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Liver volume in children measured by computed tomography

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Abstract Liver volume was measured by computed tomography in 54 children and young adults with no history of liver disease. Their ages ranged from 10 days to 22 years. The volume was calculated as follows: (1) the edges of the liver were traced on each scan image and the area was calculated by computer; (2) the areas were summed and multiplied by the scan interval in centimeters. The mean liver volume (± SD) was 178.2 ± 81.9 cm^3 in infants (less than 12 months old) and 1114.3 ± 192.9 cm^3 in adolescents (more than 16 years old). The mean liver volume in relation to body weight (± SD) was 34.1 ± 5.5 cm^3/kg in infants and 20.2 ± 3.1 cm^3/kg in adolescents. In general, liver volume increases rapidly in infants, gradually in schoolchildren, and not at all in adolescents. Volumetry might be clinically useful for evaluating the liver function in children and determining the graft size in liver transplantation.

Introduction

Liver volume reflects the functional capacity of the liver, and volumetry of the liver may be useful for clinical examination. Since Heymsfield et al. [1] first measured liver volume by computed tomography (CT), the liver volume in adults has been used to assess the progression of various liver diseases [2–4], for preoperative prediction of the risk in hepatectomy [5], and for measurement of liver regeneration after major hepatectomy [6, 7]. However, there are few reports regarding the liver volume in children. In this paper, we discuss the normal liver volume in children as measured by means of CT.

Patients and methods

Upper abdominal CT films of 54 children and adolescents aged 10 days to 22 years were selected. None had any history of liver disease, and CT had been performed for other clinical purpose. The patients were divided into six groups: group I, less than 12 months old ($n = 6$); group II, 13 ~ 24 months old ($n = 6$); group III, 25 months to 4 years old ($n = 7$); group IV, 5 ~ 9 years old ($n = 10$); group V, 10 ~ 15 years old ($n = 8$); group VI, more than 16 years old ($n = 17$).

Serial transverse scans of the upper abdomen were taken with a GE Hi-Speed Advantage CT unit (GE Medical Systems, Milwaukee, Wis.) at 0.7- to 1.0-cm intervals. The liver edges on each CT scan image were traced on tracing paper and the area was calculated using an image analyzer, IBAS-2 (Zeiss, Germany). The areas were then summed and multiplied by the scan interval in centimeters.

Results

The mean liver volume of each group is shown in Table 1. Liver volume tended to increase significantly with ageing until 15 years of age. However, no significant difference in volume was observed between groups V and VI. In contrast to the mean absolute liver volume, the liver volume relative to body weight tended to decrease with increasing age (Table 1). Liver volume showed a positive correlation with body weight, the correlation coefficient being 0.96 (Fig. 1), whereas a negative correlation was observed between the liver volume relative to body weight and body weight itself, with a

Table 1 Mean liver volume and liver volume relative to body weight in each group

Group	*n*	Mean age	Liver volume (cm^3)	Liver volume/body weight (cm^3/kg)
I	6	3.2 months	178.2 ± 81.9*	34.09 ± 5.5
II	6	1 year 5.7 months	281.0 ± 51.7**	28.56 ± 5.4
III	7	3 years 4.1 months	425.9 ± 94.9*	31.83 ± 5.9
IV	10	7 years	596.5 ± 218.3**	25.42 ± 4.5
V	8	13 years 9.4 months	1024.0 ± 210.3	23.77 ± 3.9
VI	17	18 years 10 months	1114.3 ± 192.9	20.17 ± 3.1

* $P < 0.05$; ** $P < 0.01$

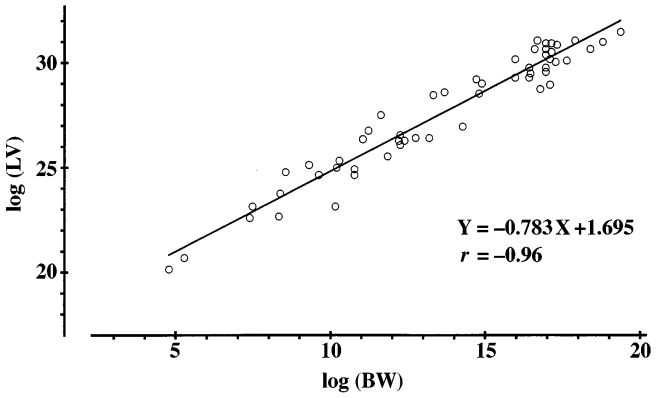

Fig. 1 Relationship between liver volume and body weight (*LV* liver volume; *BW* body weight)

