Normal Liver, Spleen, and Kidney Dimensions in Neonates, Infants, and Children: Evaluation with Sonography

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OBJECTIVE. The objective of this study was to determine the normal range of dimensions for the liver, spleen, and kidney in healthy neonates, infants, and children.

SUBJECTS AND METHODS. This prospective study involved 307 pediatric subjects (169 girls and 138 boys) with normal physical or sonographic findings who were examined because of problems unrelated to the measured organs. The subjects were 5 days to 16 years old. All measured organs were sonographically normal. At least two dimensions were obtained for each liver, spleen, and kidney. Relationships of the dimensions of these organs with sex, age, body weight, height, and body surface area were investigated. Suggested limits of normal dimensions were defined.

RESULTS. Dimensions of the measured organs were not statistically different in boys and girls. Longitudinal dimensions of all three organs showed the best correlation with age, body weight, height, and body surface area. Height showed the strongest correlation of all. This correlation was a polynomial correlation.

CONCLUSION. Determination of pathologic changes in size of the liver, spleen, and kidney necessitates knowing the normal range of dimensions for these organs in healthy neonates, infants, and children. Presented data are applicable in daily routine sonography. Body height should be considered the best criteria to correlate with longitudinal dimensions of these organs.

Sonography provides a quick assessment of visceral organ dimensions without any risk of radiation. The normal range of visceral organ sizes in adults and children determined with sonography has been reported elsewhere [1–13]. However, available data are limited for the liver and the spleen in children, which causes difficulty in defining hepatomegaly and splenomegaly sonographically.

Our purpose was primarily to document the normal range of dimensions of the liver in children. The relationship of each dimension with sex, age, body weight, height, and body surface area was determined. A similar evaluation was done for the spleen and the kidney at the same time.

Subjects and Methods

We prospectively examined 307 pediatric subjects (169 girls and 138 boys) with sonography. The range of age was from full-term newborns (5 days) to 16 years. Patients who did not have normal growth curves (who were not in the third to 97th percentiles) were not included in the study. Another major criterion for selection of children was having no clinically or sonographically pathologic findings related to the studied organs. Most children were completely healthy, although some were undergoing follow-up for a disease unrelated to the measured organs, such as hip dysplasia or undescended testes. No child had a history of oncologic, hematologic, or traumatic conditions. Some children with urinary tract infection were included in the study, but only liver and spleen dimensions were recorded in those patients. We also did not record dimensions of a number of spleens for which abdominal gas distention prevented reliable size measurements. All measured organs had a normal position and shape and normal echo texture.

We used high-resolution real-time sonographic scanners (SSA 270A; Toshiba, Tokyo, Japan; and EUB-515 and EUB-515A; Hitachi, Tokyo, Japan) with 3.5-MHz convex transducers. Patients had neither preparation nor sedation.

Liver measurements were performed in all subjects ($n = 307$). In a subject lying in the supine position, longitudinal and anteroposterior dimensions were obtained in the midclavicular and midsagittal

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planes for the right and left lobes. "Midsagittal plane" means that the plane passes through the xiphoid process. In both planes, the upper margin of the liver was defined as the uppermost edge under the dome of the diaphragm, whereas the lower margin was defined as the lowermost edge of the lobe (Fig. 1).

Spleen measurements were performed in 169 girls and 130 boys (n = 299). Longitudinal and transverse dimensions in the coronal plane were obtained with the subject in the supine or slightly right lateral decubitus position. Longitudinal size measurement was performed between the most superomedial and the most inferolateral points of the spleen. The transverse dimension was measured between the hilum and the most superolateral margin of the spleen (Fig. 2).

Kidney measurements were performed in 155 girls and 124 boys (n = 279). Longitudinal and transverse dimensions of both kidneys were obtained in the coronal plane passing through the renal hilum with subjects in the supine or slightly right or left lateral decubitus positions (Fig. 3).

