

Ultrasonographic Measurements of the Liver, Gallbladder Wall Thickness, Inferior Vena Cava, Portal Vein and Pancreas in an Urban Region, Malaysia

Abdul Sattar Arif Khammas^{1*}, Rozi Mahmud²

¹Department of Radiological Techniques, College of Health and Medical Technology/Baghdad, Middle Technical University, Baghdad, Iraq, ²Department of Imaging, Faculty of Medicine and Health Sciences, University Putra Malaysia, Selangor, Malaysia

Abstract

Background: Ultrasonographic (USG) measurements of the liver length, gallbladder wall thickness (GBWT), diameters of the inferior vena cava (IVC), portal vein (PV), and pancreas are valuable and reliable in diagnosis hepatobiliary and pancreas conditions. This study is aimed to determine the normal values of liver length, GBWT, AP diameters of the IVC and PV, AP diameter of the head and body of the pancreas. **Methods:** A prospective cross-sectional study was carried out in this study. A total of the 408 participants were randomly recruited using a systematic method. According to the USG reports, the subjects who had normal USG report for liver, biliary system, and pancreas were described as normals, whereas the subjects who had hepatobiliary diseases such as fatty liver, liver cysts, hemangioma, cirrhosis, gallbladder wall thickening, acute cholecystitis, gallstones, and polyps were recorded as abnormal subjects. **Results:** Of the 408 participants with a mean of 52.6 ± 8.4 years old. Of those, 294 (72.1%) participants were normal and 114 (27.9%) subjects were reported as abnormal. More than half of the study population was males, 52.9% versus 47.1% of females. There was a significant difference of liver length, head, and body of the pancreas between genders ($P = 0.004$, 0.002 , and $P < 0.001$, respectively). Moreover, the pancreatic body only was significantly correlated with age ($P = 0.026$). There also was a significant difference of the liver length, head, and body of the pancreas between normal and abnormal subjects ($P < 0.001$, $P = 0.007$, and $P < 0.001$). **Conclusion:** Liver length, diameter of the head, and body of the pancreas were significantly associated with gender and hepatobiliary diseases. In addition, only the diameter of the body of the pancreas was significantly correlated with age.

Keywords: Gall bladder, liver, Malaysia, pancreas, ultrasonographic measurements

INTRODUCTION

Abdominal ultrasonography (USG) is widely used in evaluating liver size as it is noninvasive, safe (no ionizing radiation), available and lower cost than other radiological modalities such as magnetic resonance imaging and computed tomography.^[1] The most common measurement of the liver size is obtained in the midclavicular line (MCL).^[2] Liver size is affected by many conditions such as malignant tumors, fatty liver changes, and infective diseases.^[1] Therefore, it is considered as indicator for diagnosing some diseases.^[3,4] Moreover, the liver size is related to anthropometric variations of the people from different races and geographical regions.^[5,6] Recent studies carried out to determine a normal range of liver size.^[7,8] These studies focused on age and sex as affecting factors.^[9]

Gallbladder wall (GBW) is thickened by some conditions such as acute cholecystitis, acute hepatitis, gallbladder (GB) carcinoma, hepatic cirrhosis, hypoalbuminemia, pancreatitis, acute pyelonephritis, and myeloma.^[10] However, several literature showed that GBW thickening and impaired contractility are closely associated with liver cirrhosis, hepatic failure, and portal hypertension.^[11]

The portal vein (PV) is formed by the union splenic and superior mesenteric vein posterior to the head of the pancreas.^[12] It conveys blood from the bowel and spleen to the

Address for correspondence: Asst. Lecturer. Abdul Sattar Arif Khammas, 10047, Bab Al Muadham, Baghdad, Iraq. E-mail: alazawi.2014@hotmail.com

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liver. Portal hypertension is a major feature of chronic liver disease.^[13] USG can be used to assess PV diameter, which is useful in evaluating portal hypertension in chronic liver disease patients.^[14]

USG is also used for evaluating inferior vena cava (IVC) diameter in ventilated and hemodynamic unstable patients. In healthy controls, variations in intrathoracic pressure could be transmitted to the IVC and reducing its diameter by 50%.^[15] Moreover, the hepatic portion of the IVC is highly related to the liver parenchyma so that variations in the IVC lumen could be occurred by variations in the liver parenchyma.^[16]

