

ORIGINAL ARTICLE Abdominal Imaging

Determination of mean portal vein diameter: An approach with Computed Tomography

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SUBMISSION: 15/7/2020 - ACCEPTANCE: 8/10/2020

ABSTRACT

Purpose: The aim of study is to determine the range of values and upper limit of mean portal vein diameter (MPVD) in healthy individuals and to investigate the effect of gender, age, height, liver and spleen size, as well as body mass index (BMI) on these values.

Material and Methods: In this retrospective study, the MPVD of the individuals with BMI between 18.5-24.9, without cardiac or liver disease, were evaluated by consensus of two radiologists on contrast-enhanced CT images. A total of 180 individuals, 15 men and 15 women from each decade between the ages of 20-80, were included. The correlation between the parameters was evaluated with Spearman's correla-

tion test. $p < 0.05$ values were considered statistically significant.

Results: MPVD was 12.75 ± 1.20 mm (SD), and mean BMI of the participants was 22.2 kg/m². There was a positive correlation between MPVD and height and BMI (BMI; CI, 0.517-0.752, Height; CI, 0.536-0.719). In comparison by gender, MPVD was found to be significantly wider in males than in females.

Conclusions: The results of our study indicate that acceptable value for the upper limit of MPVD is 13 mm, but the upper limit should be assessed according to body measurements such as BMI, height and gender in order to evaluate patients for portal hypertension.



KEY WORDS

Mean portal vein diameter; Computed tomography /contrast enhanced



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Introduction

Two-thirds of the liver vascularisation originates from the portal vein (PV) and one-third is from the hepatic artery (HA). The PV is composed of the superior and inferior mesenteric veins, coronary vein and splenic vein. Mean portal vein diameter (MPVD) values are variable according to age and gender [1, 2]. Several studies have been conducted to determine the normal upper limit of the MPVD. The first studies were in the 1980s, and then in the 2000s, ultrasound (US)-based studies were conducted and the results were observed to be inconsistent [3-6]. In two of these studies, greater than 13 mm for MPVD were accepted as a cut-off value for portal hypertension (PH) [3, 4]. PH is the most common complication of chronic liver disease and is one of the most common causes of death [7]. Therefore, it is important to evaluate the MPVD. Variations in MPVD are thought to be caused by variations in anthropometric characteristics of various populations and regions. In addition, MPVD is known to vary depending on factors such as gender, age, weight, height, and body mass index (BMI) [8]. The majority of studies in the literature evaluating the range of MPVD are US based. However, values can differ due to the user-dependent characteristic of ultrasonographic evaluation and patient-related reasons, such as respiration during the evaluation. Computed tomography (CT) is a modality in which diameter measurement can be made more optimal. In this retrospective study, the distribution of values of PV diameter in healthy individuals according to age range and gender was evaluated by CT.

Material and Methods

Patients

For this retrospective study, ethical committee approval was obtained from Clinical Research Ethics Committee Adana City Training and Research Hospital. In the study, upper abdominal contrast-enhanced CT examinations performed between January-December 2018 were evaluated. A total of 180 individuals, 15 men and 15 women from each decade between the ages of 20-80, mean age 50.07 ± 17.77 years, were included into the study. In the hospital information system, patients with abdominal pain, epigastric pain, dyspeptic symptoms and pelvic pain were screened. Patients with fatty liver on US or CT,

abnormal liver function tests, liver steatosis, viral hepatitis, previous liver operation history, haemoglobinopathy, copper excretion disorder, primary or secondary haemochromatosis, primary biliary cirrhosis, autoimmune hepatitis, metabolic storage disease, myeloproliferative disease, history of previous PV thrombosis, pancreatic disease (tumour, chronic pancreatitis, pseudocysts), hypersplenism, cardiac disease and chemotherapy history due to malignancy which can affect the liver were excluded from the study. PV diameter, liver and spleen caraniocaudal long axis were evaluated by CT. Weight, height and BMI of the patients were also noted.

