Balkan Med J 2012; 29: 419-23 • DOI: 10.5152/balkanmedj.2012.050

Are Hepatic Portal Venous System Components Distributed Equally in the Liver? A Multidetector Computerized Tomography Study

Mehmet İncedayı[1], Serkan Arıbal[1], Ali Kemal Sivrioğlu[1], Güner Sönmez[1], Ersin Öztürk[1], Bülent Yalçın[2], Cihad Çınar Başekim[1]

[1]*Department of Radiology, Gülhane Military Medical Academy, İstanbul, Turkey*
[2]*Department of Anatomy, Gülhane Military Medical Academy, Ankara, Turkey*

ABSTRACT

Objective: We aimed to evaluate the relationships between the splenic index, right and left hepatic lobe volumes, diameters of splenic vein (SV), superior mesenteric vein (SMV) and the portal vein (PV) by Multidetector Computerized Tomography (MDCT). We also investigated indirect signs of portal venous flow pattern using these parameters.

Material and Methods: Following their contrast thoracoabdominal and abdominal 64-MDCT examinations, the images of 100 cases (61 males and 39 females) were evaluated retrospectively. For each case, the splenic index, total hepatic volume, left and right hepatic volumes were calculated on the post-contrast portal venous phase (50th sec) images. Spearman correlation tests were carried out with the purpose of determining the relationships between the variables. Statistical significance level was set at $p<0.005$.

Results: A statistically significant relation was demonstrated between the diameter of the SMV and right hepatic lobe volume ($p<0.0001$), and according to Pearson's correlation analysis, a positive correlation of medium strength ($r=0.36$) was observed. A positive correlation was demonstrated between the diameter of the splenic vein and left hepatic lobe volume ($r=0.36$). Statistically significant relation between the diameters of the splenic vein and right hepatic lobe was not observed ($p=0.62$). A strong correlation between the left hepatic lobe volume and the splenic index ($r=0.556$) was observed.

Conclusion: We observed a positive correlation and a significant relation between the diameter of the SMV and the right hepatic lobe, and a relation between the splenic vein and splenic index and both hepatic lobes. We believe that this situation is related to the streamline flow in the portal vein, and as demonstrated in the literature, the flow in the SMV is directed at the right lobe, whereas the splenic vein empties into the liver homogenously. Our study is the first study in the literature performed by multidetector CT, which is a technique that reveals the relations between the streamline flow in the portal vein, the splenic index and the hepatic lobe volumes.

Key Words: MDCT, laminar flow, portal vein, splenic index

Received: *25.01.2012* ***Accepted:*** *08.06.2012*

Introduction

We aimed to evaluate the relationships between the splenic index, right and left hepatic lobe volumes, diameters of splenic vein (SV), superior mesenteric vein (SMV) and the portal vein (PV) by Multidetector Computerized Tomography (MDCT). We also investigated indirect signs of portal venous flow pattern using these parameters.

In the literature, it is accepted in general that several pathologies which spread into the liver by the superior mesenteric vein are predominantly emptied into the right hepatic lobe through the streamline flow in the portal vein (1-4). The term laminar flow refers to the fact that the blood cells move in layers, one layer sliding over another, with the different layers being able to move at different velocities. In laminar flow, the blood cells remain in their layers (5). The streamline flow in the portal vein is the reason for the occurrence of the infectious diseases and metastases predominantly in the right hepatic lobe through the superior mesenteric vein (1). There are also studies which aim at demonstrating that the blood which is carried by the splenic vein from the spleen is emptied into the left hepatic lobe or into both hepatic lobes (2-6). These studies suggest that there is a more significant relationship between the superior mesenteric vein and the right hepatic lobe, whereas the relationship between the splenic vein and the left hepatic lobe is rather complicated.

