Sonographic Measurements of the Normal Liver, Spleen, Pancreas, and Portal Vein

Measurements of liver, pancreas, and spleen size based on percussion and palpation are inaccurate and unreliable, while radiography and radionuclide studies expose the patient to gamma radiation (1-10). Ultrasound has been found to be both accurate and reliable; however, despite widespread clinical use, we know of no generally accepted standards of liver, pancreas, and spleen size. Previously, ultrasonic dimensions have been determined in inhomogeneous populations or small groups of subjects, sometimes including patients with gastrointestinal diseases (11-17). We therefore conducted a prospective study of a large group of healthy subjects to correlate organ size with sex, age, weight, height, and body surface area.

MATERIAL AND METHODS

Subjects: One thousand consecutive blood donors were examined by ultrasound between August and December 1981. There were 160 women and 840 men 18-65 years of age. All gave informed consent, and the study was approved by the Ethics Committee of this institution. Eighty-five subjects were excluded because of (a) a history of hepatic, biliary, or pancreatic disease [n = 55] or suggestive ultrasonic, clinical, or laboratory findings, (b) upper abdominal surgery [n = 10], or (c) alcohol consumption of more than 60 g/day in men and 20 g/day in women [n = 20]. Sex, age, weight, height, body surface area, medical history, and results of the physical examination were recorded, along with erythrocyte sedimentation rate, hematocrit, white cell count, platelet count, SGOT, SGPT, HBsAg, anti-HBs, and serologic tests for syphilis. All subjects had normal chest radiographs.

Ultrasound Examination: We employed a high-resolution real-time scanner with a 3.5-MHz transducer (Siemens Imager). Subjects were examined (a) supine, (b) with the right side elevated to demonstrate the porta hepatitis, and (c) with the left side elevated to show the longitudinal axis of the spleen. Length was measured to the nearest millimeter with dividers.

Longitudinal scans of the liver were obtained in the midclavicular line and midline, measuring the longitudinal and anteroposterior (AP) diameters as shown in Figures 1-4. In the midclavicular line, the upper portion of the liver was partly masked by the air inside the lung, so that the margin between lung and liver was used as the upper limit of the longitudinal diameter (Figs. 1, 2, and 4). In the midline, the upper margin of the liver under the dome of the diaphragm served as the upper limit of the longitudinal diameter (Figs. 1 and 3). The AP diameters were measured at the midpoint of the longitudinal diameters (Figs. 2-4). Both the liver and spleen were measured during deep inspiration in order to minimize masking by the lung and eliminate morphological variation due to respiration. The cross-sectional area of the liver was calculated from the longitudinal and AP diameters using the equation

(longitudinal diameter \times \text{AP diameter})/2 = \text{cross-sectional area}

Normal values and upper limits (95th percentile) of liver, spleen, pancreas, and portal vein size were determined prospectively with ultrasound in 915 healthy subjects. Sex, age, weight, height, and body surface area were determined in each case. Since correlation of longitudinal and transverse organ diameters with physical data was poor (r ≤ 0.3), the authors do not consider it necessary to correct the measurements accordingly. However, the liver is oriented longitudinally in slender subjects and transversely in heavy subjects; thus both longitudinal and anteroposterior diameters need to be measured, since the longitudinal diameter alone will give too high or too low a value, respectively.

Index terms: (GI system, normal variants, 70.130; GI system ultrasonography, 70.1298) • Liver, ultrasound studies • Pancreas, ultrasound studies • Portal vein, ultrasound studies • Spleen, ultrasound studies

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1. AP view. 1 = midclavicular longitudinal diameter of the liver; 3 = midline longitudinal diameter of the liver; 4 = transverse diameter of the spleen; 5 = longitudinal diameter of the spleen; 7 = diagonal diameter of the spleen. The upper regions of the liver and the spleen are located in the dome of the diaphragm and hidden by the air in the lung, so that their longitudinal diameters can be measured only as far as the margin of the lung.

