Journal of Ultrasound (2021) 24:297–302
https://doi.org/10.1007/s40477-020-00521-3

ORIGINAL PAPER

Spleen–left kidney ratio and liver–right kidney ratio: novel measures of normal liver, spleen, and kidney dimensions in Southwestern Nigerian children

F. T. Akinlade[1] · **O. M. Akinlade**[2] · **A. A. Aremu**[1]

Received: 6 June 2020 / Accepted: 1 August 2020 / Published online: 11 September 2020

Abstract

Purpose Figures can sometimes be difficult to handle when considering whether the ultrasound dimensions of the liver, spleen, and kidneys of children are within normal limits in a typical clinical setting. Therefore, it is imperative to think of a simple measure that can be easily adopted when the question of whether these organs are enlarged or reduced in size is to be answered by a sonologist. We hypothesize that the liver–right kidney ratio and spleen–left kidney ratio are constant, regardless of age and sex among children, provided that the reference organ is not diseased.

Methods This observational, cross-sectional study was carried out in public primary schools in the Ogbomoso metropolis. A total of 1000 apparently healthy children aged 5–13 were subjected to abdominal sonography from July 2016 to December 2016. The length of the liver, spleen, and both kidneys as well as the anthropometric parameters of each subject were obtained and correlated. Data were analyzed using SPSS version 20.

Results The SPL:LKL (spleen to left kidney length) ratio varies with age, and this is statistically significant in female subjects ($p=0.042$), but not in males ($p=0.360$). The RLL:RKL (right lobe of the liver to right kidney length) ratio of 1.19 ± 0.18 does not significantly vary with age or sex ($p=0.337$).

Conclusion The SPL:LKL ratio of 1.11 ± 0.18 can be only used as a measure of normality of organ dimensions in males. On the contrary, the RLL:RKL of 1.19 ± 0.18 can be used in all children, regardless of sex, provided that the reference organ is normal.

Keywords Children · Liver · Spleen · Kidney · Ultrasound · Ratio

Introduction

In a busy ultrasound clinic, when a decision needs to be made regarding the normality of the liver, spleen, and kidney dimensions in children, figures can sometimes be difficult to handle when considering whether the ultrasound dimension of these organs among the pediatric population is within normal limits. Therefore, it is imperative to think of a simple measure that can be easily adopted when the question of whether these organs are enlarged or reduced in size is to be answered by a sonologist. Organ dimension ratio is a measure that looks promising in this regard and might prove useful in determining normality in the dimensions of these organs.

An ultrasound scan is a safe and easily available procedure worldwide. It is a relatively inexpensive, fast, noninvasive, and radiation-free imaging modality. Portability and simplicity are the characteristics that make ultrasound an indispensable modality compared with others [1–5]. It is a widely used and excellent imaging modality for the evaluation of the dimensions of the aforementioned organs, making diagnosis and repeated follow-ups easy [6].

In common practice, measurements of the size of these organs at any age are compared with measurements that are predicted by standard nomograms [7–11].

A number of nomograms have been generated for different ethnic groups in Nigeria. However, these may be cumbersome to use in a typical clinical setting among a pediatric

✉ F. T. Akinlade
sadeakinlade@gmail.com

[1] Department of Radiology, LAUTECH Teaching Hospital, Ogbomoso, Nigeria

[2] Department of Internal Medicine, LAUTECH Teaching Hospital, Ogbomoso, Nigeria

age group in which a lot of factors, which rapidly change during childhood, such as age, weight, height, ethnicity, and body surface area, all contribute to organ dimensions in each child. Since the current nomogram among different ethnic groups in Nigeria varies significantly and a child from any of the ethnic groups in the country can go to an ultrasound clinic, it is compelling to devise a simple organ ratio that can be easily used to determine a change in size or otherwise of the aforementioned organs [12–15].

