

Changes of Hepatic Volume after Successful Kasai Operation

YASUHIRO WATANABE, TAKUJI TODANI, AKIRA TOKI,
TAKUO NODA, YASUHISA SATO, KAORU OGURA, MIKIKO
YOSHIKAWA, SAE YAMAMOTO and ZHONG-QIU WANG

*Department of Pediatric Surgery, Kagawa Medical
University, Kagawa 761-07*

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—— The number of long term survivors who have undergone Kasai operation for
biliary atresia is increasing, but some have a hepatic dysfunction likely to require
liver transplantation in the near future. Hepatic volume possibly reflects whole
liver function, and our objective was to assess the changes of hepatic volume after
Kasai operation. Ten patients were studied. Ages ranged from 3 to 27 years.
They underwent Kasai operation at ages ranging from 50 to 80 days. Liver areas
(cm²) on CT images were measured with an image processing and analysis program
(NIH Image 1.57). Hepatic volume (cm³) was calculated by summing up the areas
of each image and multiplying by slice thickness (cm). After Kasai operation, the
size of the liver increased to 1.7-1.9 times the standard volume, and then reduced
to normal size around 5 years of age. In the teens, hepatic volume decreased below
the standard volume. Segmental hypertrophy accompanying atrophy of other
hepatic segments was observed in 9 out of 10 patients; right lobe hypertrophy: 6,
medial segment: 2, and lateral segment: 1. Therefore, progressive hepatic atrophy
begins in the teens, but is compensated for by segmental hypertrophy. ———
biliary atresia; follow-up study; liver volumetry; computed tomography

The number of long term survivors who have undergone the Kasai operation for biliary atresia is increasing. More than half of them have favorable liver function, while some show a hepatic dysfunction likely to require liver transplantation in the near future. Hepatic volume can be easily measured with computed tomography (CT) images, and possibly reflects whole liver function. However, hepatic volume change has not been studied in patients who have undergone Kasai operation. We measured the whole and segmental hepatic volume in survivors to clarify the changes of hepatic volume after a successful Kasai

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Address for reprints: Yasuhiro Watanabe, M.D., Department of Pediatric Surgery,
Kagawa Medical University, 1750-1 Miki, Kitagun, Kagawa 761-07, Japan.

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operation.

MATERIALS AND METHODS

Ten patients were studied and are summarized in Table 1. Ages at the time of study ranged from 3 to 27 years (median: 15.0 years). They underwent Kasai operation at ages ranging from 50 to 80 days (average: 66.2 days). As an early postoperative complication, cholangitis developed in 7 out of 10 patients, and as late postoperative complications, esophageal varices developed in 5 and hypersplenism developed in 7 patients. Recent data from these patients indicate mild to moderate impairment of liver function. Although the oldest patient will possibly become a candidate for liver transplantation in the future, her current liver function is still compensated for at the lowest level.

Contrast CT films were taken 2 to 5 times in each patient, mainly for the assessment of splenomegaly or esophagogastric varices. Contrast enhanced CT images could identify major hepatic lobulation, that is the lateral segment, medial segment and right lobe. The images were converted to digital pictorial data with a flat head scanner (GT9000, Epson, Suwa), a personal computer (Power Macintosh 7100/66AV, Apple, USA) and photo-retouch software (Adobe PhotoShop 3.0J, Adobe Systems, Mountain View, CA, USA). An image processing and analysis program (NIH Image 1.57, National Institutes of Health, USA) was used for the measurement of liver areas (cm²) on the digital CT images. Hepatic volume (cm³) was calculated by summing up the area of each image and multiplying by slice thickness (cm).

Standard hepatic volume for age and body weight was calculated by our formulas, which were derived from the data of 54 normal Japanese children and young adults:

TABLE 1. *Patients*

Sex	Type	Age at operation (days)	Present age (years)	Recent chemical data		
				Total Bil. (mg/100 ml)	GOT (IU/liter)	GPT (IU/liter)
F	II-b1- β	78	27	2.6	144	155
F	III-a1- ν	64	25	0.6	17	9
M	III-cl- μ	80	22	1.4	27	27
F	III-cl- μ	50	18	2.2	45	54
F	Icyst-cl- β	69	17	1.6	46	39
F	III-b1- ν	66	11	1.6	108	118
F	III-b1- ν	64	9	0.6	69	54
M	II-a1- ν	74	5	1.5	35	14
F	III-b1- ν	53	5	0.5	26	19
M	III-b1- μ	64	3	0.7	72	44

$$hv = 112.6 m^{0.401}$$

hv: hepatic volume in cm^3 m: age in months

$$hv = 49.5 kg^{0.783}$$

hv: hepatic volume in cm^3 kg: body weight in kilo-grams

RESULTS

Whole hepatic volume

Up to 5 years of age, hepatic volume tended to exceed the standard volume, and increased with growth (Fig. 1). Hepatic volume remained near normal range in the teens, then tended to progressively decrease in the twenties.

