Transpl Int (1996) 9 [Suppl 1]: S 191–S 194

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How to estimate the size of the donor liver

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Abstract Of readily available methods to estimate the donor liver size, measurement of the body circumference at the xiphoid level (xiphoid measure) appeared to be the most accurate in the present prospective study of 60 donors and 57 recipients ($r = 0.64$, $P = 0.0001$). The estimated liver volume could be calculated using the equation: bloodless liver volume (l) = 1.44 × xiphoid measure (m). The difference between donor and recipient xiphoid measures was significantly higher in slowly recovering patients than in those recovering uneventfully (7 ± 7 cm vs. – 5 ± 8 cm, $P < 0.001$). The bloodless donor liver volume measured by water displacement averaged 1249 ± 230 ml and had increased by 3 weeks post-transplant by 64 ± 28 % as determined using computed tomography. The volume of the liver graft seemed to adapt to the recipient as it correlated positively with body weight ($r = 0.64$, $P < 0.01$) and negatively with the age of the recipient ($r = -0.42$, $P < 0.01$). The liver graft volume seemed to increase less markedly in patients with a slow recovery than in those with an uncomplicated recovery (37 % ± 15 % vs. 68 % ± 24 %, $P < 0.001$). We conclude that a simple measurement of the body circumference at the xiphoid level can be used to estimate the donor liver volume. A gross mismatch of this parameter between the donor and the recipient seems to increase the risk of graft dysfunction. We also found that the change in the liver graft volume is influenced by the recipient's age and body weight.

Key words Liver radiography · Liver transplantation · Liver anatomy

Introduction

Liver size disparity is a well-known major problem in pediatric liver transplantation surgery. Accurate size-matching between adult liver donors and recipients is also important because of increased complications after transplanting a disproportionate liver graft. Hepatic artery or portal vein thrombosis may be caused by compression of an oversized graft [8]. Graft dysfunction [9] and increased risk of rejection [11] have been seen when an undersized graft has been used. On the other hand, a larger liver than expected for the donor body size carries a risk of occult liver disease and especially a risk of advanced alcoholic liver disease [10, 12].

As the most reliable clinical method for assessing the liver size, computed tomography (CT) [3] is usually not available for the donor, so the liver volume is estimated by the donor body size. According to previous findings there is a relationship between the total liver volume and the body surface area (BSA) [5, 6, 13]. However, to calculate the BSA, body height (BH) and weight (BW) have to be estimated by the donor hospital personnel. In addition, the actual size of the organ is usually only approximately estimated by the donor surgeon.

Table 1 Donor and recipient characteristics

	Donors	Recipients
Number	60	57
Sex (male/female)	43/17	24/33
Age (years)	37 ± 11	49 ± 8
Body weight (kg)	70 ± 9	69 ± 13
Body height (cm)	175 ± 7	170 ± 7
Body surface area (m^2)	1.84 ± 0.15	1.78 ± 0.19
BMI (kg/m^2)	23 ± 2	25 ± 10
Xiphoid measure (cm)	86 ± 6	89 ± 9
Umbilical measure (cm)	78 ± 10	92 ± 12
Liver volume (ml)		
After harvest	1249 ± 230	
3 weeks posttransplant		2036 ± 342

We sought to determine a relationship between easily available body dimensions and the exactly measured liver volume. The other interest was to find factors that determine the change in the size of the liver graft after transplantation.

Materials and methods

This prospective study included 60 consecutive liver donors and 57 adult recipients between September 1992 and August 1995. Recipients receiving reduced liver transplants or imported liver grafts were excluded from the evaluation. Of the 57 transplantations, 44 were performed because of chronic liver disease and 13 because of acute fulminant liver failure. In three cases the procedure was a retransplantation. The recovery of the patients was evaluated against graft function and biliary complications at the end of the first postoperative month and at the end of the follow-up period.

The body circumference at the xiphoid and the umbilical levels of the donor and the recipient were precisely measured by the coordinators of the transplantation centre. The bloodless volume of the donor liver was first measured by water displacement on the back table after harvesting and the perfused liver 3 weeks after the transplantation by CT scanning. CT scans were obtained at 8-mm intervals on a Somatom CR CT. Using a track ball device, the perimeter of each slice of the liver was outlined, and the enclosed area was calculated electronically. The donor BW and BH were provided by the personnel of the donor hospital. BSA was determined from the table of DuBois and DuBois [2] and the body mass index (BMI) was calculated using the standard formula: BW/BH^2.