Owing to its faster rotation times and higher spatial and temporal resolution potential, the multidetector CT has launched a new period in cross-sectional imaging. By this means, the volumetric and vascular studies performed by MDCT provide faster and more accurate results in comparison with the studies carried out by single slice CT (7). The speed of the MDCT enables imaging during different perfusion phases of the organs (arterial, parenchymal and portal venous phases).

This study was previously presented at the 32th Annual Meeting of Turkish Society of Radiology, Turkey

Address for Correspondence: *Dr. Mehmet İncedayı, Department of Radiology, Gülhane Military Medical Academy, Haydarpaşa, İstanbul, Turkey*
Phone: +90 505 948 74 46 e-mail: m_incedayi@yahoo.com

The relationship between the diameters of the SMV and splenic vein and the volumes of both hepatic lobes has not been examined in the past. Especially the relations between the diameter of the SMV and the right hepatic lobe, and the diameter of the splenic vein and the left hepatic lobe may be significant in terms of the streamline flow hemodynamics in the portal vein. In this study, examining these relations by MDCT, we made an attempt to evaluate the streamline flow in the portal vein. Besides, we also investigated the relations between these variables and the splenic index.

Material and Methods

Following their contrast thoracoabdominal and abdominal 64-MDCT examinations, the images of 100 cases (61 males and 39 females) were evaluated retrospectively. The patients who were included in the study ranged from age 20 to 88 (mean age: 41.78). For each case, the splenic index, total hepatic volume, left and right hepatic volumes were calculated on the post-contrast portal venous phase (50th sec) images. Cases without any known liver and spleen diseases were included in the study. Patients who were not diagnosed with any primary liver and spleen diseases (e.g., hepatosteatosis, glycogen storage disease, malignant or benign mass lesions, etc.) and with any secondary causes which might have an impact on the volumes of these two organs (e.g., anemia which may cause splenomegaly, cardiac insufficiencies which may cause congestive hepatomegaly, etc.) at the pre-diagnosis and final CT report were found eligible for the study. Moreover, certain conditions (portal vein thrombus, portal hypertension) which have an impact on other parameters measured in this study (diameters of the SMV, portal and splenic vein) were excluded from the study. In addition, cases with splenectomy and respiratory and motion artifacts were also excluded from the study.

***Hepatic volume*:** The liver segment lying on the left of the middle hepatic vein was accepted as the left lobe. In the inferior sections where the middle hepatic vein could not be observed clearly, the gallbladder itself and its fossa was accepted as the anatomical border (8, 9). In the images obtained during the portal venous phase, starting from the dome of the liver, the area was calculated in sq mm (square millimeters) by the free ROI technique and then a 9mm thick subaxial section was taken; then the same procedure was repeated (Figure 1). This procedure was carried on up to the lower edge of the liver. All values were registered and added. The area calculated in square millimeters was multiplied by the 9 mm section thickness and volume was found in cubic meters. The volume was calculated in cubic centimeters and milliliter by using the volume conversion value. Liver and splenic volumes were calculated by using the EasyVision (Philips Medical Systems) workstation.

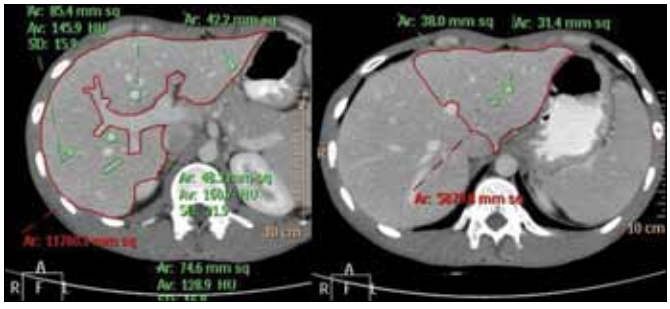

Figure 1. Liver area was calculated by free ROI technique at every subsequent axial image (red line). Intrahepatic vascular areas were removed to achieve accurate liver area (green line). This area is multiplied by scan width (9 mm) to achieve volume on each image

Splenic index was calculated as length x width and x thickness of the spleen (Figure 2). The length of the spleen was accepted as the distance between the levels where the image of the spleen was first displayed in the axial plane images and the last point it could be displayed. The width of the spleen was accepted as the longest value of the spleen in the axial plane, and its thickness was accepted as the thickest distance at this level (10).