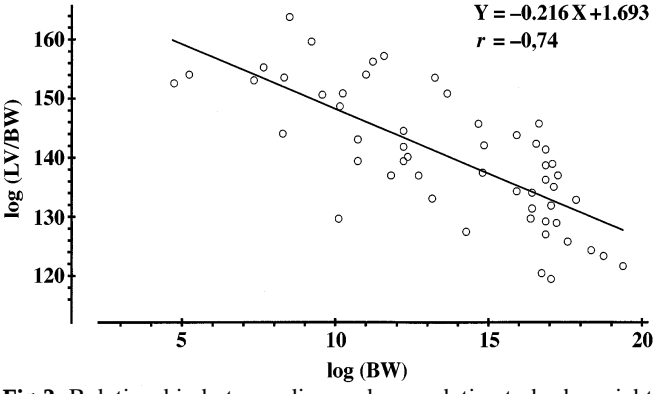

Fig. 2 Relationship between liver volume relative to body weight and body weight itself (*LV/BW* liver volume relative to body weight; *BW* body weight)

correlation coefficient of 0.74 (Fig. 2). Liver volume increased rapidly in infants and gradually in schoolchildren. The growth in liver volume was arrested in adolescence.

A chart of standard liver volume by age was produced from our data (Fig. 3). A power function was obtained as follows:

$y = 112.6 \times x^{0.401}$

where y is liver volume in cm^3 and x is age in months. The coefficient of interobserver variability was 3–7 %.

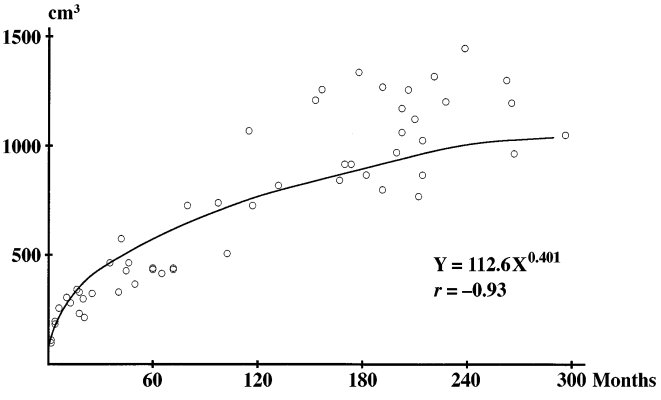

Fig. 3 A chart of liver volume by age

Discussion

Radionuclide scanning [8, 9] and ultrasound [10] are occasionally used for measurements of liver volume, and recently CT has come to be regarded as an accurate and reproducible method [11]. The GE Hi-Speed Advantage unit records one section per second, and respiratory movement greatly influences the measurement of liver volume. At the time of scanning, older children can be asked to hold their breath, but younger children or infants usually require anaesthetic drugs, such as ketamine or diazepam. When a scan interval of 0.7–1.0 cm is applied in a body, 10–15 slices can be obtained for the liver. Accordingly, calculated liver volumes in each case are generally accurate and reliable.

Liver size in children can be evaluated by palpation of the lower edge of the liver below the right costal margin or by the distance between the upper and lower borders of the liver as delimited by percussion and palpation [12]. However, there have been no reports regarding definitive measurement of liver volume in children. Measurement or prediction of liver volume in children may be beneficial in the assessment of various liver diseases or transplantation.

Liver volume has a relatively constant relationship to body weight or body surface area [13], and usually accounts for 2–2.7 % of the body weight in adults [11]. In infants and young children up to around 8 years old, however, liver volume is proportionately much greater

than in adults. During the 1st year of life, the liver accounts for approximately 5% of the body weight, but the proportion gradually decreases with age [14]. Our data showed a similar tendency for liver volume relative to body weight (Fig. 2). Liver size in infants generally increases quickly, probably because the liver is adapting to various functional demands of extrauterine life. During school age, body weight increases rapidly in comparison with liver volume, which increases gradually with age. In late adolescence, the liver reaches its adult volume.

Henderson et al. reported that the mean liver volume in 11 normal adults aged 20–30 years was 1493 cm^3 [11]. Although this is larger than in our group VI (1114 cm^3), the ratio of the liver volume to the body weight is nearly identical. Although physical stature differs among races, in children liver volume appears to be nearly the same by age. When physical differences are considered, the prediction of liver volume from body weight may be applicable to all ethnic groups:

$y = 50.12\ x^{0.78}$

where y is liver volume in cm^3 and x is body weight in kg.

In pediatric liver transplantation, therefore, the optimal liver size for a recipient can be predicted from his/her age or body weight. Moreover, the size of the left hepatic lobe or left lateral segment in donors can be estimated using CT scan at the time of living related liver transplantation [15, 16], although it differs widely among individuals and usually does not correlate with body weight.

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