch of hepatic portal vein (HPV-LB). This is the standard branching reported by various articles in 65–80% of cases (Geller et al., 2019). The HPV-RB further divides into the anterior branch of right branch of hepatic portal vein (HPV-RB-AB) and the posterior branch of right branch of hepatic portal vein (HPV-RB-PB) that supply Couinaud liver segments V and VIII and segments VI and VII, respectively (Covey et al., 2004). The HPV-LB divides into branches that supply the caudate lobe (segment I), the quadrate lobe (segment IV) and lateral segments (segments II and III) (Covey et al., 2004; Geller et al., 2019). There are two common variations from main branching reported in the literature. The most common one is trifurcation of the HPV, when the HPV-RB-AB and HPV-RB-PB divide from the portal trunk at the same point as the HPV-LB. And the other one is the HPV-RB-PB coming off the HPV rather than from the HPV-RB (Anwar et al., 2020; Arviza et al., 2021; Asad Ullah et al., 2020; Cheng et al., 1997; Covey et al., 2004; Nakamura et al., 2002; Sureka et al., 2015). Another common variation is that individual segmental branches arise away from their usual point of origin (Adhikari et al., 2021; Minami et al., 2020; Rajput et al., 2014). Not many studies until the year 2000 have explored the different types of portal venous branching (Atri et al., 1992; Cheng et al., 1997; Fraser-Hill et al., 1990; Yamane et al., 1988; Inoue et al., 1986; Soyer et al., 1995). However, since then and especially in recent years it has become an increasingly popular subject.

Knowledge of possible variations in hepatic portal vein (HPV) is essential for surgical planning of hepatectomy and liver transplantation, as well as interventional radiology procedures (Covey et al., 2004; Erbay et al., 2003; Munguti et al., 2013; Sureka et al., 2015). For example, HPV trifurcation and HPV-RB-PB branching from the HPV are especially important as the recipient requires two vein anastomoses (Covey et al., 2004; Sureka et al., 2015). Regarding the donor, when resecting a lobe with a certain segmental variation, a part of the liver could be devascularized (Sureka et al., 2015). HPV anatomical branching is important for interventional radiology procedures such as the formation of a transjugular intrahepatic portosystemic shunt (especially variations such as HPV trifurcation, HPV-RB-PB from the HPV, HPV-RB-AB from HPV-LB could make HPV-RB appear smaller) and portal vein embolisation (HPV trifurcation or quadrifurcation can result in difficult catheterisation and migration of embolic materials). Portal vein branching variations are also associated with variations in the bile ducts (Sureka et al., 2015). The anterior hepatic portal venous branch arising deep in the parenchyma accompanied by an intraparenchymal anterior biliary tributary should be considered as a contraindication for liver grafting due to the difficulty of reconstruction (Nakamura et al., 2002). An understanding of portal, hepatic vein and artery variations allows accurate localisation and efficient surgical treatment of liver lesions (Sureka et al., 2015).

However, comparing different sources from the literature is a difficult task due to methodological differences in the classification of branches and ramification patterns of the hepatic portal vein. Most studies do not use any specific classification and create descriptive (self-constructed) classifications of each HPV variation (Adhikari et al., 2021; Arviza et al., 2021; Koc et al., 2007b; Minami et al., 2020; Rajput et al., 2014). This could be explained by the lack of a unified classification of HPV branching patterns. However, there are several classifications that are commonly used across different studies: (Covey et al., 2004, Nakamura et al., 2002, and Cheng et al., 1996).

There are different imaging methods to evaluate HPV and its variations. Methods like computed tomography angiography (CTA), magnetic resonance imaging (MRI), Doppler ultrasound, and somatoscopic evaluation of corrosion specimens can be found in the literature. In most studies, CTA is a preferred technique for HPV evaluation, permitting the evaluation of portal blood vessels in high resolution multiplanar reformations and three-dimensional reconstructions. MRI can potentially evaluate vascular structures without using intravenous contrast and ionising radiation. However, compared to CT, MRI takes more time, is more susceptible to artefacts, more expensive, and less accessible (Guerra et al., 2017; Lin et al., 2019; Marcin et al., 2014; Tirumani et al., 2014). Doppler ultrasound allows one to evaluate venous flow and get anatomical information. However, this method is operator dependent, can be conditioned by body habitus and lack of patient collaboration (Carneiro et al., 2019; Ghany et al., 2022; Gomella et al., 2022).

Many anatomical departments have collections of ancient anatomical specimens (as well as corrosive preparations) that can be studied even today (Arora et al., 2003; Debbaut et al., 2014; Ioanoviciu et al., 2015; Shrikantaiah et al., 2018) but the question is whether visual (somatoscopic) assessment of branching types of the hepatic portal vein can sufficiently and objectively indicate the variations of the hepatic portal vein, and what are the differences when comparing the same hepatic specimens using somatoscopic and CT evaluation. A comparative analysis of computed tomography and somatoscopic methods would allow a better comparison of the results between studies performed on corrosive liver specimens with modern imaging studies of portal vein variations in living individuals. Detailing the anatomical knowledge of HPV is of clinical and radiological relevance when talking about various previously mentioned complex procedures.