The data are presented as means ± SD, and the relationship between variables was tested using linear regression. The significance of the regressions was determined using the F-test. The significance of differences between means was determined using the Mann-Whitney U-test for unpaired populations.

Results

The characteristics of the liver donors and recipients and the volumetric data of the livers are given in Table 1. The bloodless liver volume averaged 1249 ± 230 ml. It correlated with both donor BW and BSA ($r = 0.48$, $P < 0.001$, Fig. 1) and donor BMI ($r = 0.31$, $P < 0.05$). However, a strong correlation was shown only with the xiphoid measure ($r = 0.64$, $P = 0.0001$, Fig. 2), and this was accentuated if the donor was either less than 30 or more than 39 years old ($r = 0.75$, $P = 0.0001$). The ratio between the liver volume (l) and the xiphoid measure (m) was quite constant at 1.44 ± 0.21. Thus the expected liver volume could be calculated from the equation: bloodless liver volume (l) = 1.44 × xiphoid measure (m).

The liver volume increased 3 weeks posttransplant to 2036 ± 342 ml and was correlated with the BW of the recipient ($r = 0.40$, $P < 0.01$), although no correlation was seen between these parameters at the time of transplan-

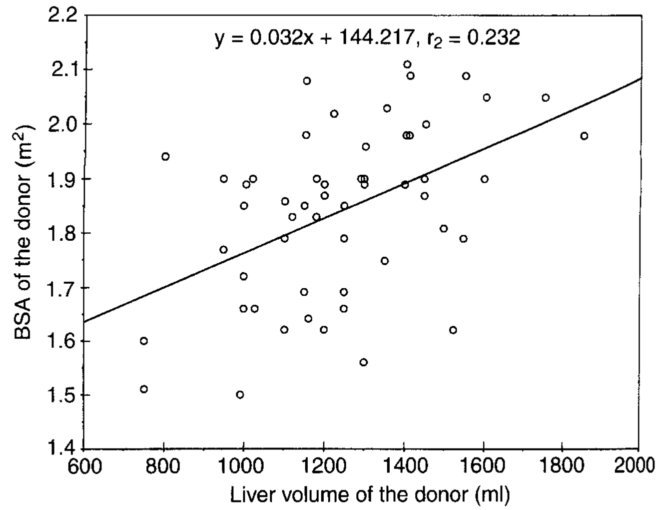

Fig. 1 Correlation between liver volume and the BSA of the donors ($r = 0.48$, $P < 0.001$)

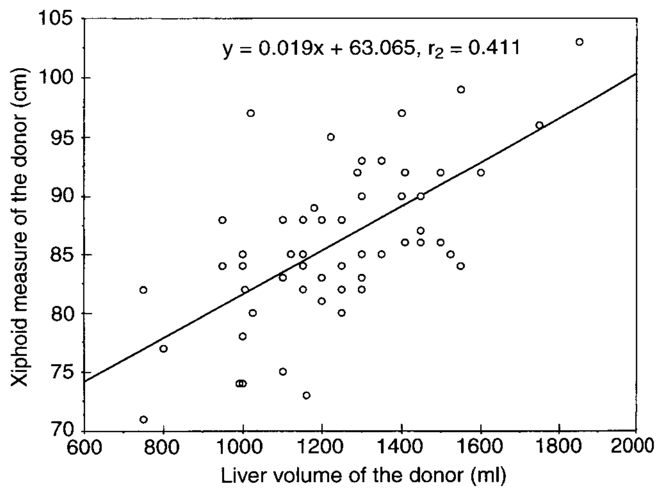

Fig. 2 Correlation between liver volume and the xiphoid measure of the donors ($r = 0.64$, $P = 0.0001$)

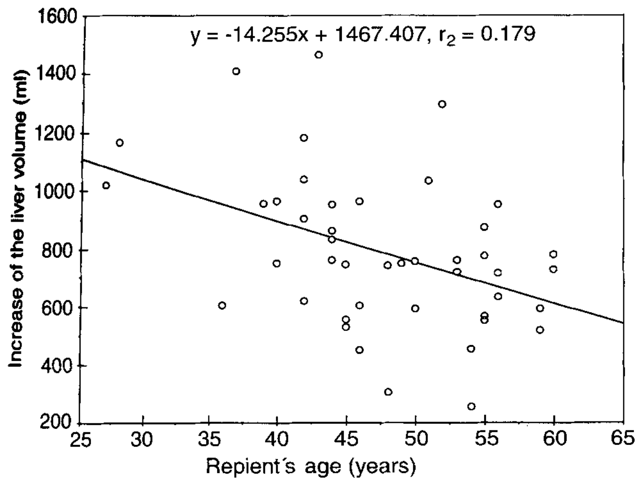

Fig. 3 Correlation between recipient's age and increase in liver volume during the 3 weeks following liver transplantation ($r = -0.42$, $P < 0.01$)

tation. The increase in liver graft volume (64 ± 28 %) correlated negatively with advancing age of the recipient ($r = -0.42$, $P < 0.01$, Fig. 3).