The spleen and left kidney are anatomically close. A parallel ultrasound investigation of the spleen and the left kidney may show to what extent there is a concordance between the two organs in children and whether the ratio varies with age. The absence of gender differences in the dimensions of both ultrasound of the left kidney and spleen suggests a noninvolvement of sex hormones in the development of these organs until the age of 17 [16].

The measurement of spleen and left kidney lengths is reliable within and between sonographers. Sonography can be used to detect mild splenomegaly if the spleen to left kidney ratio is greater than 1.3 in the absence of renal disease among school-age children, and this ratio is a constant regardless of age [17, 18].

This study aims to test this hypothesis among Southwestern Nigerian children and further look into the possibility of the ratio of the length of the right lobe of the liver to right kidney length also being able to detect minor changes in the size of the liver and right kidney.

Materials and methods

Study location

The study was carried out at public primary schools in the Ogbomoso metropolis over period of one year.

Study design

This is a descriptive, cross-sectional study of liver, spleen, and kidney parameters among Nigerian children in primary school.

Sampling method

A multistage sampling method was used. One thousand students were recruited into the study. Based on proportionate sampling, 500 children were recruited from each of the two local governments in Ogbomoso. Five primary schools were chosen in each local government by simple random sampling. Pupils were selected by systematic random sampling among volunteers from each class (primary 1 to 6) based on the school's population and the number of children in each school.

Inclusion criteria

Boys and girls from ages 5 to 13 who were attending public primary schools in the Ogbomoso metropolis were included in the study after approval was given by the respective school's board and a written informed consent was granted by the parent/guardian.

Exclusion criteria

The clinical exclusion criteria included refusal to participate, jaundice, fever $T(^{\circ}C) > 37.5$, maculopapular rash, significant lymphadenopathy, short stature (< 2 standard deviation (SD) for age), limb deformity, undernutrition, obesity, pallor, macrocephaly (head circumference > 2 SD for age), microcephaly (head circumference < 2 SD for age), chest wall deformity, and known liver, spleen, and kidney disease.

The imaging exclusion criteria included liver, spleen, and kidney parenchymal mass lesions; abnormal parenchymal echotexture and echogenicity; liver, spleen, and kidney cysts; accessory spleens; and hydronephrosis.

Data collection instrument

A semi-structured questionnaire was used. The questionnaire was pretested among 10 children attending a public primary school outside of the selected schools in Ogbomoso, and it was administered by an interviewer. We used a 2.5- to 5-MH_Z curvilinear transducer of a full digital portable ultrasound diagnostic device, SonoAce X1, China. Also used in data collection were tape measures, weighing scales, examination couches, and acoustic gel.

Methodology

Demographic data were collected on each participant at the time of their pre-participation physical examination. This information included age, sex, height, and body weight. BSA (body surface area) and BMI (body mass index) were computed from measured height and weight. Body mass index was calculated by BMI = weight (Kg)/height (m^2), while BSA was calculated by $BSA = \sqrt{\text{weight} \times \text{height}/3600}$. Anthropometric measurements of the participants wearing school uniforms without shoes were obtained. Weight was measured on a calibrated portable Salter scale to the nearest 0.1 kg. Height was measured with a metal tape measure to the nearest 0.5 cm with the participants standing upright with their head in the Frankfurt position.

Technique of ultrasound

Scanning was done with the subjects lying in supine position while the area to be scanned was exposed. The subjects' right upper limb was then raised behind the head to help widen the intercostal spaces and the space between the lower costal margin and the iliac crest, thereby creating better access to the liver [6, 13].

Using a 2.5- to 5-MH_Z curvilinear transducer of the aforementioned ultrasound machine, the length of the right lobe of the liver was measured in supine position according to the method described by Kratzer et al. [20] and Ozmen et al. [21] in which the right liver lobe size was measured in the midclavicular line (with the transducer running from the right hepatic dome to the inferior hepatic tip) from the highest to the lowest point of the liver. (Fig. 1).

