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Original Article

Nomograms of Liver, Spleen and Kidney Dimensions Based on Ultrasonographic Measurements

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Abstract

Background: *For Liver, spleen and kidney measurement, available data are not always representative for all population. This study was aimed to find out the normal measurement of kidney, liver, spleen using ultrasonography at Chattogram, Bangladesh.*

Materials and methods: *Among a total of 3699 subjects (Male: Female 1.4:1; median age 35 years) without any liver, splenic or renal diseases ultrasonographic images of these organs were from 2780, 1596, and 2780 individuals respectively. Measurements were taken for liver length, splenic length and breadth and renal length, breadth and cortical thickness.*

Results: *The average liver length in neonates and infants were 5.2 and 6.5 cm in females and 5.7 and 6.6 cm in males. After 20 years of age, average liver sizes ranged from 11.1 to 11.6 cm. The average spleen length in neonates and infants were 3.5 and 5.6 cm in females and 5.7 and 6.4 cm in males. After 20 years of age, it ranged from 8.2 to 9.0 cm. The average renal length in neonates and infants were 4.2 and 5.3 cm for right kidney and 4.3 and 5.5 cm for left kidney in females. In male neonates and infants were 4.9 and 5.3 cm for right kidney and 4.8 and 5.6 cm for left kidney. After 20 years of age, it ranged from 9.0 to 9.7 cm for right kidney and from 9.6 to 10.2 cm for left kidney.*

Conclusion: *These values may be used as reference for normal liver, spleen and kidney dimensions for populations of Chattogram, Bangladesh.*

Key words: Kidney; Liver; Measurement; Nomogram; Spleen; Ultrasonography.

INTRODUCTION

Ultrasonography is one of the most common form of imaging technique used around the world for diagnosis, screening, treatment and follow up of diseases. Since its start in the medical field by Karl Dussik it has become a very dependable tool for medical imaging.[1,2] This is an inexpensive, non-invasive and reasonably accurate method of measurement and often is the initial modality to evaluate intra-abdominal organs. Liver, spleen and kidneys are three major organs that are measured during abdominal sonography. However, their dimensions on ultrasonography vary with the age, sex and ethnicity.[3-5]

Various studies have demonstrated nomogram for liver, kidney and spleen in different geographical populations.[6] However, majority of those did not include substantial number of subjects and there is also lack of data about normal ultrasonographic measurements of these organs in Bangladeshi population of different age groups.[7] In the absence of standard measurements of these organs for this region, interpretations of ultrasonographic reports vary among centres and leads to error in the management. The aim of the study was to delineate the normal ultrasonographic parameters of liver, spleen and kidneys for population of Chattogram, Bangladesh.

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MATERIALS AND METHODS

This was a cross sectional analytical study performed in a Specialized Diagnostic Centre located in Chattogram, Bangladesh from January 2016 to July 2019. All patients referred for ultrasonological examination of abdomen were included in the study. For measurement of normal values for dimensions of liver, spleen and kidneys, patients with diseases affecting any of these organs were excluded from the study. Baseline data including the age and sex and weight were recorded. Patients were grouped into Neonate (0 – 28 days), Infant (29 days – 1 year), Pre School (1 – 5 years), 5 – 19 years, 20 – 40 years, 40 – 60 years and Above 60 years age groups. All the measurements were performed by a single radiologist. This study was approved by Ethical Review Committee of Chittgaong Medical College (memo no: CMC/PG/2021/163).

A 4D ultrasound machine (Voluson E8) with built-in UIS-App was used. In neonate, infant and children linear 9L with 2.5-8MHZ probe was used and for adults a convex 2D probe with 2-5 MHZ transducer was used.

