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Ultrasound Evaluation of Portal Vein Diameter and Its Doppler Hemodynamics In Apparently Healthy Adults in a Tertiary Health Institution In Northern Nigeria.

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Abstract

Background: Portal vein enlargement was initially considered the main sign of portal hypertension. However, the portal vein caliber does not increase angiographically and may decrease with increasing porto-hepatic venous pressure. Hepatofugal flow and/or portosystemic shunt developments also decrease the portal vein caliber, thus making the portal vein size alone a nonreliable indicator of portal hypertension.

Objective: To determine the portal vein diameter (PVD), peak systolic velocity (PSV), and pulsatility index (PI) and their relationships in apparently healthy adults based on age, gender, and anthropometric variables.

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Methods: A cross-sectional prospective study was conducted among 196 healthy adults in ATBUTH, Bauchi metropolis. An ultrasound machine, “SIEMENS G50,” with a 3.5MHz transducer and Doppler capability, was used. Following overnight fasting, subjects were examined in the supine and right side anterior oblique positions for portal vein diameter, PSV, and PI measurements. Anthropometric variables were measured before the examinations. Data obtained were analyzed using SPSS (22.0) and descriptive statistics.

Results: A total of 196 {Males=106(54.07%), Females=90(45.92%)} healthy adults were enrolled in the study. The mean portal VD, PSV, and PI were 11.15 ± 1.81 mm, 22.19 ± 7.08 cm/s and 0.59 ± 0.07 for both genders, respectively, and found a weak negative correlation between portal vein pulsatility index and portal vein diameter, age & body mass index. However, these associations were not statistically significant.

Conclusion: This study has established reference values for standard portal VD, PSV, and PI in a Northern Nigerian population with their corresponding relationships based on age, gender, and anthropometric variables.

KEYWORDS: *Portal vein, Portal vein diameter, peak systolic velocity, pulsatility index, sonography, healthy adults.*

Introduction

Generally, the average portal vein diameter caliber has been extensively studied across different ages, genders, races, and populations (1). Still, a precise description of portal vein waveform in healthy individuals needs to be improved in the literature. It is vital to characterize the pattern of typical portal vein waveform across different populations, races, and disease conditions (2). Traditionally, enlargement of the portal vein has been considered a sign of portal hypertension (3), (4), and (5). However, studies have shown that a threshold portal vein diameter greater than 13 or 15mm is sensitive for diagnosing portal hypertension (6). It has been noted angiographically that the diameter of the portal vein does not increase with the Porto-hepatic venous pressure gradient and may even tend to decrease depending on the severity of hypertension (3). Furthermore, with the development of reversed portal vein flow (hepatomegaly flow) and portosystemic shunts, the portal vein caliber will decrease; therefore, the actual size of the portal vein may not be a reliable indicator of portal hypertension (6).

Gray scale ultrasound is one of the imaging modalities of choice and has reasonable accuracy in diagnosing patients suspected of having portal hypertension. Duplex Doppler assessment of the

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portal vein has the added advantage of assessing the flow rate in both standard and abnormal cases (5).

Abdominal ultrasound is the most commonly used imaging modality to evaluate liver pathologies and portal hypertension (7). Doppler studies can add further hemodynamic information correlating with disease status, which might help diagnose portal hypertension (8). In portal hypertension imaging, ultrasound techniques such as duplex ultrasonography, spectral Doppler, color Doppler, and power Doppler imaging are chosen because of their non-invasiveness, rapidity, high sensitivity, and specificity. For patients with known cirrhosis, Doppler ultrasound has a specificity of greater than 80% (9).

This study, therefore, aims to establish the average values of portal vein diameter, pulsatility index, and peak systolic velocity in a healthy Northern Nigerian population and study their variations with age, gender, and anthropometric variables.

Materials and Methods

A cross-sectional prospective study was conducted among apparently healthy adult subjects in Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH) Bauchi from November 2020 to May 2021. Ethical clearance was obtained from the ethical clearance committee, the head of the hospital's radiology department, and written informed consent was obtained from all participants before the study. Participants were recruited from the town and staff from other departments in the hospital.

Inclusion and Exclusion Criteria

All healthy individuals between the age of 18-80 years with normal liver ultrasound findings and who gave consent to participate in the study formed the inclusion criteria, while all critically ill individuals, those with abnormal liver function test (LFT), fatty liver, splenomegaly, cardiac disease, ascites, body swelling, pregnant women and subjects on hepatotoxic drugs were excluded from the study.