To determine reproducibility, each measurement of each organ was repeated at least three times, and the most repeated value was recorded. Data obtained from the measurements were classified into 11 age groups. Relationships of all dimensions with sex, age, height, weight, and body surface area were statistically analyzed. Body surface area was derived using the patient's height and weight from the nomogram modified from the data of E. Boyd by C. D. West [14]. All measurements were plotted as a function of age in months, body weight, height, and body surface area. Types of relationships and regression lines were obtained for the various sets of data using the least squares method. The mean, minimum, and maximum value; fifth and 95th percentiles; and standard deviations were calculated (Excel 5.0; Microsoft, Redmond, WA). The lowermost and uppermost limits of normal for each age group were suggested and were derived using the previous zero or five integer values below the fifth percentile, and the next zero or five integer values above the 95th percentile, considering also the mean, minimum, and maximum values of normal [1].

Results

No statistically significant differences were found between the two sexes in any age group for any measured organ dimension (t test, $p >$ .05). Therefore, all data were rearranged without being separated according to sex.

Compared with the anteroposterior and transverse dimensions, all longitudinal dimensions of each organ showed the highest correlation with the body parameters (i.e., age, height, weight, and body surface area) (Tables 1–3). Among the body parameters, height was the one best correlated with the longitudinal dimension of each organ. Body surface area, age, and weight followed height, in that order. Correlation coefficients are presented in Tables 1–3. On regression analysis, the relationship between the longitudinal dimensions and height was of the polynomial type for each organ (Figs. 4–8).

Longitudinal dimensions of the right lobe of the liver, the spleen, and both kidneys, with corresponding values of patient height in selected age groups, are presented in Tables 4–7. Mean, minimum, and maximum values; fifth and 95th percentile values; standard deviations; and suggested limits of normal are also given. Other dimensions are presented in graphic form (Figs. 4–8). The dimensions of the left lobe of the liver, except those taken in infancy, poorly correlated with body parameters.

Significant differences were found between the longitudinal sizes of the right and left kidneys (t test, $p <$ .05). For this reason, findings

TABLE 1 Correlation Coefficients for Liver Dimensions as Revealed by Sonography in 307 Pediatric Subjects

Body Parameter	Right Lobe		Left Lobe	
	Long.	AP	Long.	AP
Height	.85	.77	.81	.50
Age	.82	.71	.78	.47
Weight	.80	.73	.74	.49
Surface area	.83	.75	.78	.45

Note.—Long. = longitudinal, AP = anteroposterior.

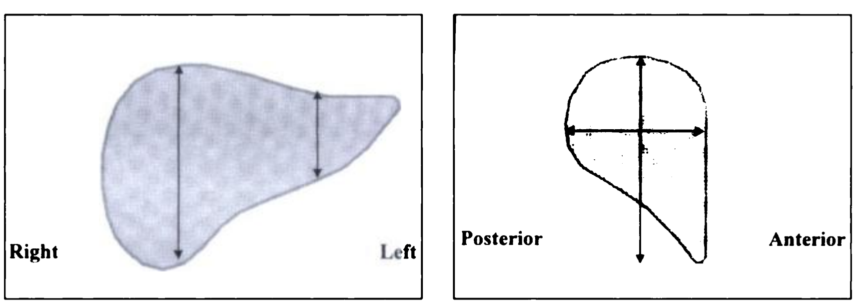
TABLE 2 Correlation Coefficients for Spleen Dimensions as Revealed by Sonography in 299 Pediatric Subjects

Body Parameter	Longitudinal	Transverse
Height	.88	.70
Age	.84	.67
Weight	.84	.69
Surface area	.86	.70

TABLE 3 Correlation Coefficients for Kidney Dimensions as Revealed by Sonography in 279 Pediatric Subjects

Body Parameter	Right Kidney		Left Kidney	
	Long.	Trans.	Long.	Trans.
Height	.94	.86	.93	.85
Age	.91	.84	.90	.83
Weight	.89	.82	.88	.79
Surface area	.91	.83	.91	.80

Note.—Long. = longitudinal, Trans. = transverse.



A B

Fig. 1.—Diagrams show how longitudinal and anteroposterior dimensions of liver lobes were measured.
A, Liver measurements were performed at midclavicular and midline sagittal planes.
B, Longitudinal and anteroposterior dimensions of right and left lobes were measured.

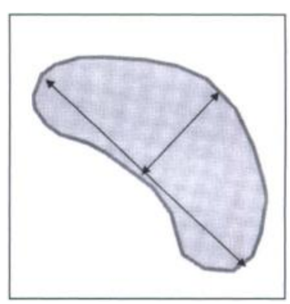


Fig. 2.—Diagram shows how longitudinal and transverse dimensions of spleen were measured in coronal section passing through splenic hilum.