CT technique and evaluation

Intravenous contrast-enhanced CT images were obtained on a 128-Slice Ingenuity Philips BT scanner (Netherlands, 2017), with a slice thickness of 1.25 mm. Axial reconstruction with 2.5 mm slice thickness was performed on these images. 120 kvp/100 mAs parameters were used to minimise radiation dose. Images were obtained following standard protocol, in the PV phase, 60-70 seconds after contrast injection, with patients in deep inspiration. CT scans were obtained at least 6-8 hours after fasting. Main PV diameter was measured at least 1 cm distal to the junction of the splenic and upper mesenteric vessels and at least 1 cm proximal to the first branch of the main PV. Measurements were performed from wall to wall of the vessel. Faulty measurements were prevented by not making measurements at the junction/separation of branches. Main PV diameter was measured in the axial plane and measurements of liver and long axis of spleen were measured on coronal images. The maximum length of the long axis of the liver was measured vertically between diaphragmatic level in the upper part and level which the liver terminates in the lower part. The maximum length between the upper and lower poles was measured in the spleen. The PV diameter was evaluated by consensus by two radiologists at the same time. Patients were recruited consecutively.

Statistical analysis

SPSS 25.0 version was used for statistical analysis. Shapiro Wilk test was used to evaluate the distribution of numerical data. Numerical data that did not

Table 1. Demographic data

Gender N: 90		Age (year)	MPVD (mm)	Height (cm)	Weight (kg)	BMI (kg/m ²)	Liver size (mm)	Spleen size (mm)
Male	Mean ± sd	50 ± 17.99	13.03 ± 1.13	171.76 ± 5.03	66.61 ± 6.15	22.52 ± 0.99	145.27 ± 6.61	97.88 ± 16.21
	Median	50.00	13.20	171.50	66.05	22.60	145.50	99.50
	Min.	20.00	8.50	164.00	53.25	19.80	133.00	80.00
	Max.	80.00	16.00	188.00	83.40	24.90	157.00	123.00
Female N: 90	Mean ± sd	50.14 ± 17.65	12.38 ± 1.18	161.54 ± 3.57	57.48 ± 4.88	21.95 ± 1.19	146.24 ± 6.48	93.35 ± 11.95
	Median	50.00	12.50	162.00	57.90	22.10	147.00	95.00
	Min.	20.00	9.20	154.00	45.80	18.80	130.00	68.00
	Max.	79.00	15.20	174.00	74.10	24.60	160.00	118.00
Total N:180	Mean ±sd	50.07 ± 17.77	12.7 ± 1.20	166.65 ± 6.72	62.04 ± 7.18	22.23 ± 1.13	145.76 ± 6.54	95.61 ± 14.38
	Median	50.00	12.90	165.00	61.70	22.40	147.00	96.00
	Min.	20.00	8.50	154.00	45.80	18.80	130.00	8.00
	Max.	80.00	16.00	188.00	83.40	24.90	160.00	123.00

min: minimum. max: maximum. sd: standart deviation

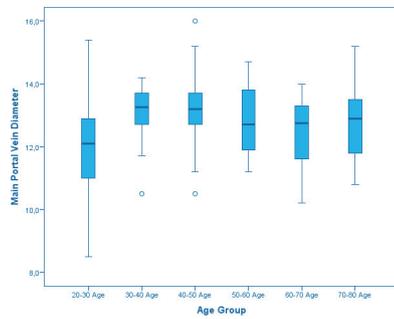
show normal distribution were expressed as median, minimum (min) and maximum (max), and categorical data were expressed as numbers and percentages. Spearman's correlation test was used to evaluate correlation between numerical data. The relationship between gender and MPVD was evaluated by Mann Whitney U test and the relationship between age groups and MPVD was evaluated by Kruskal Wallis test. Statistical values of $p < 0.05$ were considered significant.

Results

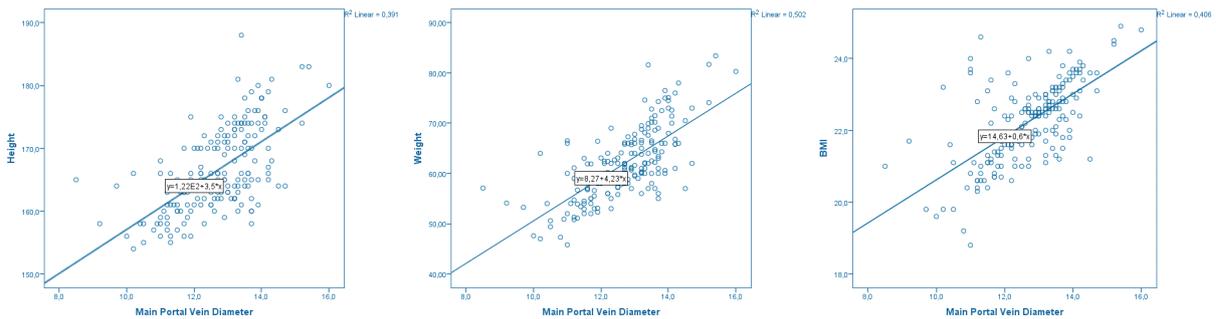
The mean MPVD was 12.38 in females and 13.03 mm in males, mean height was 161.50 cm in females and 171.50 cm in males, mean BMI was 21.95 kg/m² in females and 22.52 kg/m² males, mean craniocaudal length of the liver was 146.20 cm in females and

145.20 mm in males, mean long spleen axis was 93.30 mm in females and 97.80 mm in males. Demographic data of the participants are shown in **Table 1**. MPVD was measured 8.5 mm as min and 16 mm as max. MPVD was found to be significantly wider in males than in females ($p < 0.001$).