Liver

Liver ultrasound was performed with the patient in supine, left lateral decubitus and left oblique positions. Sagittal, transverse and oblique measurements were taken through intercostal and subcostal spaces. Cranio-caudal length of the liver was taken along the right mid-clavicular line (Figure 1).[8]

Spleen

Ultrasonography was performed with the patient initially lying-in supine and then right oblique position (30° angle), started from below left costal margin, then downwards in the left 9th intercostal space. Length and breadth of spleen was assessed from longitudinal as well as transverse plane.[8]

Right and left Kidney

Images of both right and left kidneys were taken in longitudinal and transverse planes. Patients were positioned in right and left lateral decubitus positions for easy visualization. Length and breadth of right and left kidneys were determined. cortical thickness was measured based on the different echo density of cortex and medullary pyramids.[8]

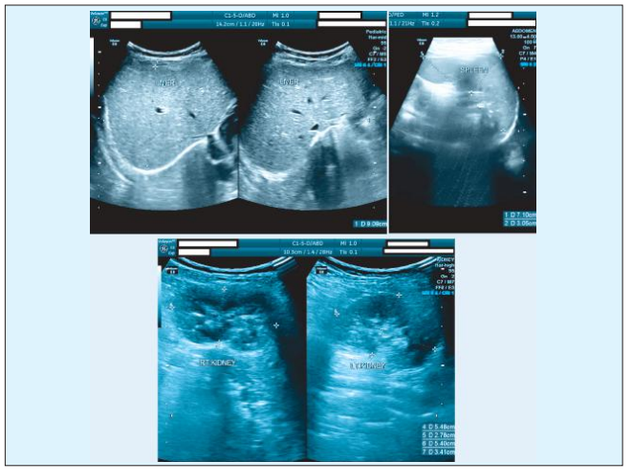

Figure 1 Measurement of (a) liver, (b) spleen and (c) kidney dimensions by USG

Continuous variables were expressed as mean, standard deviation and percentiles (25th, 50th, 95th) and their differences between two independent groups were analysed using the t test or Mann–Whitney U test. Association between spleen, liver and kidney measurements with age was assessed with the Pearson correlation coefficient. Differences in the organ measurements among age groups were analysed using one-way ANOVA. All statistical analyses were performed by SPSS version 22 and Microsoft excel version 2019.

RESULTS

Among a total of 3699 subjects, 2126 were female and 1573 were male (Female to Male ratio 1.4:1) . Liver ultrasound images were taken from 2780 participants (Female: Male =1.5:1), splenic images from 1596 subjects (Female: Male =1.5:1) and renal images from 3377 subjects (Female: Male =1.4:1) (Table I). All median age of patients who underwent imaging of liver, spleen and kidneys were 35 years.

Table I Demographic characteristics of respondents (n= 3699)

Image	Number of Patients	Number of Images	Mean	Age (yr)		Percentile			Sex	
				Median	SD	25th	50th	95th	Male	Female
Liver	2780	2780	36.6	35	19.1	24	35	70	1103	1677
Spleen	1596	1596	37.6	35	17.1	26	35	68	643	953
Kidney	3377	3377*	37.3	35	18.6	25	35	70	1407	1970
Total	3699	7753	37.1	35	18.7	25	35	70	1573	2126

*3377 images are from each kidney measurement which were displayed in a single image.

Liver Nomogram

Age of the patients of liver USG ranged from 2 days to 93 years (Mean 36.5 ± 19.1 years, , IQR 24-50 years). The average neonatal liver length measured in right midclavicular line was 5.2 ± 1.0 cm in girls and 5.7 ± 1.3 cm in boys (Table II). Infant girls and boys had an average liver length of 6.5 ± 0.7 cm and 6.6 ± 0.9 cm, respectively. After 20 years of age, average liver sizes ranged from 11.1 to 11.6 cm among different age groups. The maximum value of liver length observed in this study was 14.9 cm which was in women of 40-60 years age group. Liver length correlated significantly positively with age ($r=0.46$, $p<0.01$). There were significant differences among age groups with regards to liver length ($P<0.01$). However, the difference between sexes was not statistically significant ($p=0.15$). Figure 2 shows 25th, 50th and 95th percentile of liver lengths in different age groups.

Table 2 Nomogram of ultrasound measurement of liver, spleen and kidney dimensions among Population of Chattogram

Nomogram of liver length in cm (±SD) (n= 2780)			
Age groups	No (%)	Male (Mean ± Standard Deviation)	Female (Mean ± Standard Deviation)
0-28 Days	4 (0.1)	5.7 (±1.3)	5.2 (±1.0)
29 Days-1Years	60 (2.2)	6.6 (±0.9)	6.5 (±0.7)
1-5 years	93 (3.3)	8.6 (±1.1)	7.8 (±1.1)

