Determining standard liver volume: assessment of existing formulae in Indian population

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Background: With the increasing numbers of living-related donor liver transplantation, accurate means of calculating standard liver volume (SLV) based on patient body indices becomes important. Three formulae reported in literature for this purpose have been derived from studies on Western and Japanese populations. Aim: To assess the existing formulae for calculation of SLV in Indian population. Method: Total liver volume (TLV) of 238 patients was measured using axial helical CT images obtained for conditions unrelated to the hepatobiliary system. Body surface area (BSA) was calculated from height and weight. Measurements obtained using CT were compared with the SLV calculated based on the previously reported formulae. Results: Though there was significant difference (p<0.001) between the TLV obtained by CT and the SLV calculated using the three formulae, they also showed good agreement. On an average the formula derived from the Japanese population underestimated the SLV by 63 (202) cc (p<0.001). Regression models for SLV (SLV = 243 + [186 x BSA] + [11.4 x Weight], SLV = 375.23 + [14.24 x body weight], SLV = -204.092 + [874.461 x BSA]) were derived from the data obtained from our population. Age and gender had no effect on the SLV. Conclusions: Formulae derived from Japanese population for calculation of SLV is not suitable for the Indian population. The newly described formulae may prove useful in the Indian population. [Indian J Gastroenterol 2007;26:22-25]
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Intra-observer variability was determined by outlining the body surface at three contiguous sections from the level of L1 upper end plate and calculating the volume; this was repeated five times on the same day. The data obtained were used to assess the reproducibility of manual lining procedure.\

Inter-observer variability was determined by two observers (CA and EA) independently drawing outlines of the liver of 5 subjects randomly chosen from the sample. Differences between the volumes measured by the two observers and intra-class correlation coefficients (ICC) were reported as the inter-observer variability.

Patient age (years), height (cm) and weight (Kg) were recorded. BSA was calculated using Mosteller’s formula. SLV was calculated using the formulae based on BSA and body weight.

1. Formulae derived from Western population-based study:

   \[
   SLV = -794.41 + 1267.28 \times BSA \text{ in square meter}
   \]

   \[
   SLV = 191.80 + 18.51 \times \text{weight in Kg}
   \]

2. Formula derived from Japanese population-based study:

   \[
   SLV = 2.4 + 706.2 \times BSA \text{ in square meter}
   \]

Statistical analysis

Data analysis was performed using SSPS 11.5. ICC was calculated to assess the agreement between the SLV and TLV. Wilcoxon signed rank test was performed to determine the significance of difference between SLV calculated using the formulae and total liver volume (TLV) measured with CT. Univariate and multivariate linear regression analysis was used to predict SLV using BSA, body weight, age and gender.

Results

A total of 238 consecutive patients (150 male) were included. Their median age was 46.5 years (range 10-70); weight was 57.5 Kg (22.7-99.7); height was 162 cm (111-186); BSA was 1.60 square meters (0.88-2.25); TLV was 1186 cc (639.3-2359.4). The intra-observer variability for the CT volume measurement was 0.3%; the difference between the observation and the mean ranged from 0.12 cc to 4.7 cc. The inter-observer variability ranged between 1.3 cc and 26 cc, with an average of 0.55%. There was a strong inter-observer agreement, with ICC of 0.99.

Fig. 1 shows the correlation between the TLV as measured by CT and the body surface area. On comparing the SLV obtained by the three formulae with TLV measured by CT, there was significant difference (p<0.001), yet there was close agreement (Table 1). Fig. 2 compares the agree-
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The determination of the SLV estimated by the various formulae with the TLV measured by CT. On an average, the formula derived from the Western population based on BSA overestimated SLV by 90 (67.2) cc and the one based on weight overestimated the SLV by 93 (69) cc, whereas the formula derived from the Japanese population underestimated SLV by 63 (202) cc, which were all significantly different from the TLV measured by CT (p<0.001). These values were obtained by calculating the difference of means between the TLV and SLV using each of the three formulae.