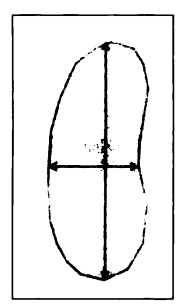


Fig. 3.—Diagram shows how longitudinal and transverse dimensions of kidney were measured in coronal section passing through renal hilum.

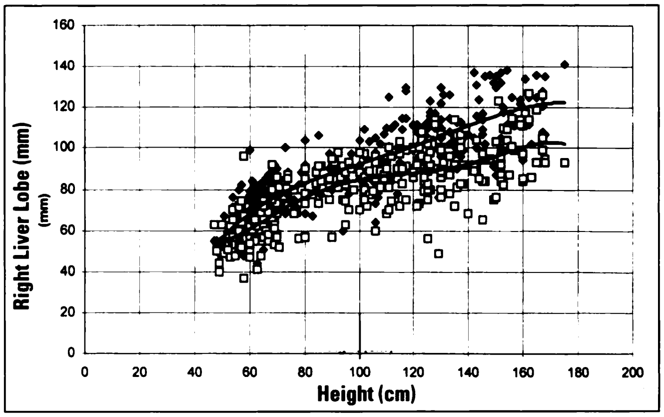


Fig. 4.—Scatter diagram shows longitudinal (♦) and anteroposterior (□) dimensions of right lobe of liver plotted against heights of patients. Note that longitudinal dimensions of right lobe are longer than anteroposterior dimensions and this difference increases with height.

for the right and left kidneys are presented separately in Tables 6 and 7 and in Figures 7 and 8.

Discussion

In the literature, studies about normal liver and spleen dimensions in children are rare, especially for the liver. Most studies do not include enough children to separate the subjects into appropriate age groups [1–9]. We studied many children of all ages, and to our knowledge, this study covers the largest series of pediatric liver and spleen dimensions.

Sonography is a simple and reliable way to visualize and to measure abdominal visceral organs without the risk of ionizing radiation. Organ volumes or ratios obtained by using various organ dimensions and body surface areas are already used in correlation with body parameters to describe the normal dimensions and to measure the degree of pathologic deviation from normal. However, those techniques are time-consuming and impractical in daily use. On the other hand, either one or more of the longitudinal, anteroposterior, and transverse dimensions of these organs are measured as part of routine abdominal sonographic scanning. Therefore, use of these measurements seems more practical for purposes of determining "normal." Any other data, when necessary to combine with the above measurements, should also be easily obtainable. Age, body weight, and height are such parameters.

We did not find any significant difference in measured organ sizes between the two sexes of any age group (t test, $p > .05$). This finding is similar to the findings of others [2–7, 10–12]. Therefore, sex certainly is not a

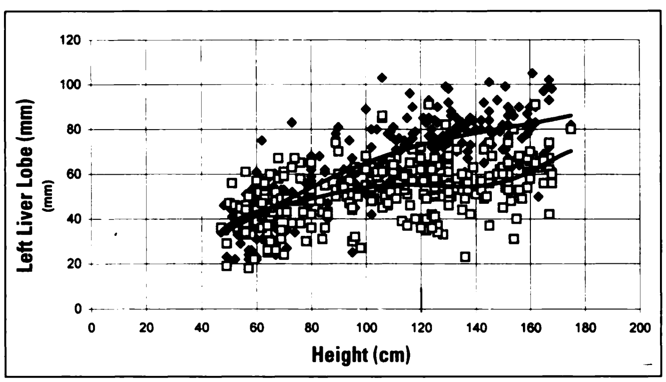


Fig. 5.—Scatter diagram shows longitudinal (♦) and anteroposterior (□) dimensions of left lobe of liver plotted against heights of patients. Note that longitudinal dimensions of left lobe are shorter than anteroposterior dimensions at patient heights of less than 70 cm but longer at patient heights of more than 70 cm.