USG of the pancreas is challenging as it locates retroperitoneal with overlying structures and relatively small in size. Particularly, the sensitivity and specificity of USG for the diagnosis of pancreatic diseases, as well as the ability to distinguish between acute and chronic pancreatitis, are still not determined.^[17] The normal echogenicity of the pancreas is equal to or slightly higher than that of the liver.^[18] An increase in echogenicity of the pancreas due to lipomatosis and decrease in size is very common with age advances.^[19-21] A previous study also showed that hyperechogenicity of the pancreas is closely associated with hepatic steatosis.^[22]

The aim of this study is to determine the differences of ultrasound measurement of the liver length, gallbladder wall thickness (GBWT), IVC, PV, and pancreas among genders and between normal and abnormal subjects.

METHODS

Study population

In this cross-sectional prospective study, a total of the 408 participants (294 normal vs. 114 abnormal subjects) were randomly recruited using systematic methods over 5 months from August 2015 to January 2016. According to USG reports, the participants who had normal USG report for the liver, biliary system, and pancreas were described as normals, whereas the subjects who had hepatobiliary diseases such as fatty liver, liver cysts, hemangioma, cirrhosis, GBW thickening, acute cholecystitis, gallstones, and polyps were recorded as abnormal subjects. Participants with ages ranging between 19 and 75 years underwent a screening program at the Golden Horses Health Sanctuary located in Seri Kembangan, Klang Valley, Malaysia. This center serves medical screening and checkups for people living in this region. Several medical checkups such as USG, computed tomography, conventional radiograph, physical examination, blood tests with physician consultation are performed in this center. For this study, abdominal USG, including measurements of the liver length, GBWT, IVC, PV, and pancreas, were only reported and included. The participants who under 18-year-old, had previous liver, GB, and pancreas cancer or surgeries, had taken chemo – or/and radiotherapy and were unable to read or did not complete the questionnaire were excluded from this study. Although, the study involves human study, the IRB/IRC approval is exempt, because of the data such as sonographic measurements of organs involving

in this study have been prospectively collected from medical records and not directly from the subjects. In addition, this study has no included blood taking or any test else that might carry risk for the participants. The informed consent form was signed by all participants.

Abdominal USG technique

Abdominal USG was performed by five radiologists with an experience of 15 years. USG machine (Philips medium-range/HD 15) equipped with a 3.5 MHz convex probe was used in this study. In this study, B-mode was applied in all examinations. The subjects were recommended to take nothing by the mouth at least 8 h preceding the ultrasound examination. The subjects lied in the supine or lateral decubitus (if needed) positions. Participants were asked to take a deep inspiration and to hold it when it was required. A coupling agent (gel) was applied on the required area. To obtain the best visualization of the organs, longitudinal, transverse, and oblique planes with a slow rocking movement of the probe were achieved. In all participants, the organ size, parenchymal homogeneity, echogenicity, and contours were evaluated.

The liver examination was performed in subcostal and intercostal spaces. On the longitudinal plane, the liver size was measured in the right MCL extending from the liver top to the bottom. The liver size was measured in the right lobe only because it is so difficult to measure accurately overall its size. The normal liver parenchyma is homogenous with echogenicity similar to or slightly greater than the right renal cortex and spleen.^[23] Variations in liver parenchyma or echogenicity were described as abnormal.

GB appears as anechoic pear shape structure on a longitudinal scan and oval or rounded on the transverse scan. Its wall is reflective (hyperechoic) and appears thickening when it is contracted and thinning when it is distended. As well as supine position left lateral decubitus position was also performed to get the best window of GB. GBWT was measured on a longitudinal scan with an ultrasound beam perpendicularly oriented at the level of the GB anterior wall.

The IVC was measured through the liver on transverse scan from anterior to posterior walls (AP diameter). IVC scan was obtained in the right subcostal space, particularly in a level 1–2 cm distal to the confluence of main hepatic veins. The optimal AP diameter of the IVC was measured during normal expiration.