The aim of the present study was to investigate the intrahepatic branching of the portal vein in corrosive liver specimens using different evaluation methods (somatoscopic and CT) as well as classifications of portal vein branching, and to compare these results with similar studies.

2. Materials and methods

2.1. *Corrosion specimens*

A total of 105 liver corrosive cast specimens from Vilnius University, Faculty of Medicine, Department of Anatomy, Histology and Anthropology collection, prepared between 1960 and 1980, were investigated. A total of 105 liver corrosion specimens (51 male and 54 female) were included in this study, with a mean age of 59.46 ± 15.16 years, the age range of the subjects in this study was 21 – 90 years.

In the period from 1960 to 1980, liver corrosive specimens for examining the portal vein were produced in the following way. The hepatic portal vein was injected with polymethyl methacrylate (PMMA) with the addition of pigment to colour the vein trunk and its branches. Standard syringes (20 ml) were used for injections. After injection, heat treatment (up to 2 hours in boiling water) was performed, and then the specimens were placed in a container with a 20% sulphuric acid solution. Corrosion time of the organs varied up to two weeks depending on the size of the sample, with regular (daily) washing of the sample with running water to totally remove the tissues.

Because the study involves plastic replicas of the portal vein, made approximately 50 years ago, which do not contain human biological material (which was completely removed during sample preparation) and are not linked to personal data, this type of research is outside the scope of the Research Ethics Committee (REC) according to the Law on Ethics of Biomedical Research of Republic of Lithuania, and therefore has not been submitted for the REC approval.

2.2. Evaluation and imaging

Branching patterns of the hepatic (HPV), left (HPV-LB), right branch of hepatic portal vein (HPV-RB) and their segmental branches were examined somatoscopically and scanned with a 64 slices CT scanner GE Medical Systems Discovery CT750HD. Parameters used: total collimation width – 40 cm, single collimation with – 0.625 mm, slice thickness – 1.25 mm, spacing between slices – 1.25 mm, window width – 350. Three-dimensional reconstructions of the corrosive cast specimens were made (Fig. 1) and investigated using RadiAnt (Medixant, Poland) DICOM viewer (window length: 189, window width: 1903).

*HPV – hepatic portal vein, HPV-LB – left branch of hepatic portal vein, HPV-RB-AB – anterior branch of right branch of hepatic portal vein, HPV-RB-PB – posterior branch of right branch of hepatic portal vein, HPV-RB – right branch of hepatic portal vein, HPV-RB-PSB – posterior superior branch of right branch of hepatic portal vein, HPV-RB-PIB – posterior inferior branch of right branch of hepatic portal vein.

2.3. Classification of hepatic portal vein branching patterns

In the present study standard HPV ramification was considered, when HPV divided into HPV-LB and HPV-RB, HPV-RB bifurcated to the anterior and posterior branches, further segmental ramification into the superior and inferior branches was considered standard. The self-developed classification (Table 1) of this study included the main branch variations (trifurcation of HPV, HPV-RB-PB as the first branch of HPV, quadrifurcation of HPV) and the variations of segmental branches that were considered standard branching patterns if the main branch variations were absent. The lengths and diameters of HPV-LB and HPV-RB were compared between manual measurements (performed directly on corrosive specimens) and CT measurements. A review of the literature was performed on portal vein branching variations and four most common classifications of HPV branching were found as follows:

- Covey et al. (2004) – Type I – standard anatomy, Type II – trifurcation, Type III – HPV-RB-PB as first branch of HPV, Type IV – segment VII branch as separate branch of HPV-RB, Type V – segment VI branch as separate branch of HPV-RB;