2. Lateral view of the liver in the midclavicular plane. 1 = midclavicular longitudinal diameter; 2 = midclavicular AP diameter, measured at the midpoint of the longitudinal diameter. The upper region of the liver is masked by the air in the lung.

3. Midline longitudinal scan of the liver. 3 = midline longitudinal diameter; 4 = midline AP diameter, measured at the midpoint of the longitudinal diameter; D = diaphragm; L = liver; ST = stomach (target); P = pancreas; A = aorta. The upper margin of the liver, under the dome of the diaphragm, served as the upper limit of the longitudinal diameter.

4. Longitudinal scan of the liver in the right midclavicular plane. 1 = midclavicular longitudinal diameter; 2 = midclavicular AP diameter, measured at the midpoint of the longitudinal diameter; L = liver; G = gallbladder. The margin between the lung and liver was used as the upper limit of the longitudinal diameter, since the upper region of the liver was partly masked by the air in the lung.

5. Longitudinal scan of the spleen. 5 = transverse diameter; 6 = longitudinal diameter; 7 = diagonal diameter; S = spleen; K = kidney. The margin between the lung and spleen served as both the transverse diameter and the upper limit of the longitudinal diameter.

Figure 6

LIVER

Transverse scan. 8 = maximum AP diameter of the head of the pancreas; 9 = maximum AP diameter of the body of the pancreas; PV = portal vein; SMA = superior mesenteric artery; IVC = inferior vena cava; A = aorta. The portal and splenic veins, which represent the posterior (dorsal) boundaries of the pancreas, are not included.

Figure 7

Transverse scan. 8 = maximum AP diameter of the head of the pancreas; 9 = maximum AP diameter of the body of the pancreas; L = liver; PV = portal vein; IVC = inferior vena cava; SMA = superior mesenteric vein; A = aorta; SP = spine. The upper abdominal vessels served as pancreatic landmarks. The portal and splenic veins are not included.

The spleen was viewed along its longitudinal axis. Transverse, longitudinal, and diagonal diameters were measured from the image showing the maximum cross-sectional area as shown in Figures 1 and 5. The margin between lung and spleen served as both the transverse diameter and the upper limit of the longitudinal diameter. The cross-sectional diameter was calculated using all three diameters:

\[
\text{area} = \frac{\text{diagonal} \times \sqrt{\text{transverse}^2 + \text{longitudinal}^2}}{2}
\]
at the porta hepatitis were measured, with the inner dimensions being used for sonographic assessment.

Statistics: Statistical calculations were performed on a Telefunken TR 440 computer using a routine program. Linear regression analysis was carried out for age, sex, weight, height, surface area, and all diameters. The 95th percentile was considered the upper limit of normal, i.e., 95% of all measurements lay below this point. Results of the \( \chi^2 \) test were evaluated using Yates' correction.

RESULTS

Mean values, standard deviations, and upper normal limits of all diameters are shown in TABLE I, and the diameters are correlated with the physical data in TABLE II. The diameters were smaller in women than in men and demonstrated a positive correlation with height and surface area. Liver and spleen diameters decreased with age, while pancreatic and portal vein diameters increased with age.

Liver diameters in heavy and slender subjects are shown in TABLE III. In thin persons, the longitudinal diameter was large and the AP diameter small, whereas in heavy subjects the reverse was true. This indicates that the liver is oriented longitudinally in thin persons and transversely in heavy subjects.

Correlation between the midcavicular and midline longitudinal diameters of the liver \( (r = 0.61) \) was strong, while that between the two AP diameters was 0.20 \( (p \leq 0.001) \). There was a significant correlation between the longitudinal and transverse diameters of the spleen; \( (r = 0.42; p \leq 0.001) \) and between each of these measurements and the diagonal diameter \( (r = 0.63 \text{ and } 0.61, \text{ respectively}; p \leq 0.001) \). No significant correlation was found between any liver and spleen diameters. Correlation between the two pancreatic diameters was 0.4 \( (p \leq 0.001) \). There was a weak positive correlation between pancreatic and portal vein diameters \( (r = 0.20; p \leq 0.001) \). Correlation between the two portal vein diameters was highly significant \( (r = 0.75; p \leq 0.001) \).