***Diameters of the splenic vein and SMV*:** The diameters were measured in the axial plane images at the 1cm long segment before the portal confluence where they could be displayed most clearly. Within this segment, especially in cases where branches with a potential dilating effect joined to the SMV, the measurements were performed at the segment proximal to the aforesaid segment which had a caliber closer to the real diameter. The diameter of the portal vein was measured at the segment following the confluence at the portal hilus level (Figure 3).

All studies were carried out by a multidetector CT (Philips Brillance 64). Technical parameters were as follows: detector collimation, 64x0.625; slice thickness, 3 mm; reconstruction index, 1.5 mm; and pitch, 1. Iodinated contrast material (300 mg/mL, 100 mL) was administered by a power injector at a rate of 4 mL/s. Curved coronal and sagittal reformatted im-

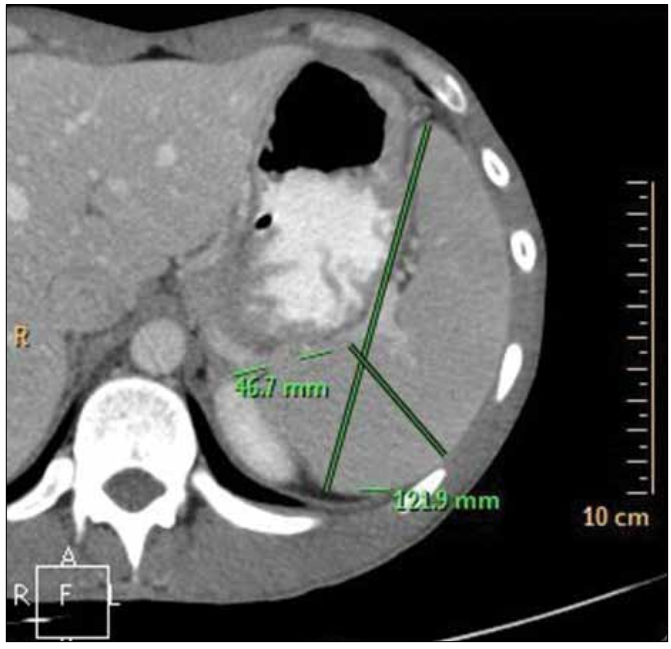

Figure 2. The width of the spleen was accepted as the longest value of the spleen in the axial plane (long line), and its thickness was accepted as the thickest distance at this level (short line)

ages were reconstructed from the raw data. FOV was 350 mm, and matrix was 512x512.

All statistical analyses were performed by a SPSS (Statistical Package for the Social Sciences) for Windows ver 15.0 software. Spearman correlation tests were carried out with the purpose of determining the relationships between the variables. Statistical significance level was set at $p<0.005$

Results

Total hepatic volume varied between 854 and 1866 cc, right hepatic lobe volume varied between 565 and 1335 cc, and left hepatic lobe volume varied between 217 and 636 cc. Splenic index value varied between 146.2 and 938. Portal vein diameters varied between 10.1 and 16.2 mm; splenic vein diameters varied between 5 and 13.8 mm, SMV diameters varied between 8.1 and 15mm. The mean values for these parameters are summarized in Table 1.

A statistically significant relationship between the splenic index and left hepatic lobe volume and total volume was demonstrated ($p=0.001$). Positive correlations between the left hepatic lobe volume and splenic index ($r=0.55$), and between the right hepatic lobe volume and splenic index ($r=0.32$) were also exhibited. However, the correlation between the left hepatic lobe volume and the splenic index was relatively stronger compared to the correlation between the right hepatic lobe volume and the splenic index ($r=0.55$ versus $r=0.32$).