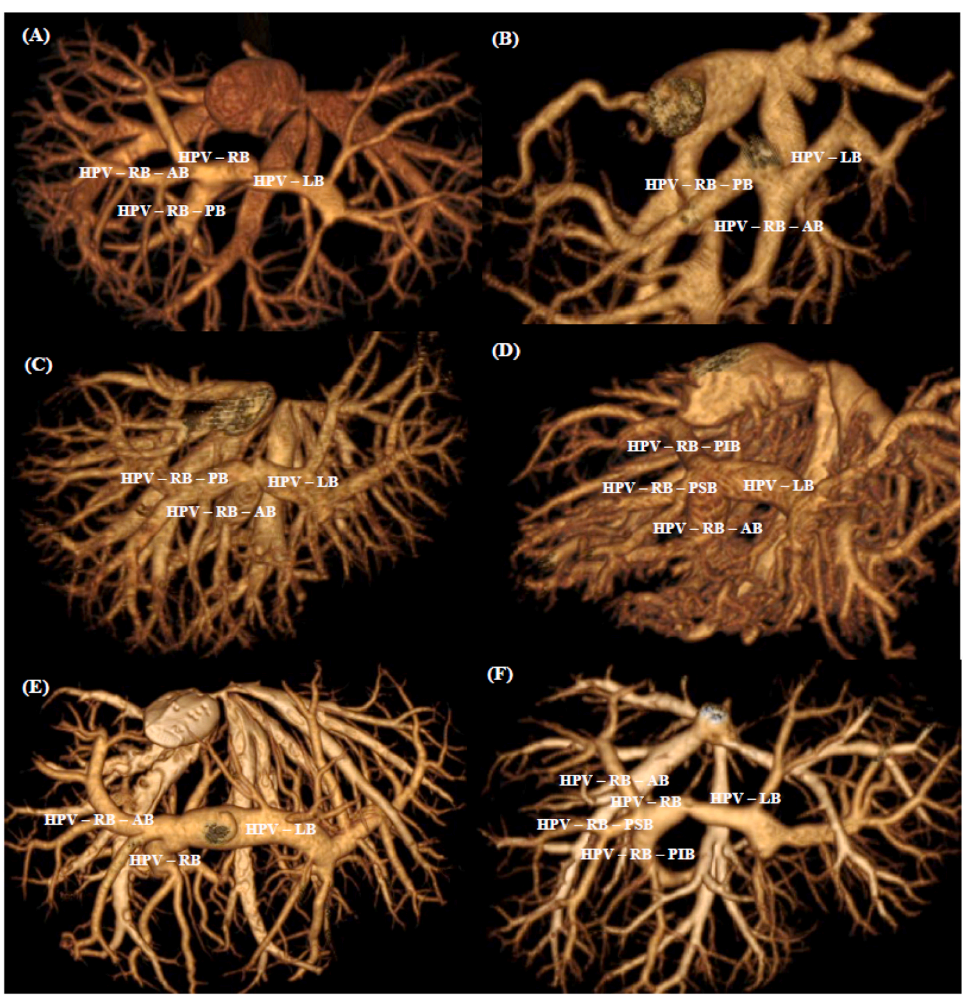
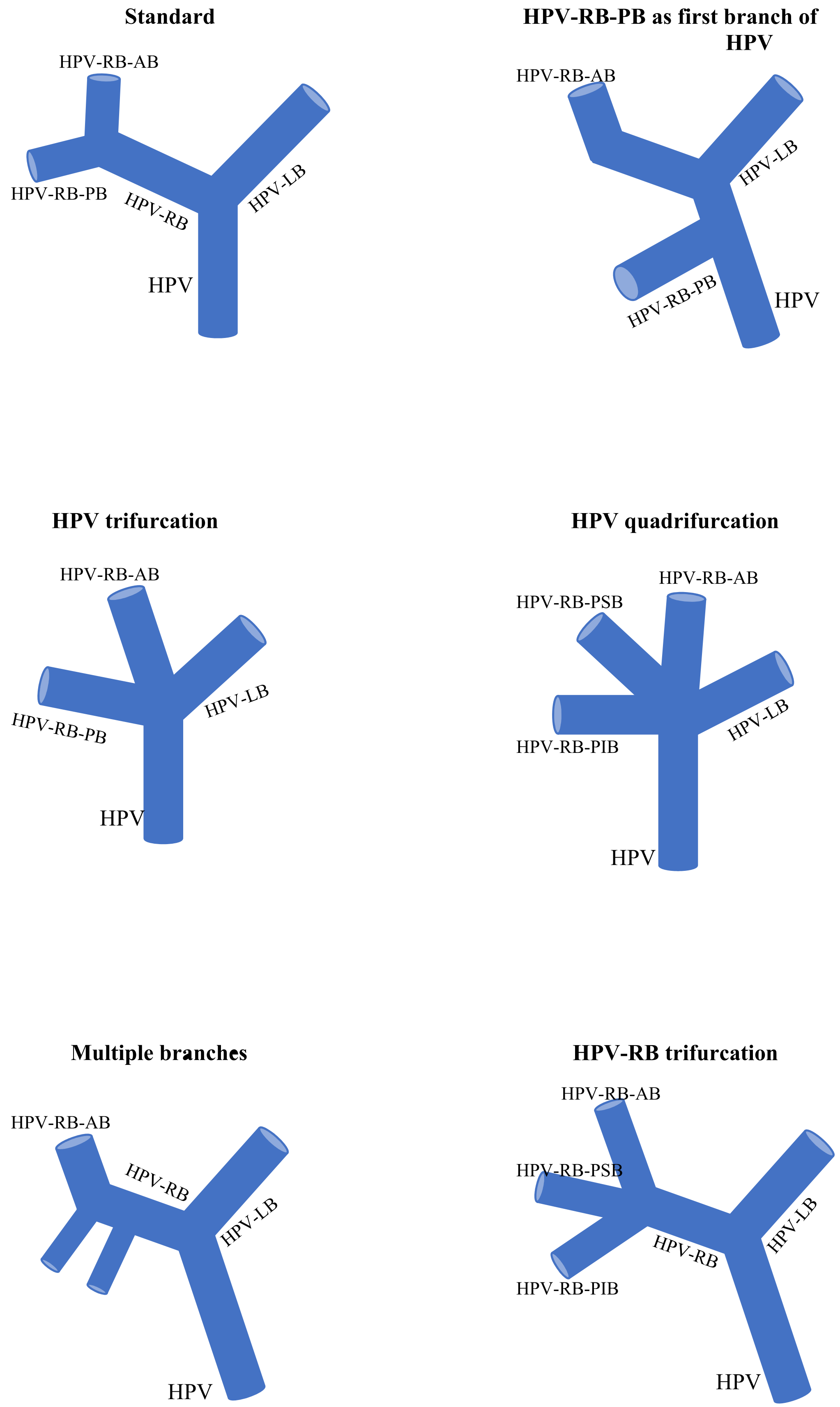