Nomogram of liver length in cm (±SD) (n= 2780)			
Age groups	No (%)	Male (Mean ± Standard Deviation)	Female (Mean ± Standard Deviation)
5 -20 Years	316 (11.4)	10.2 (±1.3)	10.1 (±1.0)
20-40 Years	1222 (44.0)	11.4 (±1.0)	11.2 (±1.0)
40-60 Years	744 (26.8)	11.6 (±0.9)	11.4 (±0.9)
Above 60 Years	341 (12.3)	11.2 (±.1.0)	11.2 (±1.0)
Nomogram of spleen [Length in cm (±SD)x breadth in cm (±SD)](n=1596)			
Age groups	No (%)	Male	Female
0-28 Days	3 (0.2)	4.8 × 2.3*	3.5 (±0.3) × 1.9 (±0.2)
29 Days-1 Year	16 (1.0)	5.7 (±0.9) × 2.7 (±0.4)	5.6 (±0.6) × 2.4 (±0.4)
1-5 Years	23 (1.4)	6.4 (±0.9) × 2.9 (±0.6)	6.0 (±1.0) × 2.9 (±0.7)
5 -20 Years	171 (10.7)	8.5 (±1.5) × 3.7 (±0.8)	8.2 (±1.2) × 3.6 (±0.7)
20-40 Years	760 (47.6)	9.0 (±1.1) × 3.9 (±0.7)	8.5 (±1.2) × 3.7 (±0.8)
40-60 Years	467 (29.3)	8.9 (±1.4) × 3.9 (±0.9)	8.1 (±1.2) × 3.5 (±0.8)
Above 60 Years	156 (9.8)	8.8 (±1.6) × 3.8 (±1.0)	8.1 (±1.4) × 3.5 (±0.8)
Nomogram of right Kidney [Length in cm (±SD)x breadth in cm (±SD)], Cortical thickness in cm (±SD) (n=3377)			
Age groups	No (%)	Male	Female
0-28 Days	19 (0.6)	4.9 (±0.4) × 2.2 (±0.5), 0.8 (±0.2)	4.2 (±0.5) × 2.0 (±0.3), 0.7 (±0.1)
29 Days-1 Year	67 (2.0)	5.3(± .6) × 2.4 (±0.4), 0.8 (±0.2)	5.3 (±0.8) × 2.4 (±0.5), 0.9 (±0.2)
1-5 Years	98 (2.9)	6.6 (±0.70 × 3.0 (±0.4), 1.1 (±0.1)	6.6 (±1.0) × 2.9 (±0.4), 1.1 (±0.2)
5 -20 Years	350 (10.4)	8.7 (±1.1) × 3.7 (±0.6), 1.4 (±0.3)	8.8 (±1.1) × 3.6 (±0.5), 1.4 (±0.2)
20-40 Years	1503 (44.5)	9.7 (±0.8) × 4.3 (±0.5), 1.6 (±0.3)	9.6 (±0.8) × 4.0 (±0.5), 1.5 (±0.2)
40-60 Years	948 (28.1)	9.7 (±0.9) × 4.5 (±0.6), 1.6 (±0.3)	9.4 (±0.09) × 4.1 (±0.5), 1.5 (±0.3)
Above 60 Years	392 (11.6)	9.4 (±1.0) × 4.4 (±0.6), 1.5 (±0.3)	9.0 (±0.9) × 4.0 (±0.5), 1.4 (±0.3)
Nomogram of left Kidney [Length in cm (±SD)x breadth in cm (±SD)], Cortical thickness in cm (±SD) (n=3377)			
Age groups	No (%)	Male	Female
0-28 Days	19 (0.6)	4.8 (±0.4) × 2.5 (±0.4), 0.9 (±0.3)	4.3 (±0.4) × 2.3 (±0.3), 0.8 (±0.1)
29 Days-1 Year	67 (2.0)	5.6 (±0.6) × 2.7 (±0.5), 1.0 (±0.2)	5.5 (±1.0) × 2.7 (±0.5), 1.2 (±0.3)
1-5 Years	98 (2.9)	6.9 (±0.8) × 3.3 (±0.5), 1.3 (±0.3)	6.8 (±0.9) × 3.3 (±0.5), 1.4 (±0.3)
5 -20 Years	350 (10.4)	9.0 (±1.3) × 4.3 (±0.7), 1.7 (±0.3)	8.8 (±1.2) × 4.2 (±0.6), 1.7 (±0.3)
20-40 Years	1503 (44.5)	10.0(±0.9) × 4.9 (±0.6), 1.9 (±0.4)	10.1 (±0.9) × 4.6 (±0.6), 1.8 (±0.3)
40-60 Years	948 (28.1)	10.2 (±0.9) × 5.0 (±0.6), 1.8 (±0.4)	9.8 (±1.0) × 4.6 (±0.6), 1.7 (±0.3)
Above 60 Years	392 (11.6)	9.8 (±1.0) × 4.9 (±0.6), 1.7 (±0.4)	9.6 (±0.9) × 4.3 (±0.7), 1.6 (±0.3)