Between the diameter of the SMV and right hepatic lobe volume, a statistically significant relation was demonstrated ($p<0.0001$), and according to Pearson's correlation analysis, a positive correlation of medium strength ($r=0.36$) was observed.

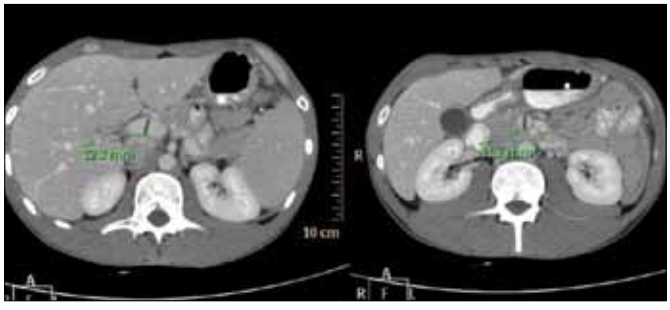

Figure 3. Examples to measure the diameter. The diameter of the portal vein was measured at the segment following the confluence at the portal hilus level (left figure). The diameter of the SMV was measured in the axial plane image at the 1cm long segment before the portal confluence where they could be displayed most clearly (right figure)

Table 1. The mean values of parameters

Parameters (n=100)	Mean±2SEM
Splenic index	433.3±32.2
Splenic vein diameter	9.34±0.3
Portal vein diameter	13.32±0.31
Liver volume	1222.9±43.2
Liver left lobe volume	380.4±17.8
Liver right volume	842.±32.3
SMV diameter	11.21±0.32

SMV: Superior mesenteric vein, SEM: Standard error of mean

Correlation was demonstrated between the diameter of the splenic vein and left hepatic lobe volume ($r=0.36$). A statistically significant relation between the diameters of the splenic vein and right hepatic lobe was not observed ($p=0.62$).

A statistically significant relation between the diameters of the portal vein and the splenic vein was observed ($p<0.01$), and according to Pearson's correlation analysis, a strong correlation between the portal vein and the splenic vein ($r=0.615$) was exhibited.

Similarly, a statistically significant relation was demonstrated also between the diameters of the portal vein and the SMV ($p<0.01$), and despite the strong correlation which was observed between the portal vein and the SMV based on Pearson's correlation analysis, this correlation was more significant in the diameter of the splenic vein.

The diameter of the portal vein is affected more in SMV when compared with SV.

The relation between age and the splenic index was statistically significant ($p=0.027$), and according to Pearson's correlation analysis, an inverse correlation of medium strength was observed ($r=-0.40$).

A strong correlation between the left hepatic lobe volume and the splenic index ($r=0.556$) was observed.

No correlations between gender and the variables were detected.

Discussion

The streamline flow in the portal vein is a situation which is generally accepted in the literature (1, 5, 6). The portal vein drains blood from the intestinal system to the right hepatic lobe through the mesenteric veins. Direct and indirect evidence on this subject has been reported in several studies. As a result of this phenomenon, 90% of the amebic abscesses which are normally prone to develop in the caecum are carried to the right hepatic lobe via the portal vein and 70% are established in the right hepatic lobe (1, 4, 11).

Several studies suggest that the locations of the primary metastases of colorectal cancer in the liver are associated with the locations of the primary tumor, and this is a situation compatible with the streamline flow in the portal vein (3, 4).

In their study carried out on portal scintigraphy with iodine-123-iodoamphetamine, Shiomi et al. (5) demonstrated that, in the control group which is constituted of 7 persons and in 31 patients with chronic hepatitis, the SMV did not carry blood to the left lobe. However, in the patients with cirrhosis, the streamline flow changed and in 12 of the 51 patients with cirrhosis the SMV supplied blood to the left lobe.

