RESEARCH PAPER

Normal Values of Liver and Spleen Size by Ultrasonography in Indian Children

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Received: December 1, 2008; Initial review: January 12, 2009; Accepted: June 3, 2009.

Objectives: To establish normative data for the ultrasonographic measurement of liver and spleen size in healthy Indian children.

Setting: Tertiary-care pediatric teaching hospital.

Design: Cross-sectional, hospital-based study.

Participants: 597 healthy children between the ages of 1 month to 12 years.

Measurements: Ultrasonographic evaluation for the assessment of liver and spleen size. These were correlated with the age, sex, height/length and weight of the participants.

Results: Normal liver and spleen length and range were obtained sonographically. The liver and spleen length significantly correlated highly with the height/length of the subjects (P=0.0001).

Conclusions: The study provides the normal values of liver and spleen size by ultrasonography in healthy Indian children.

Keywords: *Children, Liver, Measurements, Organometry, Spleen, Ultrasonography*.

Published online: 2009 September. PII:S097475590800697-1

Liver and spleen size vary widely according to age. Many diseases can affect their size, ranging from infective processes to malignant disorders(1,2). Palpation and percussion are the standard bedside techniques to document liver and spleen size, but are far from accurate to detect small increase in size(1,2). The spleen has to be enlarged two to three times its normal size to be clinically palpable(3), although it may be normally palpable in 15-17% of healthy neonates(4) and 10% of healthy children(3). Clinical assessment of hepatomegaly by palpation and percussion has also been shown to lack both accuracy and reliability(2).

Ultrasonography is a non-invasive, established, safe, quick and accurate method for measurement of liver and spleen size(5). We conducted this study to establish standards of liver and spleen length by ultrsonography in healthy Indian children, based on age, sex and somatometric parameters, as the available literature is scarce(6,7).

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METHODS

We enrolled 650 asymptomatic children between the age-group 1 month to 12 years, visiting the out-patient department either for routine immunization or accompanying their siblings, between January to December 2005. Any child under evaluation for/ follow-up case of a condition which could affect the size of the spleen or liver *e.g.* viral hepatitis, malaria, hemolytic anemia, enteric fever, congestive heart failure and malnutrition (Grade III and IV, IAP

classification) was not included in the study. It was ensured by detailed structured parental history, examination and medical record review (if available) that these children did not have any pre-existing suspected inflammatory, metabolic, traumatic, collagen or hematopoietic diseases and malignancies, that could affect liver and spleen size (excluded, *n*=11). Informed, written consent was obtained from the accompanying caregivers/parents of all children, and verbal assent taken from all children older than 5 year. No child refused assent, whereas there were 42 parental refusals for participation (in the majority due to lack of time to spare, 85.7%).

Baseline data including the age, sex, height/ length and weight were recorded for all the children in a structured performa. The age was recorded to the nearest completed month. An electronic weighing scale (accuracy 50 g) and a wall mounted stadiometer (1 mm markings) were used to measure the weight and height/length, as per standard methodology(8). In each child, the clinicians (SS) identified the acromioclavicular and the sternoclavicular joints by palpation and marked the midpoint of a line joining these two points– the midclavicular point. A vertical line was drawn from the midclavicular point to the midinguinal point and was defined as the midclavicular line (MCL). All clinical as well as sonographic measurements were done with reference to this line(9).

Ultrasonographic evaluation: All the children underwent an ultrasonographic assessment of the liver and spleen size on the same day by a single radiologist (RK), who was unaware of the clinical condition and the observations made by the clinician, using a Philips Envisor® Color Doppler system with a multi-frequency 3.5 to 5 MHz probe. The measurement of spleen length was the optically maximal distance at the hilum on the longitudinal coronal view (between the most supero-medial and the most infero-lateral points) as the spleen length at the hilum is considered the most reproducible linear measurement(10). The liver length was measured with the child in supine position and the section level along the MCL was determined by simultaneous demonstration of the right kidney as per standard methodology(11). The upper and lower points of the measurement of the liver span were marked and then measured from the sonographic image. The measurements were made during quiet breathing in younger children and during breath-holding in older children. Neither preparation nor sedation was used.

Statistical analysis: Differences of continuous variables between two independent groups were assessed with the *t* test and the non-parametric Mann–Whitney test; more than two groups were assessed with analysis of variance. Association between spleen or liver length and each of the three variables- age, height/length and weight was assessed with the Pearson correlation coefficient; to identify the exact pattern of the relationship, non-linear regression analysis was performed. Multiple regression analysis was applied in a backward stepwise fashion to test the independent effect of all the factors on liver/spleen length. All statistical analyses were performed by the biostatistician using STATA 10 software.