Data presented as mean ± Standard deviation.
*There was only one male infant in this group, for this reason, there was no SD.

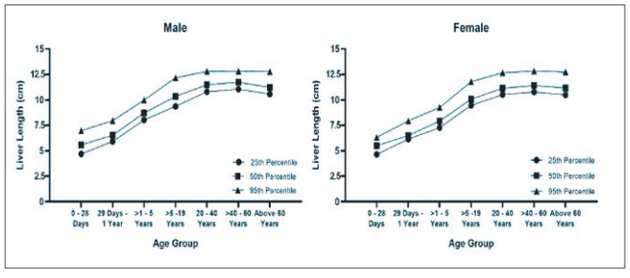

Figure 2 25th, 50th and 95th percentile of liver lengths among different age groups between sexes

Spleen Nomogram

Age of the patients of spleen USG ranged from 2 days to 93 years (mean 37.5 ± 17.0 years, IQR 26-50 years).The average splenic lengths of neonatal male and female were 4.8 cm and 3.5 cm, respectively (Table II). The mean splenic breadths were 2.3 cm and 1.9 cm in male and female neonates, respectively. In infants, mean splenic lengths were 5.6 and 5.7 cm for females and males, respectively and mean breadths were 2.4 and 2.7 in female and male, respectively. The highest mean splenic length was observed among 20-40 years age groups (Males, 9.0 cm and female 8.5 cm) and the highest breadths in 40-60 years age group for male (3.9 cm) and in 20-40 years age group for female (3.7 cm) (Figure 3). Spleen length correlated significantly positively with age (r=0.10, p<0.01), but spleen breadth did not correlate significantly with age (p=0.19). However, there were significant differences among age groups with regards to both spleen length and breadth (r=0.03, P<0.01). Both splenic length and breadth differed significantly between sexes (p<0.01).

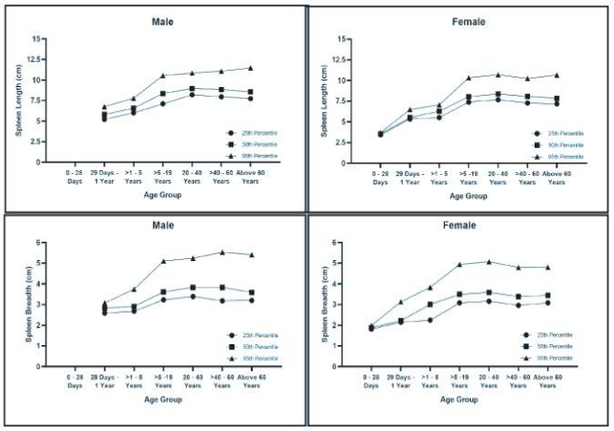

Figure 3 25th, 50th and 95th percentile of splenic length and breadth among different age groups between sexes

Renal Nomogram

Age of the patients of renal USG ranged from 2 days to 93 years (Mean 37.3 ± 18.5 years, IQR 25-50 years). The average length of right and left kidney in male neonates were 4.9 cm and 4.8 cm respectively (Table II). For female neonates, the mean lengths were 4.2 cm (Right kidney) and 4.3 cm (Left kidney). Among 20-40 years age groups of male population, average length of right kidney was 9.7 cm and left kidney was 10.0 cm. Females of this age group had an average length of 9.6 cm for right kidney and 10.1 cm for left kidney. Mean length, breadth and cortical thickness of left kidney was significantly more than right kidney irrespective of age and sex (p<0.01). The ratio between length of left kidney and right kidney in all age groups (Except neonates) was 1.0 (Figure 4). Mean length of both kidneys did not vary significantly between sexes (p=0.13, right kidney and P=0.57, left kidney). However, breadth and cortical thickness of both kidneys were significantly more in male than female (p<0.01). On the other hand, renal length, breadth and cortical thickness correlated significantly positively with age (r=0.34, 0.35, 0.42, 0.38, 0.21 and 0.12 for length, breadth and cortical thickness of right and left kidney, respectively, p<0.01). Mean cortical thickness of