Fig. 1. Three dimensional reconstructions of series of CT-scans of the corrosive cast specimens. (A) Standard bifurcation. (B) HPV-RB-PB as the first branch of HPV. (C) HPV trifurcation. (D) HPV quadrifurcation. (E) Multiple branches. (F) HPV-RB trifurcation.

Table 1
The self-developed classification of hepatic portal vein variations.*



*HPV – hepatic portal vein, HPV-LB – left branch of hepatic portal vein, HPV-RB-AB – anterior branch of right branch of hepatic portal vein, HPV-RB-PB – posterior branch of right branch of hepatic portal vein, HPV-RB – right branch of hepatic portal vein, HPV-RB-PSB – posterior superior branch of right branch of hepatic portal vein, HPV-RB-PIB – posterior inferior branch of right branch of hepatic portal vein.

- Cheng et al. (1997), Type I – bifurcation, Type II – trifurcation, Type III – HPV-RB-PB as first branch of HPV, Type IV – HPV-RB-AB from HPV-LB;
- Nakamura et al. (2002), Type A – bifurcation, Type B – trifurcation, Type C – HPV-RB-PB as first branch of HPV, Type D – HPV-RB-AB from HPV-LB;
- Hwang et al. (2004), Type I – bifurcation, Type II – trifurcation, and Type III – HPV-RB-PB as the first branch of HPV.

We reclassified our variations according to these classifications and compared variation frequencies.

2.4. Statistical analysis

Statistical analysis of the data was performed by IBM SPSS Statistics 28.0.

3. Results

3.1. The lengths and diameters of the hepatic portal vein and its branches

In both manual and CT measurements (Table 2), the length of the HPV-LB was significantly greater than the length of the HPV-RB ($p < 0.01$) and the diameter of the HPV-RB was significantly greater than the diameter of the HPV-LB ($p < 0.01$). The widest range of variation was observed in HPV-LB (1.15 – 5.9 cm). The mean peak length was observed in CT HPV-LB (3.52 ± 0.8 cm). The diameter of HPV-LB in CT measurements varied the least (0.48 – 1.73 cm). The median length and diameter in CT measurements were 3.56 cm and 1.06 cm, respectively, they were significantly different from the corresponding medians in manually measured specimens ($p < 0.05$ and $p < 0.01$, respectively). A weak and statistically significant positive correlation ($r = 0.203$, $p < 0.05$) was found between the diameter of the HPV-LB in manually measured specimens and age. Possibly, the diameter of the HPV-LB increases with increasing age, this may be seen because the elasticity of the blood vessel wall decreases with increasing age, so the vein expands more.

The widest range of variation (Table 2) was observed in the manual measurements of the length of the HPV-RB (0.7 – 4.6 cm). The length and diameter in CT measurements did not differ significantly from the corresponding manual measurements ($p > 0.05$). The mean diameter and length of the HPV-RB did not differ significantly between biological sex groups and no significant correlations found between length or diameter and age ($p > 0.05$).

The widest range variation (Table 3) of the measurements was observed in manually measured HPV-LB length specimens from the female group (ranged from 1.15 to 5.9 cm), and the maximum length was observed in the CT HPV-LB length of the male group (3.61 cm). The lengths and diameters did not differ significantly between the male and female groups ($p > 0.05$).

3.2. Vascular patterns in the hepatic portal vein

When examining the specimens, different types of main and segmental branch variations were recorded. The main branch variations were HPV trifurcation, HPV-RB-PB as a first branch of HPV, and HPV quadrifurcation. Segmental variations alone were not considered as deviations from standard branching.