The PV interrupts the liver parenchyma and appears as a round structure on transverse scan and a tubular structure on a longitudinal scan with hyperechoic walls. On transverse scan and during expiration, the AP diameter of the PV was measured. Color Doppler was sometimes applied to differentiate PV from adjacent hepatic veins and biliary ducts. The examination was started in the epigastric area to assess the main PV, where the measurement was performed. If there are excess gases in the duodenum, the main PV may be obscured and then asked the subject to lie in the right anterior oblique or left posterior oblique to exclude the gases away from the examined area.

The normal pancreas appears homogenous with echogenicity a greater than liver and equal to or lower than that of retroperitoneal fat. Thus, variations in homogeneity or echogenicity of the pancreas are indicators for the diseased pancreas. Both transverse and longitudinal scans in the high epigastric area (to avoid colon) were performed to obtain the best visualization of the pancreas. Moreover, oblique intercostal and subcostal scans are also required to visualize the head of the pancreas. In an attempt to use a stomach and left lobe of the liver as an acoustic window, the subjects were asked to drink 3–4 glasses of water 10–15 min preceding the examination. As the tail of the pancreas is small and difficult to measure, the head and body were only measured in this study. AP diameter of both the head and body of the pancreas was recorded. The porto-splenic confluence is seen posterior to the pancreas and considered a strong landmark to highlight it.

Statistical analysis

Data were analyzed by the Statistical Package for the Social Science (SPSS) program version 22.0 (IBM, New York, United States). The descriptive statistic was used to find the percentages and frequencies for categorical variables and mean \pm Standard deviation for the continuous variables. The independent *t*-test was used to determine differences of means liver length, GBWT, IVC, PV, and pancreas between genders and between normal and abnormal subjects. Furthermore, Pearson's correlation coefficient was used to determine the linear correlation of liver length, GBWT, IVC, PV, and pancreas with age. A value of $P < 0.05$ was considered statistically significant.

RESULTS

Characteristics of the study population

The characteristics of the study population are shown in Table 1. Of the 408 subjects (aged 19–75 years) with a mean of 52.6 ± 8.4 years old. Of those, 294 (72.1%) subjects were normal and 114 (27.9%) subjects were reported as abnormal. More than half of the study population was males, 52.9% versus 47.1% females. The mean liver size in normals was 11.98 cm. In addition, IVC and PV were also measured and reported to be 2.41 ± 0.24 cm and 0.98 ± 0.14 cm, respectively. The measurement head of the pancreas was larger than the body (2.62 ± 0.53 cm versus 1.61 ± 0.49 cm, respectively).

Differences of mean liver length, gallbladder wall thickness, inferior vena cava, portal vein, and pancreas between males and females

The differences of mean liver length, GBWT, IVC, PV, and pancreas between males and females were tested and illustrated in Table 2. The liver length was larger in males (12.2 ± 1.5 cm) than in females (11.7 ± 1.5 cm). This indicates that differences of liver length between males and females were statistically significant ($t = 2.902$, $P = 0.004$). Similarly, the head and body of pancreas was also significantly larger in males (2.7 ± 0.5 cm) than females (2.5 ± 0.5 cm) ($t = 3.163$, $P = 0.002$). In the same context, the males had a larger body of the pancreas (1.8 ± 0.4 cm) than females (1.5 ± 0.5 cm), and the

difference was found to be statistically significant ($t = 4.706$, $P < 0.001$). Nevertheless, there were no significant differences of means GBWT, IVC, and PV between males and females ($t = 0.250$, $P = 0.803$, $t = 0.445$, $P = 0.657$ and $t = 0.625$, $P = 0.105$, respectively).