Participants were separated in 6 groups according to ages for each decade. **Table 2** shows the mean age, weight, height, BMI values, MPVD, liver and spleen craniocaudal long axes by gender and for all participants. PV widths were significantly different between groups ($p = 0.008$). Between the subgroups, statistically significant difference was found between the 3rd-4th decades and 3rd-5th decades (p values were 0.014 and 0.026, respectively). **Graph 1** shows the relationship between age groups. No significant difference was found between the decades in terms of



Graph. 1. Boxplot graph showing portal vein width of cases according to age groups.



Graph 2. Scattering graphs showing the correlation between height, weight and BMI and the width of the main portal vein.

Table 2. Mean and standard deviation of body parameters (portal vein diameter, liver and spleen craniocaudal length) among the group						
	Age (year)	Height (cm)	BMI (kg/m ²)	MPVD (mm)	Liver size (mm)	Spleen size (mm)
Group 1 (20-29.9)	24.6 ± 3.18	165.13 ± 6.00	22.07 ± 1.27	12.02 ± 1.64	147.43 ± 7.04	105.26 ± 11.42
Group 2 (30-39.9)	34.54 ± 2.62	168.23 ± 7.56	22.34 ± 0.89	13.11 ± 0.80	145.77 ± 5.45	92.74 ± 21.6
Group 3 (40-49.9)	45.0 ± 3.16	167.66 ± 7.90	22.78 ± 1.06	13.13 ± 1.02	149.10 ± 5.39	99.90 ± 8.50
Group 4 (50-59.9)	55.04 ± 3.21	166.50 ± 6.00	22.14 ± 1.11	12.78 ± 1.05	146.20 ± 4.61	92.49 ± 12.54
Group 5 (60-69.9)	66.02 ± 2.95	165.86 ± 5.63	21.85 ± 0.81	12.48 ± 1.05	143.81 ± 7.90	89.2 ± 12.38
Group 6 (70-80)	75.21 ± 3.69	166.55 ± 7.12	22.25 ± 1.39	12.07 ± 1.30	142.20 ± 6.19	94.01 ± 10.84

liver and spleen sizes.

Graph 2 shows scatter plots indicating the correlation between height, weight, BMI and MPVD. When the relationship between MPVD and weight, height, BMI, liver and spleen length were evaluated, the highest correlation was found with BMI. Correlation values with other parameters are shown in **Table 3**. Two samples of the measurement of PV diameter are shown in **Figs. 1 and 2**.

Discussion

There are many studies about the normal values of MPVD in the normal population. Most of these studies were performed with US. In the literature, the number of studies evaluating MPVD by CT is limited. In this study, the mean MPVD in patients with normal BMI was found to be 12.75 ± 1.20 mm (max 16 and min 8.5 mm). In studies performed with US, the normal range of MPVD was reported to be 11.7-14 mm and



Fig. 1. Measurement of diameter of the main portal vein shown on the axial contrast-enhanced CT image.



Fig. 2. Measurement of diameter of the main portal vein shown on the axial contrast-enhanced CT image.

Table 3. Correlation of portal vein diameters and body parameters (liver-spleen craniocaudal length)			
	Male	Female	Total
	r/p value	r/p value	r/p value
Years	0.860/0.420	-0.030/0.780	0.210/0.785
Weight (kg)	0.702/0.000	0.762/0.000	0.708/0.000
Height (cm)	0.661/0.000	0.719/0.000	0.626/0.000
BMI (kg/m ²)	0.578/0.000	0.639/0.000	0.637/0.000
Liver size (mm)	0.150/0.170	0.170/0.110	0.117/0.119
Spleen size (mm)	0.017/0.870	0.170/0.110	0.153/0.400

Spearman rho test. *p* value <0.05 is significant.

in these studies the upper limit for PH was accepted as 13 mm [3, 4]. However, there is no clear answer to the question whether the upper limit of 13 mm can be used in individuals with high BMI. Nevertheless, 13 mm is accepted as the upper limit in many reference textbooks and organisations such as the European Federation of Societies for Ultrasound in Medicine and Biology accept this value as the upper limit [9].