The technique of right lateral decubitus position in the coronal plane was adopted for the spleen length measurement. Longitudinal size measurement was performed between the most superomedial and the most inferolateral points of the spleen [16]. (Fig. 2).

The maximum supine length of each kidney was measured between the uppermost edge of the upper pole and the lowest edge of the lower pole (bipolar diameter) of the kidney, while the subjects were in the supine or slight right lateral decubitus position [22] (Fig. 3).

The dimensions of these organs were taken during deep inspiration. All measurements were obtained to the nearest millimeter on static original ultrasound images using electronic calipers at the time of scanning. Two sequential measurements were obtained for each organ dimension by two radiologists, with the image frozen in inspiration, and their mean was calculated; this was to minimize inter- and intra-observer error and ensure greater accuracy and reliability of the measurements [19].

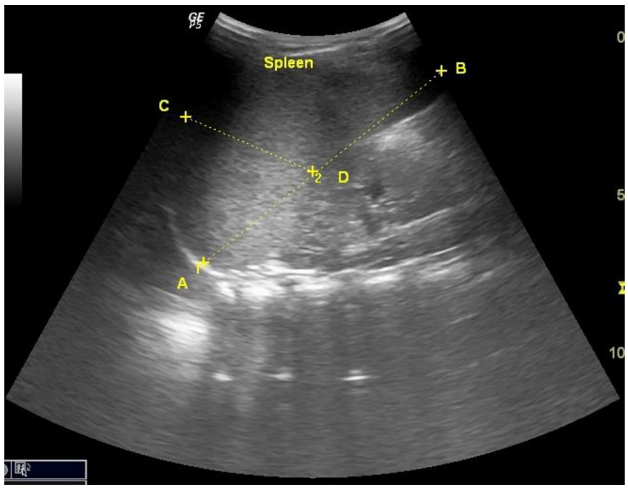

Fig. 2 A B-mode coronal ultrasound image through the spleen showing the spleen and the left kidney. (AB = Splenic length)

The spleen length to left kidney ratio and length of the right lobe of the liver to the right kidney length ratio were calculated from the sonographic measurements.

Data management

Data from the questionnaires and the liver, spleen, and kidney ultrasonographic measurements were entered into SPSS version 20. Chi square test was used to test association between qualitative variables. Frequency distribution tables were used to present the results. The student's *t* test was used as a test of association between two continuous variables while, analysis of variance (ANOVA) was used

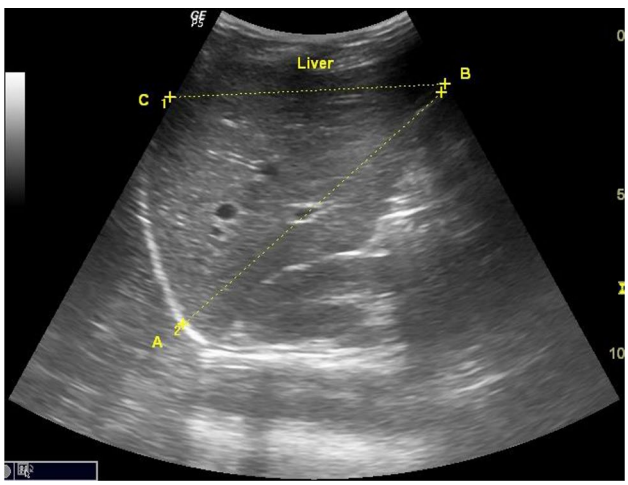

Fig. 1 A B-mode longitudinal ultrasound image through the right lobe of the liver at the mid-clavicular line showing the liver and the right kidney. (BC = length of the right lobe of the liver)

