Standard Liver Volume in the Caucasian Population

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Living donor and split-liver transplantation techniques require the calculation of a standard liver volume (SLV) as a reference point for the minimal volume necessary for the recipient. We therefore examined whether a widely used formula developed on the basis of a Japanese population sample was also adequate for the Caucasian population. The documentation of volumes of 1332 autopsy livers from a German Forensic Medicine Department was used to create a formula for an SLV for the Caucasian population. The Japanese formula estimated the Caucasian liver volume to be on average 322.6 ± 335.8 g (SD) less than they actually were. The following new formula for the calculation of SLV for Caucasians was established by linear regression analysis:

Liver volume (mL)

$$= 1072.8 * \text{body surface area } (m^2) - 345.7$$

Very extensive liver resections have become possible, leaving only a small portion of liver in the patients. This remnant liver gradually regenerates back to the standard liver volume (SLV), but more slowly than the recipient's graft.[1]

Living donor and split-liver transplantation were established for the treatment of end-stage liver disease, offering a chance to reduce the organ shortage. With these techniques, parts of the liver of a living or cadaveric donor are transplanted into pediatric recipients. In both cases, research continues to enable the application of these techniques for adult recipients. In this case, the problem is a graft substantially smaller than the normal liver size of the recipient.

To compare the results of these small-for-size livers and estimate the safety of planned procedures, it is necessary to have a calculable SLV.[2] Urata et al[3] calculated the SLV from body surface area (BSA) in the Japanese population. They established a formula by means of a regression analysis of liver volume (LV) measurements using the computed tomography (CT) scans of 96 children and adult patients without liver abnormalities. The correctness of the CT-based volume measurements was checked by plotting in vivo liver size measurements of 19 pediatric living donor transplant recipients against the actual graft weights.

The Japanese formula has been widely used by American, as well as European, groups working in the field of small-for-size transplantation. We wondered if the formula developed by Urata et al[3] could be applied to the Caucasian population.

Material and Methods

A retrospective analysis of the autopsy register at the Institute for Forensic Medicine in Hamburg, Germany, generated data on liver weight (LW) and individual BSA, including the results of 14,600 postmortem examinations since 1983. The number of cases was narrowed down to 1332 subjects (age, 50.6 ± 18.9 years; body weight [BW], 71.1 ± 11.9 kg; body length [BL], 170.7 ± 10.1 cm; LW, 1613.6 ± 389.9 g) by excluding all types of liver abnormalities; BW less than 15 kg and greater than ±25% of the range of normal weight (= BL [centimeters] – 100) were also excluded.

In a prospective study, 33 healthy livers were prepared in exactly the same way; volumes were measured according to the principle of Archimedes, resulting in an average tissue density of 1.08 kg/L (mean LW, 1724 g; mean LV, 1862 mL). The validation of the routine weighing procedure in postmortem examinations resulted in an average proportion of 2.3% of the routine LW for gallbladder and attached ligaments in our records (mean difference between LW with and without attached tissue, 41.3 g). This proportion was subtracted from the recorded weights to control systematic failures.

BSA was calculated as described by Du Bois and Du Bois[4]:

$$\text{BSA } (m^2) = \text{BW } (kg)^{0.425} \times \text{BL } (cm)^{0.725} \times 0.007184,$$

also applied by Urata et al.[3]

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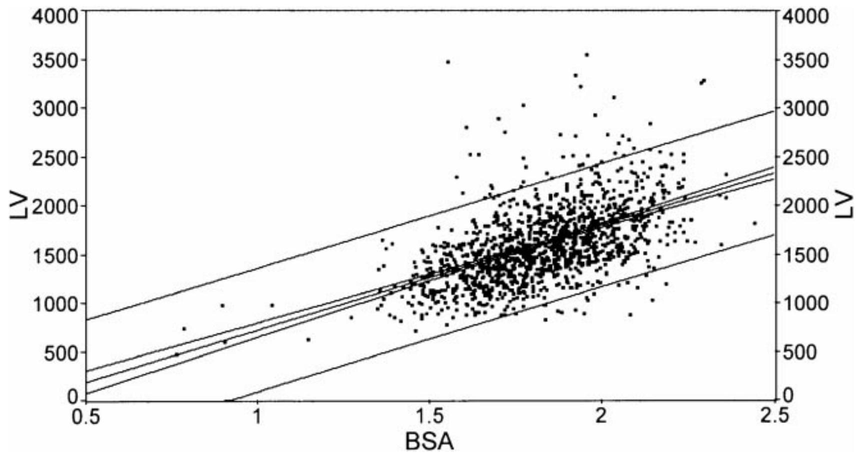

Figure 1. Correlation between liver volume (LV) and body surface area (BSA).

Table 1. Difference Between Measured and Estimated LV

Formula	Mean	SD	Median	SE
Urata et al[3]	322.6	335.8	285.1	328.2
New established	1.7	328.0	−27.2	328.2

The correlation between BSA and LV was determined by a linear formula for SLV by means of a statistical Fit-Programme (TableCurve 2D; Jandel Scientific, Erkrad, Germany).