Regression models were obtained from our population based on body indices, as

\[ SLV = 243 \times (186 \times BSA) + (11.4 \times weight), \]
with ICC of 0.6017, p<0.001;

\[ SLV = 375.23 + (14.24 \times body weight), \]
with ICC of 0.60, p<0.001;

\[ SLV = -204.092 + (874.461 \times BSA), \]
with ICC of 0.57, p<0.001 (Table 2).

There was insignificant effect of age (r² = 0.012, p=0.09) and gender (r² = 0.014, p=0.07) on SLV; hence these parameters were excluded from multivariate analysis. Fig. 3 and 4 compare the regression line obtained with that of the Japanese and Western populations. Regression lines obtained from the Western and Japanese populations clearly diverge in both extremes of BSA, with our regression line falling in between.

**Discussion**

We found that, for a given body surface area, Western formulae overestimate and the Japanese formula underestimates SLV in Indian patients. This is because the average Indian BSA (1.6 m²) lies between a higher Western BSA (1.82 m²) and a lower Japanese BSA (below 1.5 m²). The low mean BSA of the Japanese population could be attributed to the large number of children included in their study. Our cohort included patients of a wider age range.

Previous studies have shown that CT volume measurement of the liver correlated well with actual liver volume, the reported accuracy being 95%. Errors in CT volumetric measurements are due to partial volume effect, respiratory phase variation, poor contrast between tissues, and inter-observer variation. We took steps to reduce these errors by scanning with a uniform section thickness of 5 mm and administering intravenous contrast. The small intra-observer and inter-observer variations prove that the manual outlining procedure is reliable and reproducible.

Accurate estimation of liver volume is essential prior to living-related liver transplant since small-for-size grafts are known to cause complications and compromise outcome. Graft volume-to-SLV ratio of 30% or less and graft-to-recipient body weight ratio of less Table 2: Univariate and multivariate regression models for TLV

<table>
<thead>
<tr>
<th>Formula</th>
<th>Univariate</th>
<th>Multivariate</th>
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<tbody>
<tr>
<td>Age 1113.6 + (1.9 x Age)</td>
<td>0.012 = 0.09</td>
<td>0.420 Wt 0.008 0.6017 &lt;0.001</td>
</tr>
<tr>
<td>Gender 1288.5 + (-63.8 x Gender)</td>
<td>0.014 = 0.07</td>
<td>BSA 0.488</td>
</tr>
<tr>
<td>BSA -204.1 + (874.5 x BSA)</td>
<td>0.412 &lt; 0.001 0.57 &lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Weight 375.2 + (14.2 x Weight)</td>
<td>0.428 &lt; 0.001 0.6006 &lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Multivariate 243+ (186 x BSA) + (11.4 x Weight)</td>
<td>0.420 Wt 0.008 0.6017 &lt;0.001</td>
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</tr>
</tbody>
</table>
than 0.8 are associated with increased morbidity, and impaired graft and patient survival post-transplant. Our study indicates that, on an average, the formula derived from the Japanese population underestimates SLV by 63 (202) cc leading to compromised graft volume. On the other hand, the Western formulae based on BSA and weight overestimate SLV by 90 (67.2) cc and 93 (69) cc, respectively, in the Indian transplant recipient, which might compromise donor safety. Though the ICC of the Western formulae is slightly more than our regression models, they show significant difference. For these reasons we feel it is important to develop specific formulae for SLV estimation in the Indian population.

Using univariate and multivariate regression analysis we derived three formulae for calculation of SLV in Indian patients, based on body weight and BSA. Our study confirms that age has a small negative correlation with TLV and, as in the previous analysis we derived three formulae for calculation of SLV in Indian patients, based on body weight and BSA. Our study confirms that age has a small negative correlation with TLV and, as in the previous studies, does not influence the SLV calculation. Our study shows that gender does not influence the SLV calculation significantly, which is against that shown by Chan et al.

In summary, among the three formulae available to calculate standard liver volume, the formula based on body surface area derived from the Western population most closely estimates liver volumes for Indian population, with a slight overestimation. It is not advisable to use the formula derived from the Japanese population which calculates SLV in Indian patients especially with extremes of BSA. Our formulae are more accurate for calculating SLV. Comparison of TLV obtained by CT volume measurement needs correlation with Indian autopsy studies.

References