Gates and Dore demonstrated by portal scintigraphy that, in humans, the SMV supplies the right lobe under general anesthesia. They reported that the streamline flow in the portal vein may be inverted by a rapid injection and also due to the position/exercise (1). In this study, it is underlined that in general the amebic abscesses which are localized in the caecum and the hydatid cysts are carried to the right lobe.

In their study performed on 24 patients with nonalcoholic fatty liver disease, Nomura et al. (12) reported that, before dieting, the CT attenuation values of the lateral segment of the left hepatic lobe was higher than the values of the right lobe. However, the attenuation values were equalized after the patients lost weight. This situation can be explained by the fact that the blood rich in fatty acids (medium-chain fatty acids) and glucose is carried by the streamline flow in the portal vein via the SMV mainly to the right lobe.

The studies report that there is a more significant relationship between the SMV and the right hepatic lobe, whereas the relationship between the splenic vein, which is another component of the portal vein, and the left hepatic lobe is rather complicated. Some studies suggest that the pathologies which are carried to the liver via the splenic vein mainly invade the left lobe, while others report that they are spread in the liver homogenously (3-6, 11, 12).

In our study, a statistically significant relation ($p<0.0001$), and a positive correlation based on Spearman's correlation analysis ($r=0.36$) between the diameter of the SMV and right hepatic lobe volume were demonstrated. A positive correlation was demonstrated between the diameter of the splenic vein and left hepatic lobe volume ($r=0.36$). Similarly, a strong correlation between the left hepatic lobe volume and the splenic index ($r=0.556$) was observed. Our findings are correlated with the findings of Shirai and Konopke in their study performed on portal vein flow. These studies suggest that the colorectal cancers on the right side invade the right hepatic lobe, whereas the tumors originating from the left side are spread in the liver homogenously (3, 4). This difference suggests that the primary tumor location affects the pattern of lobar distribution of colorectal carcinoma liver metastases according to the streamline flow in the portal vein.

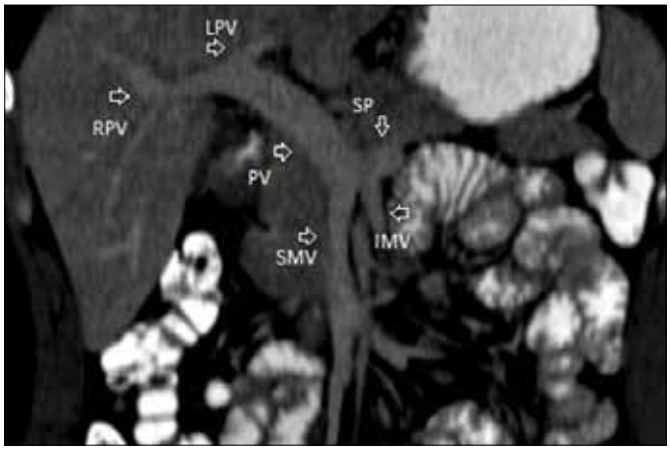

Figure 4. This high resolution coronal reformatted CT image demonstrates the relationships between the veins. The blood carried via the SMV is in a more dependant position in the portal vein compared to the blood carried by the splenic vein. This situation may help the blood carried through the SMV to flow in a streamline manner. Besides, the left portal vein is divided with a narrow angle compared with right vein. Due to this situation, despite the streamline flow, the blood carried by the splenic vein may be emptied into both portal veins

SMV: Superior mesenteric vein, IMV: Inferior mesenteric vein, PV: Portal vein, SP: Splenic vein, RPV: Right portal vein, LPV: Left portal vein

Conclusion

The blood carried via the SMV is in a more dependant position in the portal vein compared to the blood carried by the splenic vein (Figure 4). This situation may help the blood carried through the SMV to flow in a streamline manner. Besides, the left portal vein is divided with a narrow angle compared with the right one. Due to this situation, despite the streamline flow, the blood carried by the splenic vein may be emptied into both portal veins.