The standard HPV ramification pattern according to self-developed classification (Table 4) was detected in 85.7% of cases – in both somatoscopic and CT evaluation, and the frequency of variation was independent of biological sex ($p > 0.05$).

The most frequent variation of the main branches was the HPV trifurcation – 7.6% in both methods (Table 4). The least common variation of the main HPV branches was HPV quadrifurcation 1.9% and 1% respectively in somatoscopic and CT evaluation. The main variation of the segmental branches was the multiple branches of HPV-RB-PB 29.5% and 27.6% in somatoscopic and CT evaluation. There were no statistically significant differences in the rates of major branch variations between the estimates of both methods ($p > 0.05$), which allows a fairly accurate comparison of old samples with more recent data. However, a significant difference was found in the frequency of variations in segmental branches ($p < 0.05$).

Differences of variation type between the two methods were observed in several specimens, as it was more difficult to assess segmental branching pattern somatoscopically; therefore, when evaluating 3D CT reconstructions, it was possible to better assess the type of branching pattern and afterward notice these variations somatoscopically.

4. Discussion

4.1. Study data provided in literature sources

The portal vein is a relatively stable vessel with variations that rarely occur. However, deviations in standard branching are clinically significant when performing surgical procedures such as hepatectomy, liver transplantation, formation of transjugular intrahepatic portosystematic shunts, and portal vein embolisation. The frequencies of three main HPV ramification patterns vary greatly in the literature with standard branching varying 51 – 99.91%, on average (mean ± SD) – 80.68% (±10.53); trifurcation 0.01 – 34%, on average (mean ± SD) – 9.19% (±6.2) and HPV-RB-PB as the first branch of HPV 0 – 23.5%, on average (mean ± SD) – 7.86% (±5.36) (Akgul et al., 2002; Anwar et al., 2020; Arviza et al., 2021; Asad Ullah et al., 2020; Atasoy et al., 2006; Atri et al., 1992; Baba et al., 2000; Cheng et al., 1997; Clipet et al., 2019; Covey et al., 2004; Fraser-Hill et al., 1990; Guler et al., 2013; Gunasekaran and Gaba, 2017; Gupta et al., 1977; Hwang et al., 2004; Yamane et al., 1988; Yaprak et al., 2011; Inoue et al., 1986; Yu et al., 2011; Kishi et al., 2010; Ko et al., 2004; Koc et al., 2007a, 2007b; Kuriyama et al., 2018; Lee

Table 2
Lengths and diameters of the left (HPV-LB) and right branch of hepatic portal vein (HPV-RB) by assessment method in the present study.*

	HPV-LB measured manually (cm)	HPV-LB CT (3D reconstruction) assessment (cm)	p	HPV-RB measured manually (cm)	HPV-RB CT (3D reconstruction) assessment (cm)	p
Length variation (min-max)	1.15 – 5.9	1.83 – 5.74	p < 0.05	0.7 – 4.6	0.82 – 3.71	p > 0.05
Mean length ± SD	3.37 ± 0.96	3.52 ± 0.8	p < 0.05	2.08 ± 0.74	2.12 ± 0.59	p > 0.05
Diameter variation (min-max)	0.5 – 1.9	0.48 – 1.73	p < 0.05	0.5 – 1.9	0.54 – 2.08	p > 0.05
Mean diameter ± SD	1.11 ± 0.23	1.08 ± 0.23	p < 0.05	1.3 ± 0.2	1.31 ± 0.28	p > 0.05

*HPV-LB – left branch of hepatic portal vein, CT – computed tomography, HPV-RB – right branch of hepatic portal vein, SD – standard deviation.

Table 3
Lengths and diameters of the left (HPV-LB) and right branch of hepatic portal vein (HPV-RB) by assessment method and biological sex in the present study.*

		Assessment method of hepatic portal vein branching pattern							
		Measured manually				CT (3D reconstruction) assessment			
		HPV-LB length (cm)	HPV-LB diameter (cm)	HPV-RB length (cm)	HPV-RB diameter (cm)	HPV-LB length (cm)	HPV-LB diameter (cm)	HPV-RB length (cm)	HPV-RB diameter (cm)
Male	Variation (min – max)	1.5 – 5.9	0.6 – 1.7	0.7 – 4.2	1 – 1.9	1.9 – 5.74	0.55 – 1.73	0.8 – 2.14	0.65 – 2.1
	Mean ± SD	3.29 ± 0.96	1.31 ± 0.22	2.06 ± 0.8	1.37 ± 0.22	3.61 ± 0.89	1.11 ± 0.22	2.09 ± 0.58	1.37 ± 0.28
Female	Variation (min-max)	1.15 – 5.9	0.5 – 1.9	0.9 – 4.6	0.5 – 1.8	1.83 – 5.22	0.43 – 1.55	1.1 – 3.7	0.5 – 1.8
	Mean ± SD	3.47 ± 1	1.1 ± 0.25	2.12 ± 0.7	1.31 ± 0.27	3.48 ± 0.82	1.03 ± 0.25	2.14 ± 0.59	1.28 ± 0.29
$p > 0.05$									

*HPV-LB – left branch of hepatic portal vein, CT – computed tomography, HPV-RB – right branch of hepatic portal vein, SD – standard deviation.