During the follow-up, nine patients had signs of graft dysfunction leading to slow recovery and infectious complications (Table 2). Biliary stricture led to the loss of one patient. The three other patients died for reasons unrelated to graft function, namely tumour metastases or reactivation of HCV infection. The differences between the xiphoid measures of the donor and recipient were significantly higher in these nine patients than in the patients with an uncomplicated recovery (7 ± 7 cm vs. - 5 ± 8 cm, $P < 0.001$, Table 3). In addition, patients with graft dysfunction showed a significantly smaller increase in liver graft volume 3 weeks posttransplant than recipients with an uneventful recovery (37 % ± 15 % vs. 68 % ± 24 %, $P < 0.001$).

Table 2 The outcome after the liver transplantation (follow-up 2 months to 2 years)

	1 month posttransplant	End of follow-up
Good liver function	51	52
Biliary stricture	1	
Bile leakage	1	
Liver dysfunction	9	
Prolonged cholestasis	5[a]	
Biliary stricture	2	
Bile leakage	2	
Hepatic arterial thrombosis	1[a]	
Chronic rejection		1
On the list for retransplant		1
Died		4
Biliary strictures		1
Tumour metastases		2
HCV reinfection		1

[a] Three patients retransplanted, bone patient had both prolonged cholestasis and bile leakage

Table 3 Body circumferences at the xiphoid level of donors and recipients in relation to the speed of recovery after transplantation

	Slow recovery ($n = 9$) (cm)	'Normal' recovery ($n = 49$) (cm)
Donor	91 ± 4	85 ± 6*
Recipient	84 ± 8	90 ± 9
Donor – recipient	7 ± 6	- 5 ± 8

* $P < 0.05$, ** $P < 0.001$

Discussion

Our finding of only a comparatively weak correlation between the liver volume and the donor BW or BSA differs from previous studies, in which the association shown in healthy persons was highly significant [5, 6, 13]. Because in the present study the liver volume was accurately measured by water displacement the source of error seems to be the crude estimation of the donor BW and BH by the personnel at the donor hospital. Thus the estimation of the donor liver size based on these measurements may lead to most inconvenient surprises, particularly as one of the main criteria in the selection of the donor is the expected liver size. Our finding of a strong correlation between a simple measurement of the body circumference at the xiphoid level and the liver volume may be used as a guide for estimation of the liver graft volume. The present results indicate the equation for the estimation of the volume to be: bloodless liver volume (l) = 1.44 × xiphoid measure (m).

The only body dimension of the donor or the recipient predictive of graft dysfunction was also the difference in their xiphoid measures. The difference in favour of the donor was significantly higher in slowly recovering patients than in recipients with an uneventful recovery. In addition, slowly recovering patients seemed to gain significantly less hepatic volume during the first 3 posttransplant weeks. This fact is in agreement with previous findings of a correlation between the hepatic mass and the liver function both in partially hepatectomized patients [15] and patients receiving an undersized liver graft [1].

The significant increase in the liver size after transplantation did not correlate with any body dimension, but was negatively associated with the age of the recipient. This fact may indicate diminishing metabolic demands which have previously been found in elderly patients [7] and is in congruence with a finding of a negative correlation between recipient age and liver volume

[14]. In addition, the host body size seemed to determine, at least in part, the liver graft size because the BW of the recipient correlated with the liver graft volume 3 weeks posttransplant, whereas no correlation between these parameters was seen at the time of transplantation. This result confirms an earlier finding made using a canine model, in which the change in the liver graft volume was determined by the recipient's size [4].

We conclude that measuring the body circumference at the xiphoid level is the simplest and most accurate parameter for the estimation of the donor liver volume. A gross mismatch of this parameter between the donor and the recipient seems to increase the risk of graft dysfunction. We found also that a well-functioning liver graft seems to gain markedly in weight during the first few posttransplant weeks, and the change in the graft volume is influenced by the recipient's age and body size.

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