In our study, we examined the relations between the volumes of both hepatic lobes, the splenic index, portal vein, splenic vein and SMV. We observed a positive correlation and a significant relation between the diameter of the SMV and the right hepatic lobe, and a relation between the splenic vein and splenic index and left hepatic lobe. We believe that this situation is related to the streamline flow in the portal vein, and as demonstrated in the references 3 and 4, the flow in the SMV is directed at the right lobe. Our study is the first study in the literature performed by a multidetector CT, which is a technique that reveals the relations between the streamline flow in the portal vein, the splenic index and the hepatic lobe volumes.

The limited number of cases was one of the limitations of our study. If this study is carried out on a larger group of patients, the relations and correlations between the parameters can be exhibited more clearly. The difficulty in demonstrating the streamline flow in the portal system directly was another limitation. For this reason, only the indirect findings regarding this matter were evaluated.

In our study, the MDCT findings revealed statistically significant relations between the splenic index and the left lobe volume and between the diameter of the SMV and the right lobe volume. These findings may explain the dominance of the gastrointestinal system tumor metastases in the right hepatic lobe.

Information about the streamline flow in the portal vein may help us to understand the spread of the abdominal malignancies and infections and to localize their primary focus.

Conflict of Interest

No conflict of interest was declared by the authors.

References

1. Gates GF, Dore EK. Streamline flow in the human portal vein. J Nucl Med 1973;14:79-83.
2. Thrush A, Hartshorne T. Peripheral vascular ultrasound how, why and when. 2nd ed. London: Elsevier, 2005.p.53.
3. Konopke R, Distler M, Ludwig S, Kersting S. Location of liver metastases reflects the site of the primary colorectal carcinoma. Scand J Gastroenterol 2008;43:192-5. [CrossRef]
4. Shirai Y, Wakai T, Ohtani T. Colorectal carcinoma metastases to the liver. Does primary tumor location affect its lobar distribution? Cancer 1996;77:2213-6. [CrossRef]
5. Shiomi S, Kuroki T, Miyazawa Y, Ueda T, Takeda T, Nishiguchi S, et al. Hepatic distribution of blood flow from the superior or inferior mesenteric vein mapped by portal scintigraphy with iodine-123-iodoamphetamine. J Nucl Med 1996;37:51-4.

6. Kashiwagi T, Kamada T, Abe H. Dynamic studies on the portal hemodynamics of scintiphotosplenoportography. Streamline flow in the human portal vein. Gastroenterology 1975;69:1292-6.
7. Fenchel S, Boll DT, Fleiter TR, Brambs HJ, Merkle EM. Multislice helical CT of the pancreas and spleen. Eur J Radiol 2003;45:59-72. [CrossRef]
8. Barbaro B, Manfredi R, Bombardieri G, Vecchio FM, Palazzoni G, Mancini AP, et al. Correlation of MRI liver volume and doppler sonographic portal hemodynamics with histologic findings in patients with chronic hepatitis C. J Clin Ultrasound 2000;28:461-8. [CrossRef]
9. Torres WE, Whitmire LF, Gedgaudas-McClees K, Bernardino ME. Computed tomography of hepatic morphologic changes in cirrhosis of the liver. J Comput Assist Tomogr 1986;10: 47-50. [CrossRef]
10. Bezerra AS, D'Ippolito G, Faintuch S, Szejnfeld J, Ahmed M. Determination of splenomegaly by CT: is there a place for a single measurement? AJR Am J Roentgenol 2005;184:1510-3.
11. Standring S. Gray's anatomy. 39th ed. Elsevier Churchill Livingstone, 2005;1219.
12. Nomura F, Ohnishi K, Ochiai T, Okuda K. Obesity-related nonalcoholic fatty liver: CT features and follow-up studies after low-calorie diet. Radiology 1987;162:845-7.