Results

Figure 1 shows the correlation between LV and BSA (confidence and prediction interval at 95%).

The correlation turned out to be less convincing than that described by Urata et al[3] ($r^2 = 0.30$). We established a new formula for a Caucasian adult LV. The Japanese formula estimated the Caucasian LV to be on average 322.6 ± 335.8 g (SD) less than they actually were. There was a similar SE of estimation according to both formulas. The significantly more appropriate new established SLV for the Caucasian population is listed in Table 1.

The difference in the median values among the two groups is greater than expected; there is a statistically significant difference ($P < .001$, Mann-Whitney rank-sum test).

Discussion

The application of the formula of Urata et al[3] results in an underestimation of SLV in Caucasian patients. This is dangerous because the quantity of liver tissue needed to survive a liver resection of a small-for-size liver transplantation may be insuffi-

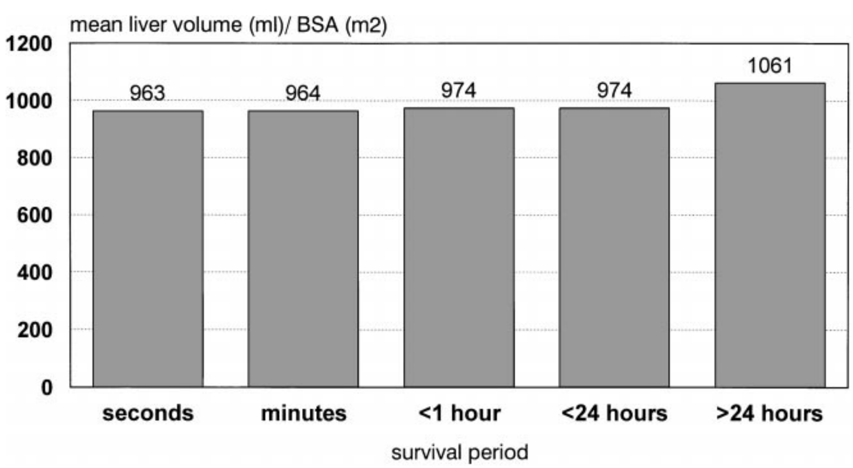

Figure 2. Mean liver volume and survival period. (BSA, body surface area.)

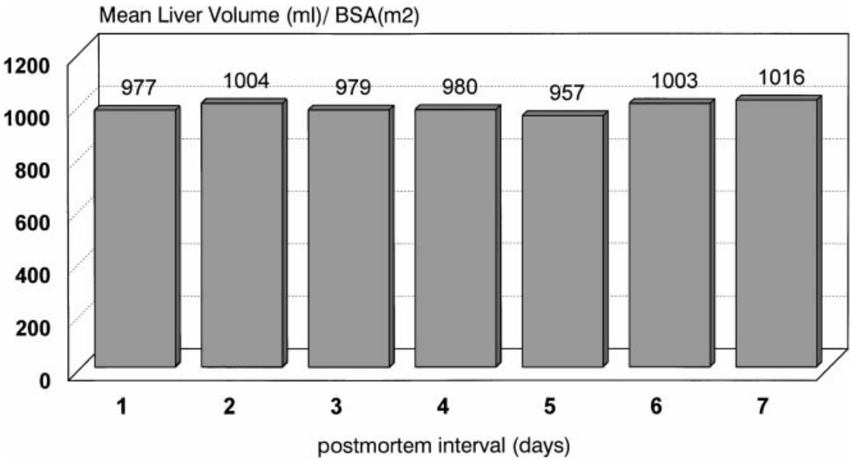

Figure 3. Mean liver volume and postmortem period. (BSA, body surface area.)

cient. Conversely, the transplanted liver graft may be too small for the metabolic demands of the recipient. Urata et al[3] were able to prove a good correlation between explant liver and CT-measured in vivo LVs.

Nevertheless, the postmortem LVs were controlled for possible confounders that might raise general questions about the method of calculation. This was the reason why the effect of terminal shock mechanisms on LV was closely checked. Autopsy signs of intensive shock mechanisms had been one of the exclusion criteria for the recruitment of cases. For the included cases, it was proved that the LV of the deceased without any survival period (e.g., death by decapitation, hanging, falling) did not significantly differ from those after a 24-hour survival period (Fig. 2). An increased LV was seen in the group with the longest survival (up to 30 days). These cases were only 12% of the total number.

Furthermore, possible postmortem changes in volume must be considered. A comparison of different intervals between the time of death and time of autopsy showed no systematic effect on LV (Fig. 3). In conclusion, reasons concerning methods are far from a sufficient explanation for the documented difference in SLV between Asians and Caucasians.

Our results emphasize that SLV in the Caucasian population can be calculated more precisely according to a population-based standard. However, because of the generally low correlation between BSA and LV, further investigations should focus on additional morphometric standards that may help to improve the prediction of the minimal need in liver transplant recipients.

References

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