Correlation between the cross-sectional areas of the liver and spleen and the physical data did not differ from that for the individual diameters. No additional information could be gained by using the cross-sectional areas instead of the diameters.

DISCUSSION

Liver and spleen size may give information about the diagnosis and course of gastrointestinal and hematologic diseases, while the pancreas is enlarged in acute and chronic pancreatitis. In addition, pancreatic tumors are sometimes manifested by a localized increase in size, and the diameter of the portal vein is helpful in evaluating splenic-portal complications. Thus determination of normal organ size can be significant. In contrast to previous studies, our data were obtained from a large group of healthy subjects, so that standard deviations and upper limits of normal were gen-

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**TABLE I**: Mean Organ Diameters

<table>
<thead>
<tr>
<th>Organ</th>
<th>Diameter (cm) (mean ± S.D.)</th>
<th>95th Percentile (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midclavicular longitudinal diameter of the liver</td>
<td>8.1 ± 1.9</td>
<td>10.9</td>
</tr>
<tr>
<td>Midclavicular AP diameter of the liver</td>
<td>8.3 ± 1.7</td>
<td>11.3</td>
</tr>
<tr>
<td>Midline longitudinal diameter of the liver</td>
<td>5.7 ± 1.5</td>
<td>8.2</td>
</tr>
<tr>
<td>Transverse diameter of the spleen</td>
<td>5.5 ± 1.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Longitudinal diameter of the spleen</td>
<td>5.8 ± 1.8</td>
<td>8.7</td>
</tr>
<tr>
<td>Diagonal diameter of the spleen</td>
<td>3.7 ± 1.0</td>
<td>5.4</td>
</tr>
<tr>
<td>Maximum diameter of the spleen</td>
<td>2.2 ± 0.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Maximum diameter of the body of the pancreas</td>
<td>1.8 ± 0.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Maximum diameter of the portal vein</td>
<td>1.2 ± 0.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Diameter of the portal vein at the porta hepatitis</td>
<td>1.0 ± 0.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**TABLE II**: Correlation with Physical Data

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>Body Surface Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;Mean</td>
<td>&gt;Mean</td>
<td>&lt;Mean</td>
<td>&gt;Mean</td>
<td>&lt;Mean</td>
</tr>
<tr>
<td>Midclavicular longitudinal diameter of the liver</td>
<td>-0.10</td>
<td>-0.23</td>
<td>-0.02</td>
<td>+0.29</td>
</tr>
<tr>
<td>Midclavicular AP diameter of the liver</td>
<td>-0.14</td>
<td>-0.05</td>
<td>+0.03</td>
<td>+0.09</td>
</tr>
<tr>
<td>Midline longitudinal diameter of the liver</td>
<td>-0.10</td>
<td>-0.20</td>
<td>-0.12</td>
<td>+0.23</td>
</tr>
<tr>
<td>Midline AP diameter of the liver</td>
<td>-0.31</td>
<td>+0.06</td>
<td>+0.28</td>
<td>+0.12</td>
</tr>
<tr>
<td>Transverse diameter of the spleen</td>
<td>-0.02</td>
<td>-0.10</td>
<td>+0.18</td>
<td>+0.12</td>
</tr>
<tr>
<td>Longitudinal diameter of the spleen</td>
<td>-0.03</td>
<td>-0.20</td>
<td>+0.14</td>
<td>+0.16</td>
</tr>
<tr>
<td>Diagonal diameter of the spleen</td>
<td>-0.07</td>
<td>-0.89</td>
<td>+0.23</td>
<td>+0.15</td>
</tr>
<tr>
<td>Maximum diameter of the head of the pancreas</td>
<td>-0.23</td>
<td>+0.17</td>
<td>+0.30</td>
<td>+0.17</td>
</tr>
<tr>
<td>Maximum diameter of the body of the pancreas</td>
<td>-0.28</td>
<td>+0.10</td>
<td>+0.23</td>
<td>+0.16</td>
</tr>
<tr>
<td>Maximum diameter of the portal vein</td>
<td>-0.23</td>
<td>+0.12</td>
<td>+0.23</td>
<td>+0.09</td>
</tr>
<tr>
<td>Diameter of the portal vein at the porta hepatitis</td>
<td>-0.22</td>
<td>+0.17</td>
<td>+0.28</td>
<td>+0.05</td>
</tr>
</tbody>
</table>