Correlation of the liver length, gallbladder wall thickness, inferior vena cava, portal vein and pancreas with age

Correlation of the liver length, GBWT, IVC, PV, and pancreas with age is shown in Table 3. Unexpectedly, our results revealed that liver length, GBWT, IVC, PV, and pancreas was

Table 1: Description of the study population (n=408)

Variables	Mean \pm SD/n (%)
Age	52.6 \pm 8.4
Gender	
Male	216 (52.9)
Female	192 (47.1)
Normal subjects	294 (72.1)
Abnormal subjects	114 (27.9)
Liver length (n=294)	11.98 \pm 1.54
GBWT (n=294)	0.22 \pm 0.14
IVC (n=294)	2.41 \pm 0.24
PV (n=294)	0.98 \pm 0.14
Pancreas (n=294)	
Head	2.62 \pm 0.53
Body	1.61 \pm 0.49

GBWT: Gallbladder wall thickness, IVC: Inferior vena cava, PV: Portal vein, SD: Standard deviation

Table 2: Differences of liver, gallbladder wall thickness, inferior vena cava, portal vein, and pancreas between males and females (n=294)

Variables	Males	Females	t-test	P
Liver length (cm)	12.2 \pm 1.5	11.7 \pm 1.5	2.902	0.004
GBWT (cm)	0.23 \pm 0.19	0.23 \pm 0.28	0.250	0.803
IVC	2.4 \pm 0.21	2.4 \pm 0.26	0.445	0.657
PV (cm)	0.99 \pm 0.14	0.97 \pm 0.14	1.625	0.105
Head of pancreas (cm)	2.7 \pm 0.5	2.5 \pm 0.5	3.163	0.002
Body of pancreas (cm)	1.8 \pm 0.4	1.5 \pm 0.5	4.706	<0.001

GBWT: Gallbladder wall thickness, IVC: Inferior vena cava, PV: Portal vein

Table 3: Correlation of liver size, gallbladder wall thickness, inferior vena cava, portal vein, and pancreas with age (n=294)

Variables	Age*	P
Liver length (cm)	0.018	0.754
GBWT (cm)	0.034	0.501
IVC (cm)	0.062	0.213
PV (cm)	0.040	0.422
Head of pancreas (cm)	0.073	0.140
Body of pancreas (cm)	0.110	0.026

*Pearson correlation value. GBWT: Gallbladder wall thickness, IVC: Inferior vena cava, PV: Portal vein

not significantly correlated with age ($t = 0.030$, $P = 0.612$, $t = 0.033$, $P = 0.576$, $t = 0.053$, $P = 0.367$, $t = 0.054$, $P = 0.361$, $t = 0.078$, $P = 0.180$, and $t = 0.102$, $P = 0.080$, respectively).

Differences of the liver length, gallbladder wall thickness, inferior vena cava, portal vein, and pancreas between normal and abnormal subjects

Table 4 shows differences of the liver length, GBWT, IVC, PV, and pancreas between normal and abnormal subjects. The mean liver length was significantly higher among abnormal subjects (12.76 ± 1.22 cm) compared to the normals (11.98 ± 1.54 cm) ($t = -5.398$, $P < 0.001$). Similarly, the mean AP diameter of head of the pancreas was also significantly higher among abnormal subjects (2.76 ± 0.43 cm) than normals (2.62 ± 0.53 cm) ($t = -2.722$, $P = 0.007$). Moreover, abnormal subjects had a significant higher AP diameter of body of the pancreas (1.78 ± 0.38 cm) as compared with the normals (1.61 ± 0.49 cm) ($t = -3.750$, $P < 0.001$). Otherwise, the differences of mean GBWT, IVC and PV were not observed to be statistically significant ($t = -1.453$, $P = 0.149$, $t = 0.960$, $P = 0.338$, $t = -1.441$, $P = 0.150$, respectively).

DISCUSSION

Ultrasound is an accurate and valuable tool in evaluating the internal organs sizes and vessel diameter. Liver length, GBWT, and pancreas can give details about the diagnosis of hepatobiliary diseases. An increase in PV diameter indicates to portal hypertension, which can consider a diagnostic feature of chronic liver disease and splenoportal complication. Dilatation of IVC indicates to right-sided cardiac failure. Compression of IVC may be caused by enlarged lymph nodes, retroperitoneal fibrosis, and hepatic tumor. Stenosis of IVC can be caused by thrombosis. In addition, the pancreatic tumor is occupationally manifested by a localized of increase in size.