RESULTS

Parents of a total of 650 children were approached for enrolment in the study, of which 42 refused permission and 11 were excluded. Thus, 597 children (347 [58.1%] boys) between the age-group 1 month to 12 years (mean [SD] age 56.5 [41.9] month) visiting the out-patient department either for routine immunization (268, 44.9%) or asymptomatic children accompanying their siblings (329, 55.1%)

TABLE I AGE AND SEX DISTRIBUTION OF THE STUDY POPULATION

Age group	Male	Female	Total
1-<3 mo	10	11	21
3-<6 mo	26	09	35
6-12 mo	28	23	51
1-<2 yr	44	33	77
2-<4 yr	79	53	132
4-<6 yr	62	53	115
6-8 yr	31	20	51
8-10 y	35	27	62
10-<12 y	32	21	53
Total (%)	347 (58.1)	250 (41.9)	597

were evaluated during the study. The median age was 48 month (range, 1-156 month). The age and sex distribution of the study population is shown in ***Table* I**. The mean (SD) splenic length was 6.99 (1.36) cm (males, 7.06cm; females, 6.88cm) and the mean (SD) liver length was 9.59 (1.98) cm (males, 9.63 cm; females, 9.54 cm). The spleen and liver length of healthy children from 1 month to 12 year according to age and sex is given in ***Table* II**. The spleen size and the liver size increased significantly with the age ($P<0.05$). Liver and spleen length correlated significantly with the height ($r=0.84$ and 0.73) and weight ($r=0.79$ and 0.69). The regression analysis with height/length as the independent continuous variable yielded a high multiple correlation between spleen length and height/length ($R^2=0.54$), and liver length and height/length ($R^2=0.70$). Multiple regression analysis with spleen

TABLE II LIVER AND SPLEEN LENGTH BY ULTRASONOGRAPHY IN HEALTHY CHILDREN (N=597)[#]

Age and Sex	No.	Liver length (cm)			Spleen length (cm)		
		Mean (SD)	3rd centile	97th centile	Mean (SD)	3rd centile	97th centile
1-<3 mo							
M	10	6.5 (1.23)	4.8	8.9	4.9 (1.44)	3.7	8.7
F	11	6.2 (0.66)	4.9	7.2	4.5 (0.53)	3.2	5.2
3-<6mo							
M	26	7.1 (0.77)	5.9	8.9	5.4 (0.61)	4.4	6.6
F	09	7.2 (0.94)	5.3	8.0	5.5 (0.51)	4.7	6.5
6-<12 mo							
M	28	7.5 (0.88)	6.1	9.5	6.0 (0.86)	4.4	8.3
F	23	7.9 (0.92)	6.3	9.6	5.6 (0.61)	4.7	7.2
1-<2y							
M	44	8.6 (0.85)	7.1	10.2	6.4 (1.01)	4.7	9.8
F	33	8.5 (1.51)	6.3	11.1	6.1 (0.74)	4.5	7.6
2-<4y							
M	79	9.0 (1.34)	7.2	11.9	6.9 (1.01)	4.1	9.3
F	53	8.9 (0.97)	6.9	11.3	6.7(0.74)	5.3	8.3
4-<6y							
M	62	10.3 (1.27)	7.3	14.7	7.4 (0.99)	5.0	10.9
F	53	9.8 (1.24)	6.5	13.3	7.1 (0.90)	5.2	9.3
6-<8y							
M	31	10.8 (0.94)	09	12.3	7.9 (0.94)	6.3	9.7
F	20	10.9 (1.29)	8.2	13.3	7.6 (0.99)	5.5	9.5
8-<10y							
M	35	11.9 (1.08)	10	14.1	8.2 (1.02)	6.8	10.9
F	27	11.7 (1.11)	9.4	14.0	8.2 (1.02)	6.5	9.8
10-<12y							
M	32	12.6 (1.20)	11	15.5	8.7 (1.84)	6.3	11.7
F	21	12.3 (1.39)	9.7	15.2	8.7 (1.20)	6.7	11.3

[#] *M-MALES, F-FEMALE, No difference between sexes either in the spleen size (P=0.11) or the liver size (P=0.57).*

length as dependent variable showed that both height (β coefficient 0.038, SE 0.006, *P*=0.0001) and body surface area (β coefficient 3.776, SE 1.68, *P*=0.02) had significant independent positive association with spleen length; no significant association could be seen with age (β coefficient 0.0003, SE 0.003, *P*=0.91) or bodyweight (β coefficient 0.006, SE 0.012, *P*=0.62). Multiple regression analysis with liver length as dependent variable showed that only height (β coefficient 0.055, SE 0.007, *P*=0.0001) had significant independent positive association with liver length; no significant association could be seen with age (β coefficient 0.003, SE 0.004, *P*=0.39), bodyweight (β coefficient 0.214, SE 0.014, *P*=0.14) or body surface area (β coefficient –1.593, SE 1.97, *P*=0.42). Thus, only height had significant independent positive association with both spleen length and liver length. The standardized ranges for ultrasound organometry of liver and spleen in 1 month-12 year old children, adjusted for height/ length and weight is provided in ***Table* III.**

DISCUSSION

Our results provide a standard set of normal range of liver and spleen size according to weight, height, age and sex of the children, as determined by ultrasonography. We also found height to be a significant correlate of the liver and spleen size across all ages and weights, in both the sexes.

