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CORRESPONDENCE

Lean-scaled weight can be used to estimate blood volume for obese patients

John H. P. Friesen, MD

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To the Editor,

Preoperative assessment of a patient's blood volume is useful in order to guide the transfusion of red blood cells and the administration of crystalloids, colloids, coagulation factors, and platelets. The blood volume increases non-linearly with increasing body mass[1] and will be overestimated in obese patients unless a correction factor is applied to the total body weight or to the blood volume index.

Lemmens *et al.*[1] have derived an empirical formula to correct the estimated blood volume in morbidly obese patients. The following example illustrates that, for all practical clinical purposes, the lean-scaled weight can be used to perform the same calculation as the Lemmens equation. The lean-scaled weight is a weight scalar that is useful for estimating doses of a number of commonly used drugs.[2] The practical advantage of this equivalence is that it is not necessary to use two separate functions to estimate blood volume and drug doses.

The Lemmens blood volume formula is an empirically derived hyperbolic function that incorporates the square root (of 22/body mass index [BMI]) as a correction factor. The function was developed using published data from four studies that measured blood volume in obese and morbidly obese patients.[1] The Lemmens calculation can be written as Equation 1 below:

$$\textit{Equation}1: \text{blood volume} = \text{body weight} \times \text{BVF} \times \text{BV}_{\text{Index}}$$

where BVF is the Lemmens blood volume correction factor, and the BV_{Index} is the uncorrected (non-obese) blood volume index expressed as $\text{mL}\cdot\text{kg}^{-1}$.

The lean-scaled weight[2] is a weight scalar that is proportional to the lean body weight and normalized to equal the total body weight at a BMI of 22. It is a non-linear function of both weight and height and therefore cannot be expressed as a function of weight alone. Nevertheless, it can be factored into the total body weight times a function of the BMI. This function can be used as a correction factor in Equation 2:

$$\textit{Equation}2: \text{lean-scaled weight} = \text{body weight} \times \text{LSF}$$

where LSF is the lean-scaled correction factor.

As shown in the Figure, the Lemmens blood volume correction factor and the lean-scaled correction factor are both functions of the BMI. (The LSFs for males and females are slightly different. The equations are provided in the Figure legend.) It is visually apparent that the functions graphed in the Figure - BVF and LSF - are so similar as to be clinically interchangeable. Using this equivalence, we can substitute Equation 2 into Equation 1 to give Equation 3:

$$\textit{Equation}3: \text{blood volume} \approx \text{lean-scaled weight} \times \text{BV}_{\text{Index}}$$

This means that using the lean-scaled weight to calculate the blood volume gives, for all practical purposes, the same result as using the Lemmens correction factor. For example: a male weighing 150 kg with a BMI of 50 will have a Lemmens correction factor of 66.33%. Using this factor and a blood volume index of 70 $\text{mL}\cdot\text{kg}^{-1}$ in Equation 1, his estimated blood volume is calculated to be 6,965 mL. He has a lean-scaled correction factor of 65.4%, a lean-scaled

The author has written a (non-commercial) mobile device application (www.bigsleep.altervista.org) that calculates the lean-scaled weight, blood volumes, and other obesity-related parameters.

J. H. P. Friesen, MD (✉)
University of Manitoba, Winnipeg, MB, Canada
e-mail: jfriesn@cc.umanitoba.ca

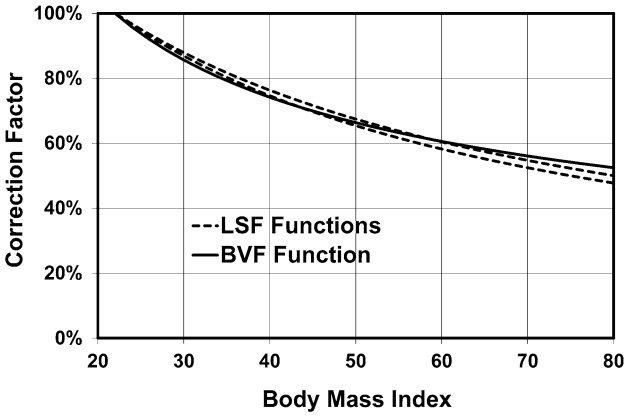

Figure The factors used in the management of obese patients for correcting the blood volume and to calculate the lean-scaled weight are plotted against the body mass index (BMI). Lean-scaled factor[2] (LSF), female = 14,148/(8,780 + 244 × BMI). Lean-scaled factor (LSF), male = 11,432/(6,680 + 216 × BMI). Blood volume factor[1] (BVF) = square root (22/BMI)

weight of 98.1 kg from Equation 2, and (using the same blood volume index) a blood volume of 6,867 mL from Equation 3. The difference between an estimated blood volume of 6,965 mL and 6,867 mL is not clinically meaningful.

Safe and effective doses of several drugs used commonly in anesthesia are proportional to the lean body weight, including fentanyl, sufentanil, remifentanil, and induction doses of propofol.[3] The appropriate weight scalar for these drugs is the lean-scaled weight.[2] Here we have shown that the blood volume corrected for obesity can be calculated using the product of the lean-scaled weight and the blood volume index. This is exactly equivalent to first correcting the blood volume index and then multiplying by the total body weight. Commonly used values for the blood volume index (International Committee for Standardization in Haematology)[4] are 70 $mL \cdot kg^{-1}$ for males and 65 $mL \cdot kg^{-1}$ for females, based on a red cell volume of 30 $mL \cdot kg^{-1}$ (95% confidence interval [CI] 25 to 35) for males, a red cell volume of 25 $mL \cdot kg^{-1}$ (95% CI 20 to 30) for females, and a plasma volume of about 40 $mL \cdot kg^{-1}$ for both males and females. Choosing a value for the blood volume index for patients of a different age, blood pressure, and aerobic conditioning is beyond the scope of this letter – a discussion can be found in Lemmens *et al.*[1] cited above. Hydration and nutritional status must also be considered.

Boer[5] has shown that blood volume normalizes to the lean body weight in non-obese patients. Since the lean-scaled weight is proportional to the lean body weight, the above discussion suggests the testable hypothesis that this relationship between blood volume and lean body weight extends into the morbidly obese range.

It is convenient that the same weight scalar, i.e., the lean-scaled weight, can be used to estimate not only the appropriate doses of commonly used drugs but also the patient's blood volume. A mobile device application for smart phones and tablets is available to calculate lean-scaled weight, blood volume, and other formulas used in the anesthetic management of obese patients,[6] but it frequently happens that no such device is immediately available. A calculator is not needed to make a good estimate of the lean-scaled weight: it is 100% of total body weight for non-obese patients, about 75% for a BMI of 40, 60% for a BMI of 60, and 50% for a BMI of 80.

Conflicts of interest None declared.

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