The longitudinal measurement of the liver length in the right MCL is currently common approach that be used to assess liver size. An autopsy study documented that liver length measuring in MCL was strongly correlated with actual liver

length assessed through autopsy.^[24] A study by Kratzer *et al.*^[25] determined the mean liver length to be 13.9 ± 1.7 cm. Another study by Patzak *et al.*^[26] recorded the mean liver length as 15.0 ± 1.5 cm in the total population. Similarly, Tarawneh *et al.*^[27] showed that mean liver length was reported to be 12.3 cm. A recent study from Turkey by Özmen *et al.*^[11] reported the mean liver length as 14.9 ± 1.6 cm in the study population. The present study revealed that mean liver length was 11.98 ± 1.54 cm in normals. The results from the current study were very close to those revealed by Tarawneh *et al.*^[27] Moreover, Patzak *et al.* and Özmen *et al.* observed that mean liver length was significantly larger in males (15.1 ± 1.5 cm and 15.0 ± 1.4 cm, respectively) than in females (14.9 ± 1.6 cm and 14.7 ± 1.8 cm, respectively). Similarly, the study also confirmed that males had larger liver lengths than females (12.2 ± 1.5 cm and 11.7 ± 1.5 cm, respectively), indicative to significant differences of the liver length among genders. This may be attributed to the significant differences of the anthropometric measurements, such as body height, weight, body mass index, waist circumference, hip circumference, and waist-to-hip ratio between both genders. Regarding age, the association between liver size and age is still controversial. A previous study confirmed a significant association between liver size measuring in MCL and age with a tendency toward an increase with age advances.^[2] In contrary, earlier studies elucidated that liver size reduces with age.^[28] Patzak *et al.* reported that age did not affect liver size. Özmen *et al.* found a weak significant correlation between liver size and age. In the same line, our findings were consistent with Patzak *et al.* findings, where we found that liver length was no correlated with age.

GBWT can be accurately measured by ultrasound. It normally appears thin, regular and hyperechogenic. It is affected by some liver diseases such as cirrhosis and portal hypertension resulting of dilated vessels in the GBW.^[29] There are several conditions causing GBW thickening such as acute cholecystitis, pancreatitis, hepatitis, and pyelonephritis.^[30] Previous literatures showed that normal upper limit of GBWT is 3 mm.^[31] In no fasting subjects, however, the thickness may exceed such a limit due to GB smooth muscle contraction.^[32] In this study, the mean GBWT was 0.22 ± 0.14 cm measuring on a longitudinal scan. Several studies reported that GBW is thickened with age >65 years.^[33-38] Same these studies also reported that males had thickened GBW than females. Conversely, the current study found that mean GBWT between males and females was the same. In light of that, we also noted no significant correlation of GBWT with age. The significant differences of mean GBWT between normal and abnormal subjects were not observed in this study.

Recently, ultrasound is widely used to estimate blood volume and guide fluid therapy by measuring IVC diameter and monitoring its variation during the respiratory cycle.^[39,40] In the normal liver group, the maximal diameter of the IVC expiration was 2.35 ± 0.34 cm and reduced during suspended respiration by 1.30 ± 0.67 cm in the abnormal liver group, measurement of IVC diameter decreased to be 1.74 ± 0.35 cm

Table 4: Differences of mean liver size, gallbladder wall thickness, inferior vena cava, portal vein, and pancreas between normal and abnormal subjects (n=408)

Variables	Normal subjects	Abnormal subjects	t-test	P
Liver length (cm)	11.98 ± 1.54	12.76 ± 1.22	-5.398-	<0.001
GBWT (cm)	0.22 ± 0.14	0.28 ± 0.39	-1.453-	0.149
IVC (cm)	2.41 ± 0.24	2.38 ± 0.23	0.960	0.338
PV (cm)	0.98 ± 0.14	1.00 ± 0.14	-1.441-	0.150
Head of pancreas (cm)	2.62 ± 0.53	2.76 ± 0.43	-2.722-	0.007
Body of pancreas (cm)	1.61 ± 0.49	1.78 ± 0.38	-3.750-	<0.001

GBWT: Gallbladder wall thickness, IVC: Inferior vena cava, PV: Portal vein

and differences of mean IVC between the two groups were found to be significant.^[16] The present study documented the mean hepatic IVC diameter as 2.41 ± 0.24 cm. Furthermore, the means IVC diameter between normal and abnormal groups were close to each other, thereby the differences of the mean IVC diameter between these two groups were not noted to be significant. The association of IVC with age and gender was not tested by previous studies. However, our study did not find a correlation of hepatic IVC diameter with age and gender.