Table 4
Frequency (%) of variation in branching of the hepatic portal vein (HPV) by different assessment methods.*

Present study (n=105)	CT (3D reconstruction) evaluation (%, n)	Somatoscopic evaluation (%, n)	p
Standard	85.7 (90)		$p > 0.05$
HPV trifurcation	7.6 (8)		
HPV-RB-PB as first branch of HPV	5.7 (6)	4.8 (5)	
HPV quadrifurcation	1 (1)	1.9 (2)	
Segmental variations			
HPV-RB quadrifurcation	1 (1)	2.9 (3)	$p < 0.05$
HPV-RB trifurcation	9.5 (10)	17.1 (18)	
Multiple branches	27.6 (29)	29.5 (31)	
HPV-RB-PSB as first branch	19.04 (20)	5.7 (6)	
HPV-RB-PIB medial branch	6.7% (7)	5.7% (6)	

*CT – computed tomography, HPV – hepatic portal vein, HPV-RB-PB – posterior branch of right branch of hepatic portal vein, HPV-RB – right branch of hepatic portal vein, HPV-RB-PSB – posterior superior branch of right branch of hepatic portal vein, HPV-RB-PIB – posterior inferior branch of right branch of hepatic portal vein.

et al., 2004; Minami et al., 2020; Munguti et al., 2013; Nakamura et al., 2002; Okten et al., 2012; Rajput et al., 2014; Sharma et al., 2017; Shrikantaiah et al., 2018; Soyer et al., 1995; Sureka et al., 2015; Uchida et al., 2010; Ülger et al., 2018; Watanabe et al., 2017; Wu et al., 2007).

4.2. *Classifications of hepatic portal vein branching*

Most studies use self-constructed classifications that usually include three main patterns of HPV branching patterns, bifurcation (standard), trifurcation, or HPV-RB-PB as the first branch of the HPV. The latter variation is sometimes referred to as the HPV-RB-AB branching from HPV-LB. However, some studies consider these to be separate variations with a difference of intraparenchymal or extraparenchymal branching of the HPV-RB-AB, which is impossible to distinguish when evaluating corrosion casts, so we considered both intraparenchymal and extraparenchymal branching of the HPV-RB-AB to be a single variation in our study.

In the present study (Table 5), the variations were reclassified according to most common classifications used in the literature – Nakamura (Nakamura et al., 2002), Cheng (Cheng et al., 1996) and Covey (Covey et al., 2004). In our results according to Cheng (Cheng et al., 1996) and Nakamura (Nakamura et al., 2002) classifications type I and A were seen in 84.8% cases, type II and B – 7.6%, type III, IV and C, D – 6.7%. According to the Covey classification, type I frequency was 63.8%, type II – 7.6%, type III – 6.7%, type IV – 18.1% and type V – 2.9% (Table 5). The frequency of the first two types among all three

Table 5
Comparison of variation frequency (%) in hepatic portal vein branching between the present and other studies using different classifications.*

Classification method of hepatic portal vein branching	Branching pattern of hepatic portal vein					
	Standard branching		Trifurcation		HPV-RB-PB from HPV and HPV-RB-AB from HPV-LB	
	Literature (mean, SD, min-max (%), study count)	Present study (%, n)	Literature (mean, SD, min-max (%), study count)	Present study (%, n)	Literature (mean, SD, min-max (%), study count)	Present study (%, n)
Self-developed classification	79 (±11.48), 51 – 92, n=15	85.7 (90)	11.37 (±8.14), 3.2 – 34, n=15	7.6 (8)	7.97 (±4.77), 0 – 18, n=15	5.7 (6)
(Covey et al., 2004)	76.65 (±9.75), 65 – 90, n=7	63.8 (67)	8.27 (±2.66), 3.6 – 12, n=7	7.6 (8)	6.34, (±3.45), 2.5 – 13, n=7	6.7 (7)
(Cheng et al., 1997)	82.07 (±8.43), 69.52 – 87.56, n=4	84.8 (89)	10.16 (±6.94), 4.5 – 19.05, n=4	7.6 (8)	7.76 (±4.48), 1.5 – 11.43, n=4	6.7 (7)
(Nakamura et al., 2002)	91.05 (±4.09), 85.5 – 95.2, n=4	84.8 (89)	3.52 (±1.92), 1.6 – 6, n=4	7.6 (8)	5.02 (±3.16), 3 – 9.7, n=4	6.7 (7)

* SD – standard deviation, HPV-RB-PB – posterior branch of right branch of hepatic portal vein, HPV – hepatic portal vein, HPV-RB-AB – anterior branch of right branch of hepatic portal vein, HPV-LB – left portal branch.