Changes of hepatic volume were checked and compared with the standard volume for body weight (Fig. 2). The liver enlarged 1.7-1.9 times the standard volume in the first year of age, just after Kasai operation, and the volume tended to exceed the standard volume in the initial 5 years. In the teens and twenties, the volume tended to decrease below the standard volume. The ratio to the standard volume ranged from 63% to 90%.

Segmental volume

Segmental hypertrophy accompanied by atrophy of other hepatic segments was observed in 9 out of 10 patients (Fig. 3), the right lobe hypertrophy (Fig. 4a) in 6 patients, lateral segment (Fig. 4b) in 1, and medial segment (Fig. 4c) in 2. The segmental hypertrophy and atrophy gradually progressed for several years, but tended to conclude in the teens in the majority of patients. However, in the oldest patients, hypertrophy of the medial segment continued to progress from 16 to 27 years of age.

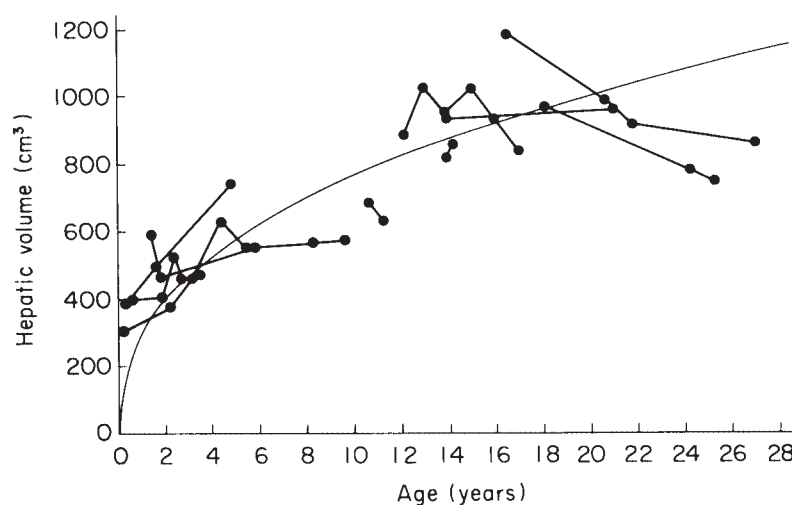


Fig. 1. Changes of the hepatic volume.

A curve indicates the standard volume for age. The hepatic volume exceeded the standard volume in the initial 5 years and decreased progressively in the twenties.

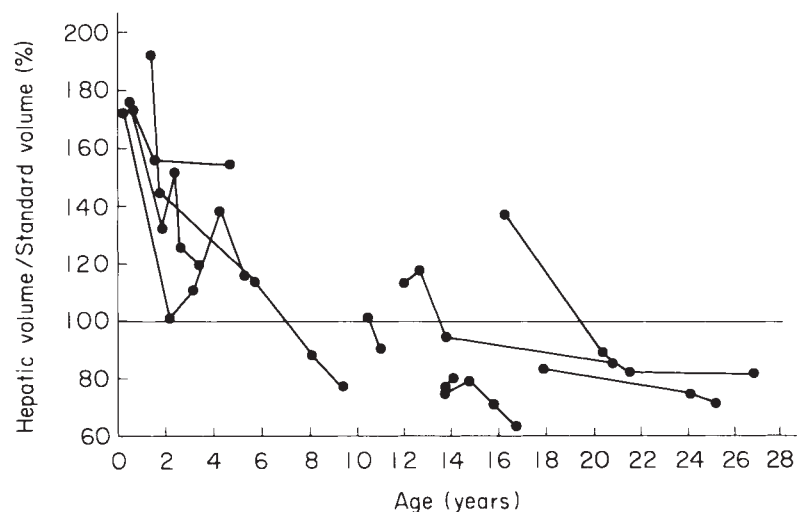


Fig. 2. Relative changes of the hepatic volume.

Measured hepatic volume was compared with the standard volume for the body weight. The liver enlarged 1.7-1.9 times the standard volume just after Kasai operation and remained large for about 5 years. The hepatic volume decreased to 63-90% of the standard volume in the teens and twenties.