USG plays an important role in the evaluation of the PV diameter, peak systolic velocity, and flow rate. Previous studies from different countries reported the mean PV diameter among healthy controls; Luntsi *et al.*^[41] and Anakwue *et al.*^[13] from Nigeria documented as 0.96 ± 0.14 cm and 0.115 ± 0.15 cm, respectively. Hawaz *et al.*^[42] from Ethiopia documented as 0.10 ± 0.18 cm. Bhattacharya *et al.*^[43] from India documented as 0.10 ± 0.089 cm. Rokni and Sotoudeh^[44] from Iran documented as 0.936 ± 0.165 cm. In this study, the mean PV diameter was closely to that reported in the studies above as it found to be 0.98 ± 0.14 cm. A bit difference of mean PV diameter was noted among previous studies that may be attributed to differences in body size and then organs among ethnicities and races. Luntsi *et al.*^[41] revealed a higher mean PV diameter in males 0.97 ± 0.14 cm than in females 0.93 ± 0.14 cm, but the difference was not observed to be statistically significant. Several previous studies also found no significant differences of the mean PV diameter between males and females.^[42,45-48] These studies are compatible with the current study where the latter confirmed a slightly larger mean PV diameter in males than that in females; however, the difference also was not significant. Earlier studies revealed that PV diameter was positively correlated with age.^[13,42,43,45,48] Nevertheless, we did not find a correlation between PV diameter and age. In the same context, a study from North-Eastern Nigeria by Usman *et al.*^[49] reported a greater mean PV diameter among patients with chronic liver disease (0.186 ± 0.259 cm) as compared to those controls (0.108 ± 0.081 cm). Regarding measurements of the pancreas segments, on the transverse scan, AP diameter of the pancreatic head in the healthy controls is 2.5 cm, body 1.5 cm, and tail 3.5 cm.^[17,50] Our study stated the mean AP diameter of the pancreatic head as 2.62 ± 0.53 cm and the body as 1.61 ± 0.49 cm. As the pancreatic tail is very difficult to access, particularly on transverse scan, therefore it was not evaluated in this study. According to factors affecting, although there was no previously stated, an association between pancreas measurements and gender, a significant larger AP diameter of pancreatic head and body was found in males than in females. In this line, the present study reported that only the pancreatic body was positively correlated with age. Otherwise, Erchinger *et al.*^[50] showed that the whole pancreas tended to decrease slightly with age. The previous studies were not taken into account an association between pancreas size and patients with hepatobiliary diseases. However, this study also

showed that the pancreas increased in size among patients with hepatobiliary diseases compared to those without.

The limitations of this study did not reflect the overall study population in Malaysia as the subjects who attended the screening program was from upper and middle classes. Regarding the measurement of the vessel's diameter, no blood flow was measured for IVC and PV; however, only AP diameter was assessed. In addition, IVC and PV diameters were only measured on expiration, whereas the measurement of inspiration with breath-holding was not assessed. The subjects who come to our healthcare center are asymptomatic so that the diseases that were recorded to assess their affecting on the organs' sizes were limited.

CONCLUSION

This study determined baseline means of the normal liver length, GBWT, IVC, PV, and pancreas in Malaysian adults. The mean normal liver length was 11.98 ± 1.54 cm, GBWT was 0.22 ± 0.14 cm, AP diameter of IVC was 2.41 ± 0.24 cm, AP diameter of PV was 0.98 ± 0.14 cm, AP diameter of pancreatic head and body was 2.62 ± 0.53 cm and 1.61 ± 0.49 cm, respectively. Liver length and AP diameter of the pancreas were significantly higher in males than in females. In contrast, only the pancreatic body was positively correlated with age. When the comparison between subjects with and without hepatobiliary diseases was made, our findings found that liver length and pancreas significantly increased in patients with hepatobiliary diseases.

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Conflicts of interest

There are no conflicts of interest.

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