The conventional method of recording the hepatic and splenic size by clinical examination has been reported to lack both accuracy and reliability(1,2,7,12-14). There have been quite a few previous reports giving the standard sizes of liver and spleen by ultrasound in children(5,6,9,11,15,16), but none has been done in Indian population. Among the more recent ones, Rosenberg, *et al.*(9) and Megremis, *et al.*(5) have provided ultrasonographic data on spleen size in 230 and 512 children, respectively. Of the studies providing normative data on both liver and spleen size, Safak, *et al.*(16) studied 712, 7-15 year old children and provided data according to bodyweight groups. Konus, *et al.*(15) studied liver and spleen sizes for 307 children and provided the data in height-range and age-group categories. Our results are comparable to these studies.

As the midclavicular line is known to vary widely when evaluated by different observers, we pre-determined it for the sonographic assessments, thus, consistency of measurement was ensured. A single radiologist performing the ultrasonograhy removed the inter-observer bias. There are also some limitations of our study. The number of subjects in the age group 1-3 months and the number of females

TABLE III LIVER AND SPLEEN SIZE ADJUSTED FOR HEIGHT/LENGTH AND WEIGHT ON ULTRASOUND ORGANOMETRY

Parameter	No	Age (mo) mean (SD)	Sex ratio (female/male)	Liver size (cm) mean (SD)	Spleen size (cm) mean (SD)
Height/length (cm)					
50-80	151	10.5 (6.7)	90/61	7.6 (1.18)	5.7 (0.99)
81-100	174	38.4 (11.6)	98/76	8.9 (1.14)	6.7 (0.90)
101-120	151	71.9 (17.5)	90/61	10.3 (1.19)	7.4 (0.99)
121-140	87	114.7 (16.5)	46/41	11.9 (1.18)	8.3 (1.0)
>140	34	141 (8.6)	23/11	12.5 (1.32)	8.8 (1.11)
Bodyweight (kg)					
≤10	143	10.5 (7.0)	59/84	7.5 (1.12)	5.6 (0.90)
10.1-20	310	50.1 (21.1)	132/178	9.5 (1.38)	7.0 (1.03)
20.1-30	100	107.1 (20.3)	44/56	11.5 (1.19)	8.1 (0.99)
30.1-40	33	134.5 (12.3)	11/22	12.4 (0.92)	8.6 (0.99)
>40	11	141.8 (12.9)	4/7	13.7 (1.02)	9.4 (1.08)

WHAT IS ALREADY KNOWN?

- Ultrasound-based organometric data is available for different population groups.

WHAT THIS STUDY ADDS?

- Ultrasound-based organometric normative data on the liver and spleen size in Indian children aged 1 month to 12 year is presented, and shown to correlate with the height/length of the child.

in the age-group 3-6 months was less than ten. Further, neonates, and children above 12 year age were not included in the study population due to administrative constraints. Although, many previous studies have published normative data using similar small numbers(5,9), the small sample size in certain groups may affect the generalizability of the values to these age-groups. Nutritional anemia and malnutrition may be associated with organomegaly and were not specifically excluded (except severe malnutritiona and clinically obvious anemia). However, by presenting the largest pediatric series so far, we provide a more accurate assessment of liver and spleen sizes in children, especially those in India.

In addition to size, there are several palpatory characteristics of the liver and spleen (tenderness, liver edge, nodularity and consistency of the surface, etc.) that contribute significantly to the overall bedside assessment of the organomegaly. Thus, clinical liver span remains a simple practical measurement of liver size, also providing additional supplemental information, and the most applicable in developing countries. The bedside assessment of liver and splenic enlargement will not obviate diagnostic imaging when such information is vital to further therapeutic management of the patient.

We believe that the results of this study can be used as a practical and comprehensive guide to indicate the normal liver and spleen length range for every child, according to his/ her age and body habitus.

ACKNOWLEDGMENTS

Dr KK Kalra, Medical Superintendent, Chacha Nehru Bal Chikitsalaya, for the permission and logistic support to conduct and publish the study.

Contributors: SS and DM conceptualized the study. BD, SS and DM were involved in patient selection, enrolment and clinical data collection. RK and SA conducted the sonographic evaluation. SS and BD collated the results, conducted the literature search and drafted the manuscript. DM supervised the conduct of the study and the manuscript preparation. RMP was involved in the planning of the study, conducted the statistical analysis, and reviewed the manuscript for important intellectual content. All the authors were involved in the approval of the final manuscript to be published. RK and DM would act as the guarantors for the relevant portions of the manuscript.

Funding: None.

Competing interests: None stated.

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