Scanning technique

Following overnight fasting, each patient was exposed from the xiphisternum to the pelvic brim, and ultrasound gel was applied to the right upper quadrant of the abdomen. During quiet respiration, when visualization of the portal vein was optimal, the portal vein diameter was measured from inner-to-inner walls at its broadest part just below the point of union between the superior mesenteric artery and the splenic vein (10). All measurements were taken twice by an

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observer of about seven years post-qualification experience, and the average was calculated to enhance the accuracy of the results and reduce inter-observer variability (11).

The peak systolic velocity and the pulsatility index were measured with a sample volume cursor placed at the center of the portal vein lumen, midway between the spleno-mesenteric confluence and portal vein division into the left and right hepatic branches. The angle between the longitudinal axis of the portal vein and the Doppler beam was maintained at 30-60 degrees (12). The indices were calculated using the mean of three consecutive spectral waves (13). The portal vein peak systolic velocity was taken as the highest value of the sinusoidal waveform. The portal venous pulsatility index, on the other hand, was calculated as $V2/V1$, where $V1$ is the peak portal vein velocity (systolic), and $V2$ is the trough velocity (end-diastolic) (13).

Before scanning, demographic data such as age, sex, weight, and height were also taken. The subject stands erect with their face facing forward, and a meter rule is placed against the subject posteriorly to measure the height. The subjects were asked to climb the clinical weighing scale after removing their shoes and any heavy object to measure the subject's weights. BMI was then calculated using the "quetlet's formula": $BMI = \text{weight (Kg)} / \text{height (m}^2\text{)}$ (14).

Data analysis

A data capture sheet was used to record all the acquired information. Data analysis was done using Statistical Package for Social Science (SPSS) Version 22.0. Descriptive statistics (mean, standard deviation, frequency, and percentage) were used to describe the portal vein diameter, peak systolic velocity, and pulsatility index. The correlation between the portal vein diameter, peak systolic velocity, and pulsatility index with age was also evaluated using inferential statistics (person correlation test).

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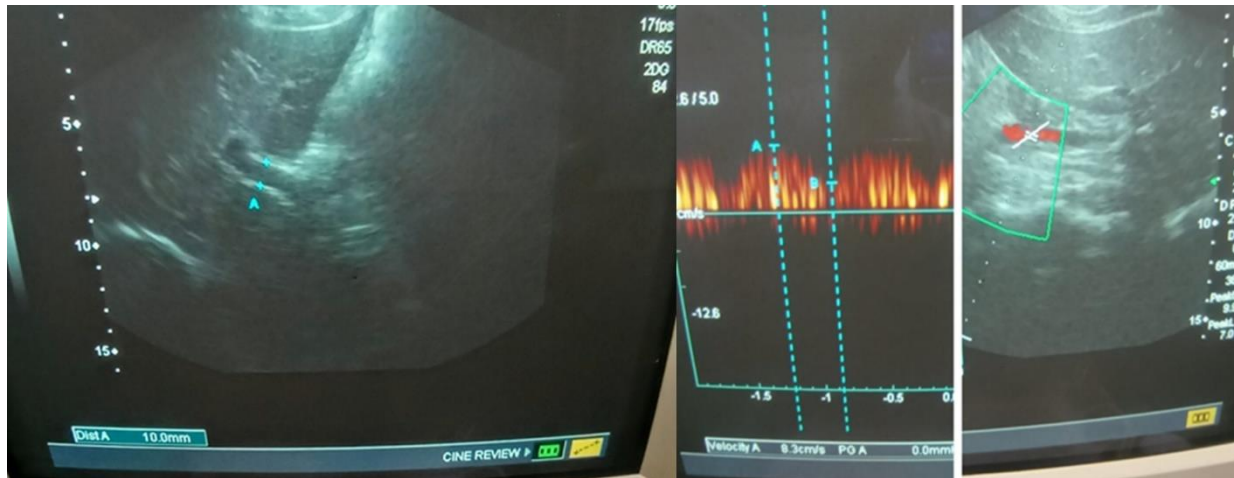


Fig1. Greyscale ultrasonographic image of portal vein diameter measurement and corresponding Doppler waveform.

Results

A total of 196 {106 (54.07%) males and 90 (45.92%) females} healthy adults were enrolled in the study. Table 1 shows the frequency distribution of these participants based on age and gender.

Tab 1. Frequency distribution is based on the age and gender of subjects.