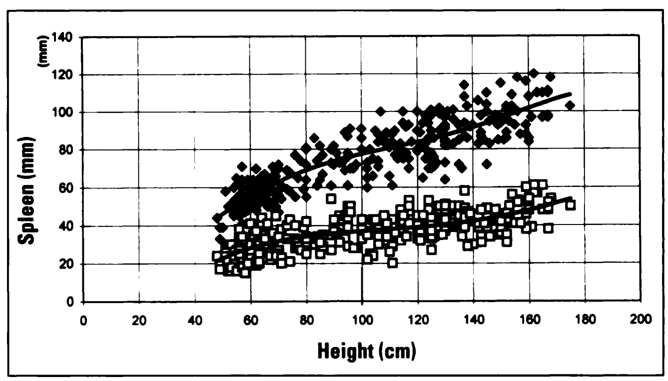


Fig. 6.—Scatter diagram shows longitudinal (♦) and transverse (□) dimensions of spleen plotted against heights of patients.

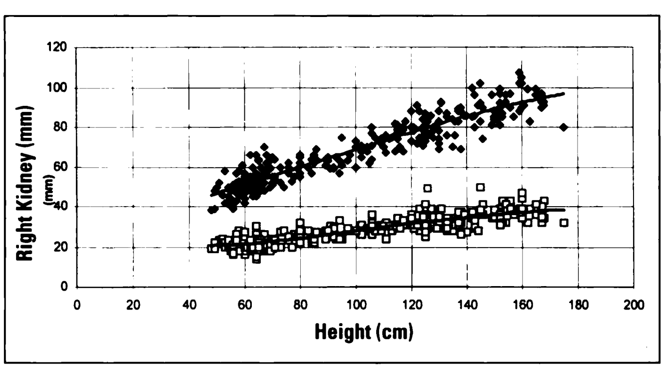


Fig. 7.—Scatter diagram shows longitudinal (♦) and transverse (□) dimensions of right kidney plotted against heights of patients.

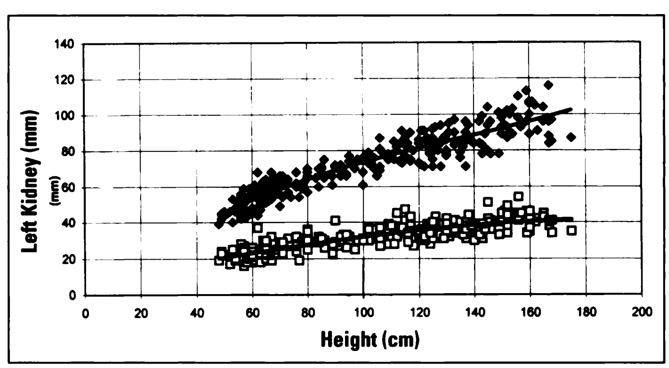


Fig. 8.—Scatter diagram shows longitudinal (♦) and transverse (□) dimensions of left kidney plotted against heights of patients. Left kidney dimensions are longer than right kidney dimensions, as seen in comparison with Figure 7.

TABLE 4 Longitudinal Dimensions of Right Lobe of Liver Versus Height and Age

Subjects			Longitudinal Dimensions (mm) of Right Lobe of Liver							
Body Height (cm)	No.	Age Range (mo)	Mean	SD	Minimum	Maximum	Percentile		Suggested Limits of Normal	
							5th	95th	Lowermost	Uppermost
47–64	53	1–3	64	10.4	45	90	48	82	40	90
54–73	40	4–6	73	10.8	44	92	53	86	45	95
65–78	20	7–9	79	8.0	68	100	70	90	60	100
71–92	18	12–30	85	10.0	67	104	68	98	65	105
85–109	27	36–59	86	11.8	69	109	63	105	65	115
100–130	30	60–83	100	13.6	73	125	77	124	70	125
110–131	38	84–107	105	10.6	81	128	90	123	75	130
124–149	30	108–131	105	12.5	76	135	83	128	75	135
137–153	16	132–155	115	14.0	93	137	95	136	85	140
143–168	23	156–179	118	14.6	87	137	94	136	85	140
152–175	12	180–200	121	11.7	100	141	104	139	95	145