right kidney was highest among 40-60 years male subjects (1.6 ± 0.3 cm) and that of left kidney in 20-40 years old males (1.9± 0.4 cm). In females, highest cortical thickness for both kidneys were among 20-40 years (right 1.5 ± 0.2 cm and left 1.8± 0.3 cm).

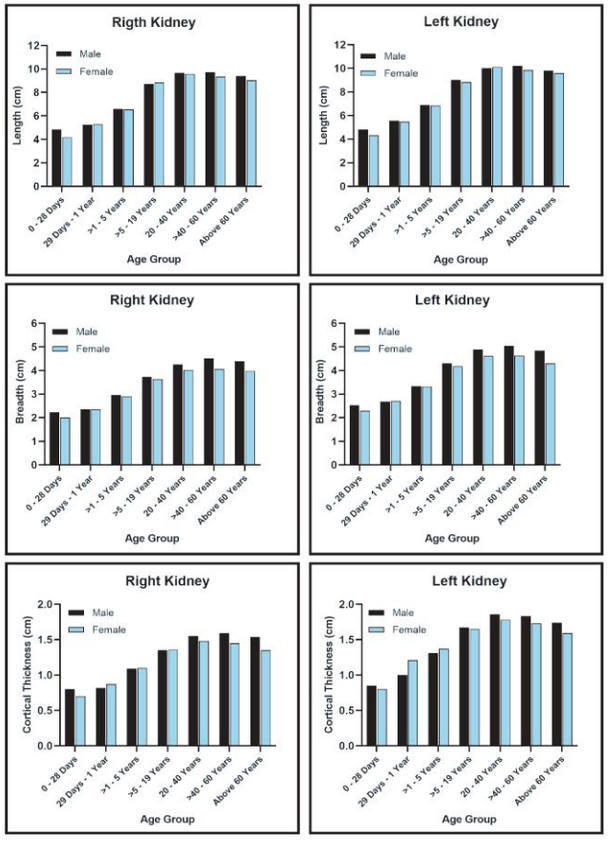

Figure 4 Mean length, breadth and cortical thickness of right and left kidneys in both sexes

DISCUSSION

This study describes normal parameters for ultrasonographic measurements of liver, spleen and kidney for Bangladeshi population of all age range. The relationship between these dimensions and age groups and differences between sexes were determined. To our knowledge, this study covers the largest series of liver, spleen and renal dimensions for ultrasonographic measurements in all age groups.

Liver

Liver is commonly measured during a routine abdominal ultrasound and liver size is a significant indicator of the presence of a disease process.[9] Measurement of liver size using ultrasound is usually determined by taking a simple linear measurement of the liver from a plane along the mid-clavicular line and cut off values are used to differentiate normal from abnormal liver size.[8,10,11] Although, different imaging techniques may be used to assess liver dimeter or volume, it has been shown that USG measurement of liver length can reliably predict true liver volume.[9,12] Commonly practiced liver length for term neonates is 5.4-5.5 cm which is derived from a European study.[13] In this study, average liver length at right midclavicular line was 5.2 (±1.0) cm in female and 5.7 (±.1.3) cm in male. The widely practiced average liver length for infants are between 6.4 cm and 8.5 cm.[6,14] In this study, the average normal value for female infants was 6.5 (±.7) cm and for male infants 6.6(±.9) cm, the highest value being 8.2 cm in female and 8.7 cm in male. These values reflect similarity to reference values from an Indian study.[15] The adult Bangladeshi population showed a slight but consistent increase in liver length in this study (Figure 2). However, as the age of the population hits the mark of 60 years and above, the liver length decreases slightly which may be due to age-related physiological atrophy of human organs.[16]