MPVD may vary with gender, age, weight, height, BMI [8]. It is one of the results of the study that MPVD is larger in males than females. In the study by Kurol et al., similar to our study, MPVD is reported to be wider in men than in women [10]. According to literature, another parameter affecting MPVD is age. However, in all groups, no statistically significant correlation was found between MPVD and age in our

study. On the other hand, in the comparison between the groups, it was observed that MPVD was smaller in individuals in the 3rd decade than in the 4th and 5th decade.

Measurement of MPVD by US is influenced by factors such as inspiration, postural changes, nutritional status and user [11]. However, although the nutritional status is an important factor in CT measurements, more objective measurements are made by CT than US. Therefore, it is possible that the measurements made on CT are higher than those obtained with US and the values in our study are expected to be slightly higher than the studies performed with US. Therefore, it is important that this study with CT measurements can give more accurate values. In addition, a higher new value was found compared to the

studies conducted with US. On the other hand, there is no comparative study on US and CT in the literature. Further studies are needed on this subject.

Another condition affecting MPVD measurement is that CT evaluation is performed with contrast images. In the study of Stamm ER et al., it was reported that the measurements in contrast-enhanced images were approximately 0.56 mm higher than non-contrast images [12]. This may be due to the difficulty in clearly distinguishing the vessel wall border from the lumen in non-contrast images.

In this study, the mean MPVD was measured as 12.75 mm and is close to the 13 mm limit which is considered as the upper limit for PH evaluation according to the literature. However, 84 healthy individuals (46.6% of the participants) had MPVD over 13 mm. The mean MPVD of this group was calculated to be 13.80 and may be the reason for the increase in the overall average. In our study, it was found that MPVD increases with BMI and height and is statistically significant.

In their recent study about the upper limit of MPVD in healthy kidney donors, Stamm ER et al. stated that the upper limit of MPVD was 15 mm [12]. It was noteworthy that the mean BMI of the patients evaluated in this study was 25.9 kg/m². MPVD is known to increase as BMI increases. The mean BMI of our participants was 22.4 kg/m² and we also observed that as the BMI of the participants came close to 25, MPVD increased and was above 13 mm. According to results of both our study and the study of Stamm ER et al., the main factors determining MPVD are height and BMI [12]. Therefore, patient height and BMI values should be considered when using the 13 mm upper limit for MPVD. However, in order to determine MPVD according to the patient, it is a fact that a standard formula that can be calculated by BMI requires multicentre studies with a large number of healthy volunteers by forming groups of participants separated by narrow BMI values.

According to our results, MPVD did not correlate with craniocaudal lengths of liver and spleen, but this may be due to the assessment of healthy participants. In our measurements, the mean long axis of the

spleen was 95 mm. We think that if normal population is compared to patients with splenomegaly, significant results could have resulted. There are studies in the literature indicating that MPVD can increase with splenomegaly [13].

The most important limitation of our study was the exclusion of PH patients and participants with BMI values above 25 kg/m² but without additional disease. Therefore, no comparison was made between the patients with PH and healthy individuals and the optimal estimation value could not be calculated. However, since the target of the study is participants who have no comorbidities, studies with comorbid diseases can contribute to the literature in this respect. Another limitation is the lack of interobserver evaluation. Although interobserver evaluations are important in terms of showing reproducibility, it was aimed that the measurements we made by making simultaneous joined decisions would lead us to more accurate data.

Conclusions

The mean MPVD was found to be 12.75 ± 1.2 mm in healthy individuals with normal BMI. With these findings, we suggest that the upper limit of MPVD can be accepted as 13 mm in PH evaluation. However, our study and similar studies in the literature showed that MPVD increases as height and BMI increase. Therefore, clinical findings, height and BMI should be taken into consideration for PH evaluation in patients with MPVD above 13 mm. In addition, there is a need for studies in a multicenter large population from each BMI group. **R**

Funding

This project did not receive any specific funding.

Ethical approval

The institutional review board of the hospital waived the requirement to obtain written informed due to retrospective study.

Conflict of interest

The authors declared no conflicts of interest.

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CITATION

Dilek O, Kaya O. Determination of mean portal vein diameter: An approach with Computed Tomography. *Hell J Radiol* 2021; 6(1): 28-34.