TABLE 5 Longitudinal Dimensions of Spleen Versus Height and Age

Subjects			Longitudinal Dimensions (mm) of Spleen							
Body Height (cm)	No.	Age Range (mo)	Mean	SD	Minimum	Maximum	Percentile		Suggested Limits of Normal	
							5th	95th	Lowermost	Uppermost
48–64	52	1–3	53	7.8	33	71	40	65	30	70
54–73	39	4–6	59	6.3	45	71	47	67	40	75
65–78	18	7–9	63	7.6	50	77	53	74	45	80
71–92	18	12–30	70	9.6	54	86	55	82	50	85
85–109	27	36–59	75	8.4	60	91	61	88	55	95
100–130	30	60–83	84	9.0	61	100	70	100	60	105
110–131	36	84–107	85	10.5	65	102	69	100	65	105
125–149	29	108–131	86	10.7	64	114	70	100	65	110
137–153	17	132–155	97	9.7	72	100	81	108	75	115
143–168	21	156–179	101	11.7	84	120	85	118	80	120
152–175	12	180–200	101	10.3	88	120	88	115	85	120

TABLE 6 Longitudinal Dimensions of Right Kidney Versus Height and Age

Subjects			Longitudinal Dimensions (mm) of Right Kidney							
Body Height (cm)	No.	Age Range (mo)	Mean	SD	Minimum	Maximum	Percentile		Suggested Limits of Normal	
							5th	95th	Lowermost	Uppermost
48–64	50	1–3	50	5.8	38	66	40	58	35	65
54–73	39	4–6	53	5.3	41	66	50	64	40	70
65–78	17	7–9	59	5.2	50	70	52	66	45	70
71–92	18	12–30	61	3.4	55	66	55	65	50	75
85–109	22	36–59	67	5.1	57	77	59	75	55	80
100–130	26	60–83	74	5.5	62	83	65	83	60	85
110–131	32	84–107	80	6.6	68	93	70	91	65	95
124–149	27	108–131	80	7.0	69	96	69	89	65	100
137–153	15	132–155	89	6.2	81	102	82	100	70	105
143–168	22	156–179	94	5.9	83	105	85	102	75	110
152–175	11	180–200	92	7.0	80	107	83	102	75	110

TABLE 7 Longitudinal Dimensions of Left Kidney Versus Height and Age

Subjects			Longitudinal Dimensions (mm) of Left Kidney							
Body Height (cm)	No.	Age Range (mo)	Mean	SD	Minimum	Maximum	Percentile		Suggested Limits of Normal	
							5th	95th	Lowermost	Uppermost
48–64	50	1–3	50	5.5	39	61	42	59	35	65
54–73	39	4–6	56	5.5	44	68	47	64	40	70
65–78	17	7–9	61	4.6	54	68	54	68	45	75
71–92	18	12–30	66	5.3	54	75	57	72	50	80
85–109	22	36–59	71	4.5	61	77	61	76	55	85
100–130	26	60–83	79	5.9	66	90	70	87	60	95
110–131	32	84–107	84	6.6	71	95	73	93	65	100
124–149	27	108–131	84	7.4	71	99	75	97	65	105
137–153	15	132–155	91	8.4	71	104	77	102	70	110
143–168	22	156–179	96	8.9	83	113	84	110	75	115
152–175	11	180–200	99	7.5	87	116	90	110	80	120

determining factor for organ dimensions in the pediatric age group.

In most other studies, sizes between the fifth and the 95th percentile were the accepted normal limits [2, 3, 5, 6, 8–10, 13]. However, this practice results in approximately 10% of children with normal visceral organ sizes falling outside these limits [11]. Besides, although plus or minus two SDs are the accepted equivalents of the fifth and 95th percentile values statistically [15], some studies were based on plus or minus one SD [7]. For this reason, we preferred to define the normal lowermost and uppermost longitudinal dimensions of the studied organs using the method originally described by Rosenberg et al. [1] in 1991.

We found that height shows the best correlation with any one of the mentioned organ dimensions. Body surface area also shows a high correlation with organ dimensions, but to a lesser degree. However, its derivation is not as practical as height. For those reasons, we preferred not to use body surface area in standard tables and graphics. Age and body weight are not as important as height and body surface area. Therefore, when deciding if sonographically obtained dimensions of an organ are normal, patient height should be the primary concern.

The liver is an organ of complex shape and varies widely from patient to patient. Our wide range of normal dimensions supports this opinion. However, it is necessary to have references for normal liver dimensions in the pediatric age group.

The findings of various similar studies differ somewhat from each other and from ours. Deligeorgis et al. [12] performed a study with direct roentgenography in 350 children to establish normal liver dimensions. They found significantly longer dimensions than we did. The reason for the difference is obviously the magnification factor on radiographs.