Table 6
Comparison of variation frequency (%) in hepatic portal vein branching between the present study and other studies using different assessment methods.*

Assessment method of hepatic portal vein [literature source]	Branching pattern of hepatic portal vein		
	Standard (mean, SD, min-max, study count)	Trifurcation (mean, SD, min-max, study count)	HPV-RB-PB from HPV and HPV-RB-AB from HPV-LB (mean, SD, min-max, study count)
CT (Adhikari et al., 2021; Akgul et al., 2002; Anwar et al., 2020; Asad Ullah et al., 2020; Atasoy et al., 2006; Baba et al., 2000; Covey et al., 2004; Guler et al., 2013; Hwang et al., 2004; Yaprak et al., 2011; Koc et al., 2007a, 2007b; Kuriyama et al., 2018; Minami et al., 2020; Okten et al., 2012; Sharma et al., 2017; Soyer et al., 1995; Sureka et al., 2015; Uchida et al., 2010; Ülger et al., 2018; Vijay Kumar et al., 2019; Watanabe et al., 2017; Wu et al., 2007)	80.04 (±9.23), 64.5 – 96, n=23	8.32 (±3.92), 1.6 – 16.1, n=23	8.76 (±6.05), 1.5 – 23.5, n=23
Corrosion cast specimens (Yamane et al., 1988; Rajput et al., 2014; Shrikantaiah et al., 2018)	87.3 (±6.43), 80 – 92, n=3	9.17 (±2.47), 7.5 – 12, n=3	3.5, (±4.09), 0 – 8, n=3
Mixed (Arviza et al., 2021; Bageacu et al., 2011; Clipet et al., 2019; Gunasekaran and Gaba, 2017; Yu et al., 2011; Kishi et al., 2010, 2004; Nakamura et al., 2002; Varotti et al., 2004)	81.67 (±3.82), 66.9 – 92.5, n=9	8.26 (±4.77), 2.5 – 17, n=9	7.32 (±3.82), 2.2 – 13.5, n=9
Liver specimens (Ko et al., (2004); Munguti et al. (2013)	69.5 (±26.16), 51 – 88, n=2	18.6 (±21.78), 3.2 – 34, n=2	10.5 (±6.36), 6 – 15, n=2
MRI (Lee et al., 2004)	89, n=1	4, n=1	6, n=1
Angiography (Cheng et al., (1997); Inoue et al., (1986)	71.61 (±2.96), 69.52 – 73.7, n=2	20.38 (±1.87), 19.05 – 21.7, n=2	8.01 (±4.83), 4.6 – 11.43, n=2
Ultrasound (Atri et al., 1992; Fraser-Hill et al., 1990)	89.91 (±14.15), 79.9 – 99.91, n=2	5.41 (±7.62), 0.01 – 10.8, n=2	4.51 (±6.35), 0.02 – 9, n=2
Present study, n=105	85.7 (90)	7.6 (8)	Corrosion cast – 4.8 (5) CT – 5.7 (6)

* SD – standard deviation, CT – computed tomography, MRI – magnetic resonance imaging. HPV-RB-PB – posterior branch of right branch of hepatic portal vein, HPV – hepatic portal vein, HPV-RB-AB – anterior branch of right branch of hepatic portal vein, HPV-LB – left portal branch.

classifications did not differ significantly ($p > 0.05$). There was a change seen in the rate of standard branching, demonstrating how results depend on the classification of branching patterns, as some authors consider more segmental variations to be a deviation from standard branching. This would explain why there are lower rates of standard branching found when classifying the portal vein anatomy according to Covey et al. (2004) as it considers Type IV and V patterns to be variations, while other authors consider them as standard branching if bifurcation of the HPV is present.

4.3. Methods of evaluating the hepatic portal vein

The evaluation method used may be another potentially significant factor that influences the variability of the HPV branching pattern frequencies between studies (Table 6). CT is the most common visualisation method, some studies recommend using maximum intensity projection to make visualisation more accurate (Asad Ullah et al., 2020) while others use CT regimens like virtual endoscopy to confirm the presence of variations and distinguish between them (Pang et al., 2015). The corrosion cast method is used in both older literature (Gupta et al., 1977; Yamane et al., 1988) and more recent studies (Macchi, 2015; Rajput et al., 2014; Shrikantaiah et al., 2018). Although the number of specimens is usually smaller in these types of studies, they describe more segmental variations (further branching of the HPV-RB), , which is possibly due to better visualisation of the segmental branches in corrosion specimens compared to using CT in liver studies of living subjects. A study by Macchi et al., (2015) (Macchi, 2015) compared the two methods and found a lower rate of standard branching in the corrosion cast group compared to the CT group (75% vs. 90%); however, when analysing the literature, we found the frequency of standard branching in corrosion cast studies is lower and vary less (87.3% vs. 80.04%).