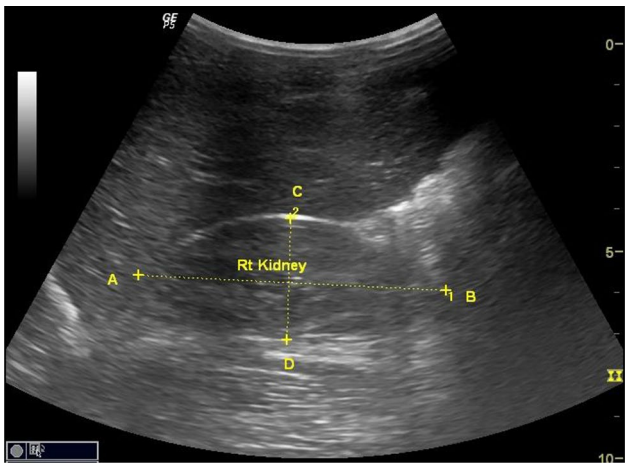

Fig. 3 A B-mode longitudinal ultrasound image through the right kidney showing the kidney and part of the right lobe of the liver. (AB = kidney length)

when there were more than two continuous variables. Level of significance was set at $p < 0.05$.

Ethical consideration

Ethical clearance was sought from the local review board of the hospital. Permission was also obtained from the respective school board. A written informed consent was sought from the parent of each child and any parent who declined had his/her child excused from the study. The parents were reassured that no harm would be done to their children.

Results

A total of 1,000 apparently healthy children were observed using the ultrasound scan and the ultrasound dimensions of their liver, spleen, and kidney correlated with their anthropometric measurements. The male–female ratio is 1:1. Nine hundred and seventy-one (97.1%) of the study population were of Yoruba ethnicity, 19 (1.9%) were Hausa, 6 (0.6%) were Igbo, and 4 (0.4%) were from other tribes.

The spleen length was significantly higher in boys (mean ± SD: 11.72 ± 1.80 vs. 11.56 ± 1.31, $p < 0.048$, 9.47 ± 1.67 vs. 9.21 ± 1.60, $p < 0.011$, respectively) than in girls, but no significant gender-based difference was observed in the length of the right lobe of the liver.

Consequently, the SPL:LKL was significantly higher in boys than in girls (mean ± SD: 1.11 ± 0.18vs 1.07 ± 0.17; $p = 0.002$), but no sexual dimorphism was seen in the RLL:RKL ($p = 0.298$) (Table 1).

Table 2 shows that spleen to left kidney length ratio varies with age, and this variation is statistically significant when all study subjects are pooled together ($p = 0.04$) and among female subjects ($p = 0.042$), but not among male subjects ($p = 0.360$).

Table 2 Correlation between age and RLL:RKL and SPL:LKL in male and female subjects

		RLL:RKL		SPL:LKL	
		r*	p value	r*	p value
Age	All subjects	0.030	0.337	0.065	0.040
	Females only	0.013	0.776	0.091	0.042
	Males only	0.048	0.287	0.041	0.360

*Pearson correlation coefficient

The ratio of the length of the right lobe of the liver to the right kidney length does not significantly vary with age in any sex ($p = 0.337$).

Discussion

The necessity for a single ratio that can be used to assess subtle changes in size of abdominal organs in children cannot be overemphasized because of the constant change in the size of these organs as the body habitus changes in response to increasing age. Absolute measurements have been documented by various researchers across different regions of the world, but remembering these values in a typical clinical setting might be quite challenging [9–14]. Hence, the need to devise a simple organ dimension ratio that can be easily used to determine small changes in the size of these organs when diseased cannot be more relevant than now. In this study, the spleen length to left kidney length (SPL:LKL) ratio and right lobe of the liver length to right kidney length (RLL:RKL) ratio were determined and correlated with age.