Age	Male N	(%)	Female N	(%)	Total N	Total (%)
20-30	41	20.91%	31	15.82%	72	36.72%
31-40	30	15.31%	28	14.29%	58	29.60%
41-50	15	7.65%	10	5.10%	45	12.75%
51-60	10	5.10%	13	6.63%	33	11.73%
>60	10	5.10%	8	4.08%	18	9.18%
Total	106	54.07%	90	45.92%	196	100%

In this study, portal VD and PI are higher in males than females, while PSV is higher in females than males. Table 2 below shows both genders' portal vein diameter, PSV, and PI mean values.

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Tab2. Mean Portal VD, PSV, and PI about gender.

Mean Parameters/group	Males (54.07%)	Females (45.92%)
	Mean	Mean
PVD(mm)	11.15±2.09	11.15±1.37
PSV(cm/s)	20.20±4.92	24.91±5.60
PI	0.60±0.07	0.59±0.07

PVD: portal vein diameter, PS: peak systolic velocity, PI: pulsatility index

Tab3. Participants' Weight, Height, PVD, Portal Vein PSV, and PI according to age groups.

Age	WEIGHT (kg)	HEIGHT (m)	PVD(mm)	PSV(cm/s)	PI
	Mean	Mean	Mean	Mean	Mean
20-30	62±7.0	1.69±0.7	11.05±2.05	18.83±5.03	0.61±0.08
31-40	68±7.0	1.69±0.6	11.18±1.65	28.21±3.19	0.58±0.06
41-50	72±8.0	1.70±0.4	11.41±1.51	21.47±4.51	0.59±0.06
51-60	72±6.0	1.70±0.4	10.66±1.67	22.19±4.85	0.57±0.05
>60	69±7.0	1.71±0.4	11.92±1.90	19.35±4.49	0.59±0.07
Total	67±8.0	1.69±0.6	11.15±1.81	22.19±7.0	0.59±0.07

Table 3 shows the mean values of the subject's weight, height, portal vein diameter, PI, and PSV, each with their respective age groups and mean totals.

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Correlation analysis shows a weak negative correlation between portal vein PI and BMI ($r = -0.211$; $p < 0.033$), age ($r = -0.168$; $p = 0.046$), and PVD ($r = -0.175$; $p = 0.039$). However, these associations were not statistically significant.

No significant correlation was found between Portal VD/PSV and age, gender, or BMI, as shown in Tables 4 and 5 below.

Tab 4. Correlation between portal VD, PSV, and PI with BMI.

	Pearson Correlation	BMI P-value	Classification	PVD	PSV	PI
BMI Classification	Pearson Correlation		1	0.107	0.124	0.211*
	Sig. (2-tailed)			0.283	0.213	0.033
PVD	Pearson Correlation		0.107	1	-0.060	0.175
	Sig. (2-tailed)		0.283		0.550	0.078
PSV	Pearson Correlation		0.124	-0.060	1	-0.052
	Sig. (2-tailed)		0.213	0.550		0.602
PI	Pearson Correlation		0.211*	0.175	-0.052	1
	Sig. (2-tailed)		0.033	0.078	0.602	

PVD: portal vein diameter, PS: peak systolic velocity, PI: pulsatility index.

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Tab 5. Correlation between Portal VD, PSV, and PI with age and Gender.

	PVD	PSV	PI	Gender	Age	
PVD	Pearson Correlation	1	-0.060	-0.175*	0.000	0.050
	Sig. (2-tailed)		0.275	0.039	0.500	0.309
PSV	Pearson Correlation	-.060	1	-0.052	0.137	0.037
	Sig. (2-tailed)	0.275		0.301	0.085	0.355
PI	Pearson Correlation	-0.175*	-0.052	1	-0.036	-0.168*
	Sig. (2-tailed)	0.039	0.301		0.359	0.046
Gender	Pearson Correlation	0.000	0.137	-0.036	1	0.057
	Sig. (2-tailed)	0.500	0.085	0.359		0.285
Age	Pearson Correlation	0.050	0.037	-0.168*	0.057	1
	Sig. (2-tailed)	0.309	0.355	0.046	0.285	

PVD: portal vein diameter, PS: peak systolic velocity, PI: pulsatility index

Discussion

The caliber of the standard portal vein diameter has been extensively studied across different ages, sexes, races, and populations (1 & 6). Still, the literature must precisely describe portal vein waveforms in healthy individuals. It is essential to characterize the pattern of average portal vein waveforms across different populations, races, and disease conditions (2 and 4).