Spleen

Measurement of splenic length by ultrasound has shown to be more reliable within and between technicians than measurement of splenic width. For this reason, splenomegaly is usually defined based on spleen length.[4] The positive correlation of age with splenic length found in this study is consistent with other studies.[5,17] Only one male neonate was examined for splenic length which was 4.8 cm. Two female neonates underwent sonological examination and average splenic length was 3.5 (±.3) cm, which is consistent with the practised reference value of 3.4 (±.5) cm and comparable to other studies.[6,13] Majority of the previous studies that determined size of the spleen failed to describe the age and sex specific variation.[4] In this study, female infants had a mean splenic length of 5.6(±.61) cm and male infants 5.7(±.9) cm. Nomogram of spleen in Bangladeshi infants were found similar to that of Indian infants.[15] This study revealed that 5-19 years old Bangladeshi average male spleen was 8.5(±.1.5) cm and female spleen was 8.2(±.1.2) cm. The highest accepted physiological length of spleen is 12 in many practices irrespective of sex, height, and girth.[5,18,19] Male subjects were found to have significantly larger spleens compared to females. Similar to liver length, the average splenic length was lower in case of elderly subjects. There has been concerns about the role of tropical environment on the size of the spleen. However, finding from this study and study from Ehimwenma and Tagbo showed that there were no major differences in splenic size in comparison with other studies without this environmental peculiarity. This suggests that immunological defence mechanism in the body does not usually have residual effect on splenic dimensions.[20]

Kidney

Renal size is commonly assessed for evaluation of renal diseases for both diagnostic and prognostic purposes. There are several advantages of ultrasonography over other methods in determining renal size, such as lack of ionizing radiation exposure, radiographic magnification and osmotic effect of the iodinated contrast material. Moreover, the procedure is real time, three dimensional and independent of organ function and phase of respiration.[21] The size of kidney depends on laterality,

age, anthropometric measurements, gender and ethnicity.[22] Nevertheless, several studied showed no co-relation between sex and renal dimensions.[21] In this study also length of both kidneys did not vary significantly between sexes, however, breadth and cortical thickness of both kidneys were significantly more in male than female. Calle-Toro JS et al. performed meta-analysis of well-established renal parameters of healthy children of different ethnic background.[6] The frequently practiced average length of right kidney and left kidney in children of 0-3 months is 4.3(±.5) cm to 5(±.6) cm and 4.3(±.6) cm to 5.3(±.7) cm respectively.[3,23] A study from Bangladesh conducted 2012 showed normal length of kidneys of neonates aged <3 days were 3.9 cm (right kidney) and 3.8 cm (Left kidney).[7] The average length of kidneys obtained from this study was 4.2 (±.5) cm for right kidney, 4.3(±.40) cm for left kidney in female neonates and 4.9(±.4) cm for right kidney and 4.8(±.4) cm for left kidney in male neonates which incline more towards the refence values available for Indian children.[21] The average length of kidneys in female Bangladeshi population of 20-60 years were 9.6(±0.8) cm to 9.4(±0.9) for right kidney and 10.1(±0.9) cm to 9.8(±1.0) cm for left kidney. For male of same age groups, the mean length of right kidney was 9.7(±0.8) cm to 9.7(±0.9) cm and of left kidney was 10.0(±0.9) cm to 10.2(±0.9) cm. The lower and upper limit of renal length was similar to that of the study conducted by Leung VY et al.[23] The length and breadth obtained for older children as well as adults shows a slight variation in dimension: average left kidney was found to be larger than right kidney in almost all age groups. The commonly used reference value for renal cortical thickness was 7 to 10 mm in children.[24] This study found higher values for cortical thickness for both kidneys in male and female.

LIMITATION

This study has several limitations. There were small number neonates for liver and splenic measurement. Moreover, height and weight were not measured in these patients and nomograms could not be created based on these.

CONCLUSION

Longitudinal parameters of liver, spleen and kidneys correlated with age. Renal breadth and cortical thickness also correlated with age but splenic breadth did not correlate with age. There was no difference between sexes with regards to liver and kidney lengths but splenic length and breadth differed significantly between sexes. There are age group specific differences in the parameters in contrast to other studies. The result of the study is more representative for population of Chattogram and may be used as a guide to interpret the normal sizes of the liver, the spleen and the kidneys.

RECOMMENDATION

This study can be used as reference values for nomograms for liver, kidney and spleen for Bangladeshi male and female population of different age groups, some of which resemble the commonly used parameters.

DISCLOSURE

All the authors declared no competing interest.

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