The spleen length in this study was found to be significantly higher in boys than in girls. This is in contrast with what was obtained in children from Enugu in Nigeria in which no gender dimorphism was observed [16] and Sudanese children, among whom the mean length of spleen

Table 1 Comparison of gender with liver, spleen, and kidney parameters in children

	Mean ± SD		t	p value
	Girls ($n = 500$)	Boys ($n = 500$)		
Liver				
Right lobe	9.86 ± 1.53	9.78 ± 1.51	0.845	0.398
Spleen				
Length	9.21 ± 1.60	9.47 ± 1.67	0.383	0.011
Kidney				
Right kidney length	8.21 ± 0.83	8.17 ± 0.70	0.856	0.392
Left kidney length	8.39 ± 0.94	8.38 ± 0.77	0.249	0.803
RLL:RKL	1.20 ± 0.18	1.19 ± 0.18	1.042	0.298
SPL:LKL	1.07 ± 0.17	1.11 ± 0.18	-3.071	0.002

in females is greater than in males [19]. Differences in genetic makeup are likely responsible for this [16, 17].

The left kidney length in this study was not statistically different in boys and in girls, and this agrees with what was observed among children of Igbo ethnicity by Eze et al. [16]. This suggests lack of significant ethnic differences in the left kidney length among Nigerian children of in terms of gender.

The spleen to left kidney ratio was found to vary significantly with age when the study population is considered as a whole and among female children, but not among boys. This is also different from the report from Southeast Nigeria, where Eze et al. reported that the ratio was constant regardless of age and sex [16].

Statistically significant gender-based difference was not found in the spleen to left kidney ratio from a similar study done in Southeastern Nigeria [16], but in this study this ratio is higher in boys than in girls. This is consequent to the disparity in the observations made on the spleen length among children from the two ethnic groups.

Therefore, a single range of value cannot be used across all age groups in female children but may be used in male children when assessing these organs for subtle change in size in the study population.

To the knowledge of the researcher, following an extensive search, no study has been done prior to this time to assess the ratio of the right lobe of the liver to right kidney length as a measure of slight differences in the size of these organs in the diseased state. The length of the right lobe of the liver and right kidney length were not significantly different between genders, according to this study. The ratio of the length of the right lobe of the liver to the right kidney length was found to be constant regardless of age, and no significant gender-based difference was seen in the value.

A single range of value can therefore be used across all age groups, in males and in females, when assessing the liver and right kidney for changes in organ dimension, provided that the reference organ is normal.

In conclusion, a range of 1.11 ± 0.18 could be used as the spleen to left kidney length ratio among male children. On the contrary, the length of the right lobe of the liver to the right kidney length ratio of 1.20 ± 0.18 can be used across all age groups, in males and in females, provided that the reference organ is not diseased.

Despite the use of a relatively large sample size in this study, a multicenter collaboration with a larger sample size both in Nigeria and in other countries would be necessary to further establish these findings and determine their applicability among children outside the studied ethnic population.

Acknowledgements We acknowledge Dr Ajayi Azeezat O. for her assistance during the execution phase of the project.

Author contributions "AFT designed, performed the project work, analyzed and interpreted the data. She was the main contributor in writing the manuscript. AOM designed, analyzed and interpreted the data, also a major contributor in writing the manuscript. AAA designed, analyzed and interpreted the data, also contributor in writing the manuscript. All authors read and approved the final manuscript."

Funding The cost of this study were borne by the investigators.

Data availability The datasets during and/or analysed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interests No conflicts of interest.

Ethics approval and consent to participate All experimental protocols were approved and performed in accordance with the guiding principles of LAUTECH Teaching Hospital Ethical Review Committee (UERC).