Some findings are contradictory even within one study. For example, in the study of Holder et al. [2], which included 185 children, sonographically measured dimensions of the liver are an average of 4 cm smaller than the same dimensions measured scintigraphically. Our sonographically measured liver dimensions are larger than those of Holder et al. The reason is probably their technique of measurement. They used linear transducers and performed the measurements in a sagittal plane passing through the midpoint of the liver's right and left margins. Linear transducers, because of the interposition of lung between the dome of the liver and the anterior abdominal wall, prevent some of the superior portion of the liver from being observed. This effect, as Holder admits, results in the "observed" lung–liver border's being determined as the superior margin of the liver, and consequently in the liver's being measured as having smaller longitudinal dimensions than the livers we measured. Convex probes, such as the one we used, prevent this complication. Besides, unlike Holder et al., we believe that the midpoint of the liver's right and left margins cannot be referred to as a standard sagittal plane because the left lobe in particular differs in extension and size from one person to another and with age. Instead, midsagittal and midclavicular planes seem more appropriate for longitudinal liver size measurements. In spite of these technical differences, Holder et al. also concluded that height is the best-correlated body parameter with liver longitudinal dimensions.

In the study of Markisz et al. [4] that included 116 children, liver and spleen dimensions obtained with scintigraphic methods also exceeded ours. Those authors used volume measurements and found a high linear correlation between the volumes of these organs and patient weights. Correlations with age were less evident. Patient height or organ dimensions were not considered in their study and limits of normal cannot be derived. From the study of Markisz et al. (like the study of Holder et al. [2]), we conclude that scintigraphically obtained organ sizes are larger than sonographically obtained ones. Therefore, differences in organ size are probably due to the difference of imaging techniques.

In 1983, Niederau et al. [13] described a study of normal liver dimensions in 1000 adult patients. Sonographically, their study showed smaller values than ours. This difference is probably the result of the same technical reason we discussed with respect to the study of Holder et al. [2]. Niederau et al. noted that organ sizes increased with height and body surface area in adults.

In 1983, Dittrich et al. [3] also used sonography to study liver dimensions in 194 children. Although they reported smaller dimensions than we did, Dittrich et al. noted the best correlation was found between liver dimensions and height, which is a linear correlation. They found also a high correlation with body surface area, but in their study only height was used as a reference parameter for further analysis.

Normal spleen dimensions and volume standards have been investigated by only a few researchers. Rosenberg et al. [1] studied normal spleen longitudinal dimensions in

230 children using sonography. Interestingly, their dimensions are smaller than ours for children under the age of 8 years, whereas in children over the age of 8 years, the findings of their study and ours are similar. They stated that body weight showed the best correlation with spleen length, which was roughly logarithmic in type. Height and age, in that order, were less well correlated with spleen length.

Schlesinger et al. [9] studied normal spleen volume in 48 children using CT. These researchers found that spleen volume correlated better with body weight than with age. The best regression model was a simple linear relationship of spleen volume to body weight.

Renal dimensions, as well as cross-sectional areas and volumetric standards of the kidneys, have been investigated by many different authors for pediatric age groups.

Christophe et al. [5] measured kidney sizes sonographically in 170 children. Values of longitudinal kidney dimensions in their study are also similar to ours. These researchers found a linear relationship between renal length and height. Additionally, they found that the longitudinal dimension of the kidneys versus body surface area yielded the most accurate correlation. However, as they stated, correlating renal length with body height is more practical.

In 1985, Dinkel et al. [10] studied renal dimensions and volumes in 325 children with sonography and provided separate graphics for the right and left kidneys. Correlations of renal dimensions with body parameters in that study are similar to our findings, and those authors stated that renal length showed a high correlation with body height. However, in their study, the correlation was a linear relationship. These researchers also found that renal volume showed the best correlation with body surface area and showed almost the same correlation with body weight. For practical purposes, however, they proposed to use the correlation of renal volume with body weight.