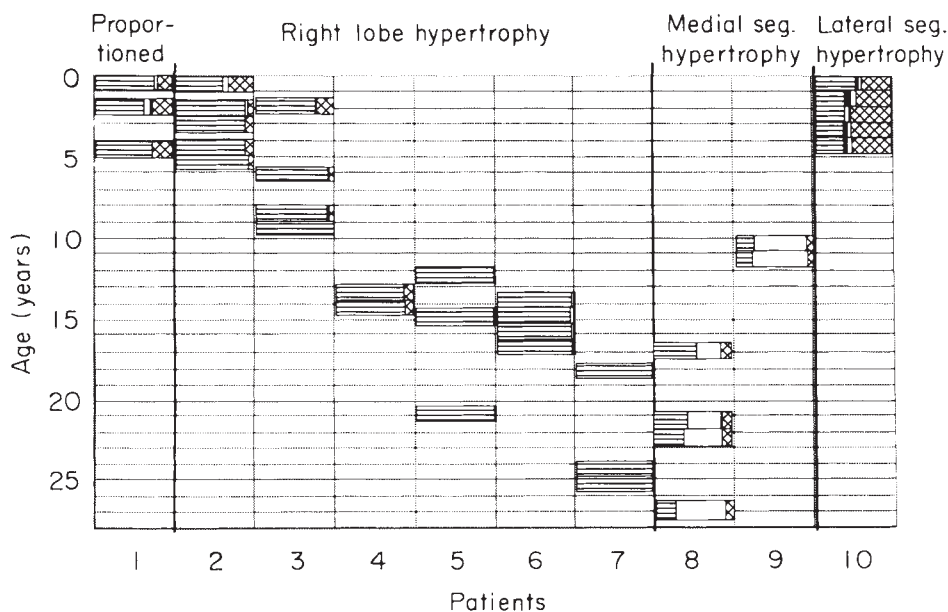


Fig. 3. Changes of the hepatic lobe/segment proportion.

Each column indicates the clinical course of each patient. Nine out of 10 patients showed segmental hypertrophy/atrophy; right lobe hypertrophy in 6 patients, medial segment hypertrophy in 2, and lateral segment hypertrophy in 1. The segmental hypertrophy/atrophy progressed mainly in initial 10 years with one exception.

DISCUSSION

Recently, liver transplantation has become a possible option for the long term survivors with hepatic dysfunction after Kasai operation for biliary atresia. Hepatic volumetry is essential before transplantation to assess the size matching