Other possible visualisation methods include liver dissection, ultrasound and MRI. Some authors combine different techniques (Arviza et al., 2021; Bageacu et al., 2011; Clipet et al., 2019; Gunasekaran and Gaba, 2017; Yu et al., 2011; Kishi et al., 2010, 2004; Macchi, 2015; Nakamura et al., 2002; Varotti et al., 2004), which might produce results that are more accurate.

4.4. Stratification by biological sex

Ambiguous information can be found on hepatic portal vein (HPV) variations in biological sex groups. Some studies claim that certain variation types are more often found in females (Covey et al., 2004 type III and V), others in males (type II and IV) (Asad Ullah et al., 2020). However, other studies do not find the difference between male and female groups statistically significant (Arviza et al., 2021; Sharma et al., 2017). When comparing lengths and diameters between biological sex, there are reports of a significantly longer HPV-RB branch in males (Shrikantaiah et al., 2018), although we did not see a significant difference between the means of lengths and diameters of HPV-LB or HPV-RB in the present study.

4.5. An epochal trend

Based on what we could find in the published sources, it is more likely that the year of publication did not affect the results on the frequency of variations in the branching of the portal vein (Table 7).

5. Conclusions

1. In both manually measured and CT measurements, the length of HPV-LB was significantly greater than the length of HPV-RB and the diameter of HPV-RB was significantly greater than that of the HPV-LB. Only the median lengths and diameters of the HPV-LB differed significantly between CT and manually measured specimens.
2. There were no statistically significant differences in the rates of major branch variations between the estimates of both methods, which allows a fairly accurate comparison of old samples with more recent data. However, a significant difference was found between the

Table 7
Comparison of variation frequencies (%) in the branching of the hepatic portal vein between studies by time.*

Year of the hepatic portal vein study [literature source]	Branching pattern of hepatic portal vein		
	Standard (mean, SD, min-max, study count)	Trifurcation (mean, SD, min-max, study count)	HPV-RB-PB from HPV and HPV-RB-AB from HPV-LB (mean, SD, min-max, study count)
Studies up to 2000 (Atri et al., 1992; Cheng et al., 1997; Fraser-Hill et al., 1990; Yamane et al., 1988; Inoue et al., 1986; Soyer et al., 1995)	83.17 (±12.18), 69.52 – 99.91, n=6	11.26 (±8.36), 0.01 – 21.7, n=6	5.84 (±4.38), 0.02 – 11.43, n=6
Studies after 2000 (Adhikari et al., 2021; Akgul et al., 2002; Anwar et al., 2020; Arviza et al., 2021; Asad Ullah et al., 2020; Atasoy et al., 2006; Baba et al., 2000; Bageacu et al., 2011; Clipet et al., 2019; Covey et al., 2004; Guler et al., 2013; Gunasekaran and Gaba, 2017; Hwang et al., 2004; Yaprak et al., 2011; Yu et al., 2011; Kishi et al., 2010, 2004; Ko et al., 2004; Koc et al., 2007a, 2007b; Kuriyama et al., 2018; Lee et al., 2004; Minami et al., 2020; Munguti et al. 2013; Nakamura et al., 2002; Okten et al., 2012; Rajput et al., 2014; Sharma et al., 2017; Shrikantaiah et al., 2018; Sureka et al., 2015; Uchida et al., 2010; Ülger et al., 2018; Varotti et al., 2004; Vijay Kumar et al., 2019; Watanabe et al., 2017; Wu et al., 2007)	80.28 (±10.37), 51 – 95.2 n=36	8.84 (±5.85), 1.6 – 34, n=36	8.19 (±5.49), 0 – 23.5, n=36
Present study, 2022 (specimens – from 1960 to 1980 period)	85.7 (90) (same frequency with both methods – CT and somatoscopic assessment)	7.6 (8)	5.7 (6)

*SD – standard deviation, HPV-RB-PB – posterior branch of right branch of hepatic portal vein, HPV – hepatic portal vein, HPV-RB-AB – anterior branch of right branch of hepatic portal vein, HPV-LB – left posterior hepatic portal branch.

frequency of segmental branch variations, suggesting more accurate estimates using CT.

3. The standard branching of the hepatic portal vein (HPV) (based on our self-developed classification) in this study was 85.7%. Depending on the classifications as proposed by other authors, the rate of standard branching in the same corrosive samples used in this study varied from 63.8% to 84.8% of all cases, indicating that the lack of a unified and stable classification makes it difficult to compare the results of different studies.

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Continuation of the study

A continuation of this study would be to evaluate CT radiographic images of patients in recent years and compare trends of change with the 1960 – 1980 y. period to determine whether there is a secular trend over the last 50 years and how the evaluation method and the chosen classification influence the frequency of the latter change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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