We observed that the increase in the longitudinal dimensions of these organs is much more rapid during the first years of life, which mirrors the accentuated body growth during infancy and early childhood (Figs. 4–8). This finding is similar to the findings of Dinkel et al. [10]. In the infancy period, the anteroposterior dimension of the left lobe of the liver may be somewhat longer than the longitudinal dimension. With aging, these phenomena change and the longitudinal dimension of the left lobe becomes longer than the anteroposterior dimension except in obese persons [13]. We observed the same phenomenon in infants. Anteroposterior dimensions of the left liver lobes were found to be somewhat longer than the longitudinal dimensions. The reason is that the intraabdominal visceral organs are larger in children than in adults when compared with total body volume. This finding leads to the conclusion that measurements of the midclavicular and midsagittal longitudinal dimensions suffice to estimate the liver size in most children, and that measurements of anteroposterior dimensions, particularly of the left lobe, must be obtained only in infants.

Data of normal visceral organ sizes according to age have been given in table form in several previous studies [1, 7]. However, the selected age groups in those studies present a wide range like 5 years, as in the studies of Rosenberg et al. [1] and Dremsek et al. [7] (whereas our selected age groups had an age range of 3 months or 2 years). In other studies, data were given only in graphic form [2–6, 10]. We present our data both in tabular and graphic forms with the aim of enabling a more practical evaluation during a sonographic examination.

Establishing normal parameters is mandatory for defining the pathologic changes in size of the liver, spleen, and kidneys in routine sonographic examinations of children. The methods of measurement and analysis we used in this study are standardized and easy to apply. Findings are handy and reliable and are suitable particularly for sonography units and pediatric departments with large numbers of patients.

Longitudinal dimension and patient height are the most important determining factors of organ size among studied dimensions and body parameters. Therefore, any specific longitudinal dimension should primarily be correlated with patient height, and findings should be compared with tables and graphics of normal parameters.

References

1. Rosenberg HK, Markowitz RI, Kolberg H, Park C, Hubbard A, Bellah RD. Normal splenic size in infants and children: sonographic measurements. *AJR* **1991**;157:119–121
2. Holder L, Strife J, Padikal TN, Perkins PJ, Kerelakes JG. Liver size determination in pediatrics using sonographic and scintigraphic techniques. *Radiology* **1975**;117:349–353
3. Dittrich M, Milde S, Dinkel E, Baumann W, Weitzel D. Sonographic biometry of liver and spleen size in childhood. *Pediatr Radiol* **1983**;13:206–211
4. Markisz JA, Treves ST, Davis RT. Normal hepatic and splenic size in children: scintigraphic determination. *Pediatr Radiol* **1987**;17:273–276
5. Christophe C, Cantraine F, Bogaert C, et al. Ultrasound: a method for kidney size monitoring in children. *Eur J Pediatr* **1986**;145:532–538
6. Han BK, Babcock DS. Sonographic measurements and appearance of normal kidneys in children. *AJR* **1985**;145:611–616
7. Dremsek PA, Kritscher H, Böhm G, Hochberger O. Kidney dimensions in ultrasound compared to somatometric parameters in normal children. *Pediatr Radiol* **1987**;17:285–290
8. Rosenbaum DM, Korngold E, Teele RL. Sonographic assessment of renal length in normal children. *AJR* **1984**;142:467–469
9. Schlesinger AE, Edgar KA, Boxer LA. Volume of the spleen in children as measured on CT scans: normal standards as a function of body weight. *AJR* **1993**;160:1107–1109
10. Dinkel E, Ertel M, Dittrich M, Peters H, Berres M, Schulte-Wissermann H. Kidney size in childhood: sonographic growth charts for kidney length and volume. *Pediatr Radiol* **1985**;15:38–43
11. Zerin JM, Blane CE. Sonographic assessment of renal length in children: a reappraisal. *Pediatr Radiol* **1994**;24:101–106
12. Deligeorgis D, Yannakos D, Doxiadis S. Normal size of liver in infancy and childhood: x-ray study. *Arch Dis Child* **1973**;48:790–793
13. Niederau C, Sonnenberg A, Müller JE, Erckenbrecht JF, Scholten T, Fritsch WP. Sonographic measurements of the normal liver, spleen, pancreas, and portal vein. *Radiology* **1983**;149:537–540
14. Berhman RE, Kliegman R. *Nelson essentials of pediatrics*. Philadelphia: Saunders, **1990**:712
15. Remington RD, Schork MA. *Statistics with application to the biological and health sciences*, 2nd ed. Englewood Cliffs, NJ: Prentice Hall, **1985**:23–43