Findings from this study showed that the Mean portal vein diameter (PVD), peak systolic velocity (PSV), and pulsatility index (PI) were $11.5\text{cm} \pm 1.81\text{cm}$, $22.19 \pm 17.08\text{cm/s}$ and 0.59 ± 0.07 respectively. These findings were similar to those reported by Chou (12) in Malaysia, Songmen (8) in Indian Nepalace populations, and Ahmmed (15) in Sudan who reported average PVD, PSV and PI values of ($10.34 \pm 3.2\text{mm}$, $21.58 \pm 1.76\text{cm/s}$, & 1.43 ± 1.65 respectively), ($10.4 \pm 1.18\text{mm}$, $33.35 \pm 9.3\text{cm/s}$ & 0.76 ± 0.07 respectively) and ($11.16 \pm 1.70\text{mm}$, $38.58 \pm 5.83\text{cm/s}$) accordingly. Harshita (16) in North India also reported similar findings of a portal vein diameter of

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9.17±2.33mm (males) and 8.95±1.9mm (females), respectively, with an average PSV value of 13-15cm/s and Gallix (17) reporting an average portal vein PI value of 0.48±0.31. The similarities in these results may not be unconnected to the employment of similar methods, techniques of measurements, instruments, and observer expertise since sonography is a highly operator-dependent imaging modality (18).

Many available and currently accepted literature have reported variations of portal vein diameter, PSV, and PI with age, gender, and anthropometric variables. In this study, the average portal vein diameter was higher in males than in females. However, the difference was not statistically significant, with a p-value >0.05, which corroborates most local and international research reports across different localities, ethnicities, and races. There was no correlation found between portal vein PSV and PI with gender. Al-Nakshabandi (4), Luntsi (5), Adeyekun (19), Gosh (1) and Adeyekun (20) reported similar findings. The difference between male and female PVD can be explained since females show less growth in comparison to their male counterparts. Therefore, their body organs (including the liver and portal veins) are also smaller (21). Differences in the phases of respiration at the time of ultrasonographic measurements can also influence this variation of the portal vein diameter with gender (4).

The study reports a weak negative correlation between PI and BMI ($r = -0.211$; $p < 0.033$). This finding corroborates with that of Gallix (17), who reported that thin subjects have more pulsatile portal vein flow than obese subjects (17). Recent evidence suggested that an increase in the liver size associated with an increase in BMI is generally attributed to a build-up in the workload and physiological adaptation to the rise in metabolic demands (20), possibly resulting in lesser resistive flow to meet the high demand.

There was also a weak negative correlation found between portal vein PI and age ($r = -0.168$; $p < 0.046$); however, this contradicts the findings from Songmen (8), who reported an absence of correlation of the PI with age. The negative correlation between PI and age could be due to the

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fragmentation of smooth muscles and loss of elasticity in the reticular network of the vein with age (20), and hence, the gradual decrease in the vein pulsatility index with increasing age.

There was a weak negative linear correlation between PVD and PI ($r = -0.175$; $p = 0.039$). However, no correlation was found between PVD and PSV and PSV and PI. Several findings have reported an increase in portal VD and formation of collaterals in subjects with abnormal increase in portal venous pressure (Portal hypertension), and a PVD $>15\text{mm}$ is currently utilized as a cardinal marker of portal hypertension (3, 4, 6, 10, 11, 13 & 15). Such instances may result in low blood flow resistance in the portal vein and, hence, the possible reasons for the gradual decrease in portal vein PI with increasing diameter.

The findings from this study showed no significant correlation between the portal vein diameter and peak systolic velocity, age, and BMI. This is in line with the findings from Adeyekun (19), who reported the absence of a correlation between PVD and age as well. Still, however, these findings were different from the previous works conducted by Gosh (1), Luntsi (4), Ankwue (22), Harshita (16), and Hawaz (5). These variations may be due to the differences in the study population, geography, ethnicity, age involvement of the extreme, and variations in the measurement techniques.

Limitations: Employment of a small sample size with dependency on a single observer, which might lead to observer's or instrumental bias.

Conclusion

This study has established the baseline values for normal ranges of portal vein diameter, peak systolic velocity, and pulsatility index in a Northern Nigerian population to be $11.15 \pm 1.81\text{mm}$, $22.19 \pm 7.08\text{cm/s}$ and 0.59 ± 0.57 respectively, and found a weak negative correlation between pulsatility index and portal vein diameter, age, and body mass index.

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Ethics Approval and Consent to Participate: All procedures followed were by the ethical standards of the responsible committee on human experimentation of the University of Maiduguri and Abubakar Tafawa Balewa University Teaching Hospital Bauchi and with the Helsinki Declaration of 1964 and later versions.

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