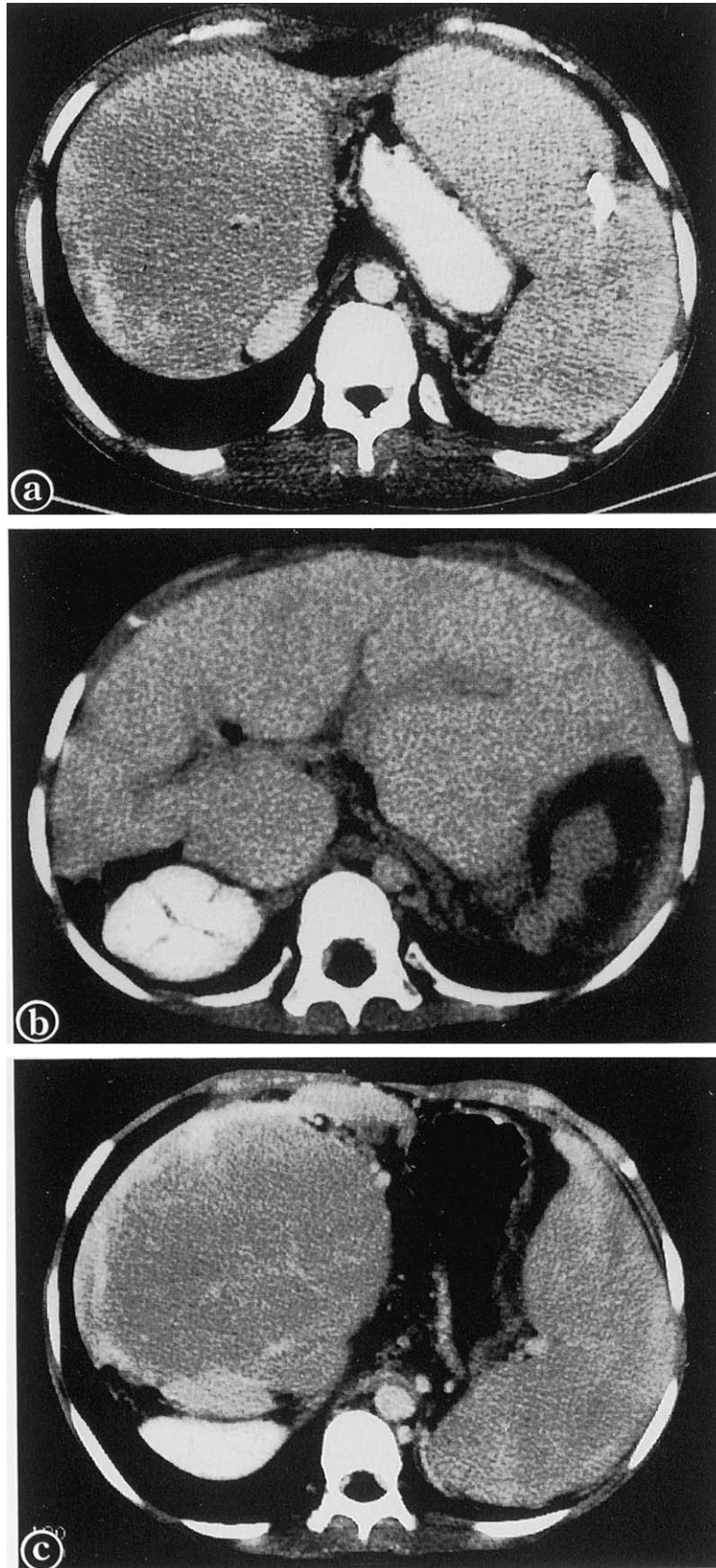


Fig. 4. Computed tomography images of segmental hypertrophy and atrophy. a: Right lobe hypertrophy with left lobe atrophy. b: Left lobe hypertrophy with right lobe atrophy. c: Medial segment hypertrophy with lateral segment and right lobe atrophy.

between donor and recipient. This is especially important in children (Higashiyama et al. 1993; Heffron et al. 1994). Total hepatic volume reflects the outcome of liver cirrhosis. The liver in patients between 20 and 55 months before death due to liver cirrhosis is small as compared with the liver in surviving patients with cirrhosis (Zoli et al. 1990). Measurements of change of hepatic volume in biliary atresia patients could provide useful information regarding total liver function and also predict the need for future liver transplantation. However, the exact indication of transplantation should be decided after several other assessments (Bein et al. 1995).

Measurement of the hepatic volume obtained by CT images (Breiman et al. 1982; Heymsfield et al. 1979) has the following advantages over other volumetry methods (Dittrich et al. 1983; Kavanagh et al. 1990; Chiu et al. 1994): (1) A retrospective measurement is possible from CT images taken earlier for other purposes; and (2) Measurement is easy, even if a CT machine does not have volumetry software, or an image file is lost from a backup tape. The volume can be measured with image films using a personal computer with a flat head scanner, photo-retouch software, and excellent free software for image processing and analysis.

The liver in patients who underwent Kasai operation enlarged 1.7–1.9 times the standard volume during the first year after surgery. Although good bile excretion was obtained by Kasai operation, hepatomegaly, probably due to cholestasis, tended to persist for several years.

Conversely, the liver in patients in their teens and twenties gradually decreased below the standard volume, and the ratio of standard volume for body weight ranged from 63% to 90%. These values may still be sufficient to maintain normal liver function, because all patients show compensated liver functions.

The decrease in liver volume is due to atrophy of the hepatic segment(s) resulting from poor bile drainage which is caused partially by the operative technique (Kimura et al. 1979; Toyosaka et al. 1994) but mainly by repeated cholangitis (Ohi et al. 1990; Chiba et al. 1992). Cholangitis usually occurs in the early postoperative period (Ecoffey et al. 1987; Gottrand et al. 1991) and repeated cholangitis causes segmental deterioration of small bile ducts resulting in segmental damage and atrophy of hepatic parenchyma. The atrophic liver is partially compensated for by hypertrophy of other intact lobes. In our series, segmental atrophy and hypertrophy tended to progress slowly in the first five years. However, our longest survivor still shows these phenomena at the age of 27. Progressive shrinkage of hepatic volume may indicate a liver transplantation in the future. Therefore, periodical volumetries are necessary in long term survivors of biliary atresia, even if liver functions are well compensated for at any particular time.

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