* For \(-0.12 \geq r \geq +0.12, p \leq 0.001\); for \(-0.09 \geq r \geq +0.09, p \leq 0.01\).

**TABLE III**: Light and Heavy Subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>Midline Longitudinal Diameter of the Liver</th>
<th>Midline AP Diameter of the Liver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Subjects</td>
<td>&lt;Mean (25%)</td>
<td>&gt;Mean (75%)</td>
</tr>
<tr>
<td>(&lt;5 kg)(n = 41)</td>
<td>11 (25%)</td>
<td>33 (75%)</td>
</tr>
<tr>
<td>Heavy Subjects</td>
<td>30 (77%)</td>
<td>9 (23%)</td>
</tr>
<tr>
<td>(&gt;95 kg)(n = 39)</td>
<td>(\chi^2 = 20.27 (p \leq 0.001))</td>
<td>(\chi^2 = 36.58 (p \leq 0.001))</td>
</tr>
</tbody>
</table>

* Calculated using Yates' correction.
eraly smaller than those reported by other authors (11, 15–18). The lack of correlation between liver and spleen size may also be due to this fact.

We employed only simple and commonplace methods of measurement. Determination of the midclavicular and midline longitudinal diameters of the liver is still the predominant clinical method of estimating its size. Since the liver may vary widely even in healthy subjects, the AP diameter and cross-sectional area were measured as well. Morphological variation due to respiration was eliminated, and measured diameters were correlated with the physical data to assess changes attributable to the patient's sex, age, weight, height, or surface area. The volume of the liver and spleen were not measured, because this is too difficult and time-consuming for routine clinical use (12, 14, 19–21); perhaps the computer may be helpful in future volume determinations. Measurements of the transverse and longitudinal diameters and cross-sectional area of the spleen along its longitudinal axis have been shown to be an accurate and reliable method of estimating its size (13). In the case of the pancreas, only the maximum AP diameter was measured on a transverse/oblique scan, since previous studies have shown no difference between transverse/oblique and longitudinal scans in estimating pancreatic size (16).

We found that organ size increases with height and body surface area. Our results are in accord with previous estimates of liver size by clinical methods, autopsy, and ultrasound (9, 11, 22–24). Some of these authors noted stronger correlations than we did because exact measurement of liver weight was made possible by autopsy, or because children with large variations in height were studied (24, 25). As in autopsy studies, it was found that men have larger gastrointestinal organs than women (23, 24). The liver and spleen decrease with age, while the pancreas and portal vein increase with age, corroborating previous studies of the spleen and pancreas (17, 23). Nevertheless, most diameters correlated poorly with the physical data. We feel that it is not necessary to routinely correct the measured diameters for physical data; moreover, calculations of the cross-sectional area of the liver and spleen may be omitted without loss of information. Longitudinal and transverse diameters are sufficient to estimate the size of the spleen, since both measurements correlate well with the diagonal diameter and cross-sectional area. Measurement of the midclavicular and midline longitudinal diameters suffices to estimate liver size in most cases; only in slender or heavy subjects need the AP diameter be measured, since the longitudinal diameter alone will give too high or too low a value, respectively. The portal vein is sufficiently represented by either diameter, since each correlates well with the other.

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References