References

1. Seitz K. Ultrasound first. Vol. 115, Deutsches Arzteblatt International. Deutscher Arzte-Verlag GmbH; 2018. p. 8–9
2. Monti J (2017) Revolution or evolution? A proposal for the integration of point-of-care ultrasound into physician assistant clinical practice. J Physician Assist Educ 28(1):27–32
3. Bélard S, Tamarozzi F, Bustinduy AL, Wallrauch C, Grobusch MP, Kuhn W et al (2016) Review article: point-of-care ultrasound assessment of tropical infectious diseases-a review of applications and perspectives. American journal of tropical medicine and hygiene. Am Soc Trop Med Hyg 94:8–21
4. Dietrich CF, Sirlin CB, O'Boyle M, Dong Y, Jenssen C (2019) Editorial on the current role of ultrasound. Appl Sci 9(17):3512
5. Klibanov AL, Hossack JA (2015) Ultrasound in radiology: From anatomic, functional, molecular imaging to drug delivery and image-guided therapy. Investigative radiology. Lipp Williams Wilkins 50:657–670
6. Safak AA, Simsek E, Bahcebasi T (2005) Sonographic assessment of the normal limits and percentile curves of liver, spleen, and kidney dimensions in healthy school-aged children. J Ultrasound Med 24(10):1359–1364
7. Sulaiman Aloraini A, Mekbel Aldahmashi A (2018) Sonographic dimensions of normal kidney among children. Egypt J Hosp Med 70:5
8. Oh MS, Hwang G, Han S, Kang HS, Kim SH, Kim YD et al (2016) Sonographic growth charts for kidney length in normal Korean children: a prospective observational study. J Korean Med Sci 31(7):1089–1093
9. Duminda WD, Pathirana KG, Fernando MUJ, Samarasinghe RANKK, Ananda WDHA, Silva KSP et al (2019) Ultrasonographic length of morphologically-normal kidneys in children presented to a premier tertiary healthcare setting of Sri Lanka. BMC Nephrol 20(1):1–7
10. Kim JH, Kim MJ, Lim SH, Kim J, Lee MJ (2013) Length and volume of morphologically normal kidneys in Korean children: ultrasound measurement and estimation using body size. Korean J Radiol 14(4):677–682

11. Otiv A, Mehta K, Ali U, Nadkarni M (2012) Sonographic measurement of renal size in normal Indian children. Indian Pediatr 49(7):533–536
12. Ehimwenma O, Tagbo M (2011) Determination of normal dimension of the spleen by ultrasound in an endemic tropical environment. Niger Med J 52(3):198
13. Eze CU, Agwu KK, Ezeasor DN, Aronu AE (2013) Sonographic biometry of liver size among Igbo school age children of South east. Niger Radiograp 19(3):228–233
14. Ezeofor S, Obikili E, Anyanwu G, Onuh A, Mgbor S (2014) Sonographic assessment of the normal limits of the spleen in healthy school children in South-East Nigeria. Niger J Clin Pract 17(4):484
15. Okoye I, Agwu K, Ochie K (2006) Sonographic splenic sizes in normal adult Nigerian population. West Afr J Radiol 12(1):37–43
16. Eze CU, Agwu KK, Ezeasor DN, Agwuna KK, Aronu AE (2014) Sonographic determination of spleen to left kidney ratio among igbo school age children of south east, Nigeria. Afr Health Sci 14(1):246
17. Y T, SD H, A M, SA A, R C, HS M (2019) (PDF) sonographic measurements of the spleen in relation to height: a prospective and observational study in northwest Ethiopian adults. Asian J Med Res 8:1
18. Spielmann AL, DeLong DM, Kliewer MA (2005) Sonographic evaluation of spleen size in tall healthy athletes. Am J Roentgenol 184(1):45–49
19. Nouri CEA, Balla EASKM (2013) Establishment local reference of spleen length in Sudanese normal school age children sonographically. Glob J Med Res 13:2
20. Kratzer W, Fritz V, Mason RA, Haenle MM, Kaechele V (2003) Factors affecting liver size: a sonographic survey of 2080 subjects. J Ultrasound Med 22(11):1155–1161
21. Özmen Z, Aktaş F, Özmen Z, Almus E, Demir O (2018) Ultrasound measurement of liver longitudinal length in a North Anatolian population: a community-based study. Niger J Clin Pract 21(5):653
22. Gatewood MB, Glasser RJ, Vanhoutte JJ (1965) Roentgen evaluation of renal size in pediatric age groups. Am J Dis Child 110(2):162–165