Correspondence

NOMOGRAMS

Nomograms for determining body surface area (BSA) and estimated blood volume (EBV) were recently published in the *Journal* (J Extra-Corpor Technol. 1994;26(3):155-156). I would like to submit further discussion to the readership so that these tables are properly referenced and clearly understood.

The work of DuBois (1) stands today as the most utilized formula for determining BSA in patients undergoing cardiopulmonary bypass (CPB). Of no less importance, however, is the work of Edith Boyd, whose research focused primarily on children. During her extensive review of the literature, Boyd found over twenty-five different formulas in use for calculating BSA. In 1935, she published a text entitled *The Growth of the Surface Area of the Human Body* (2). This manual remains the largest and most complete historical analysis of BSA determination. The DuBois formula is thought to be inaccurate below 0.6 m^2 (3). Boyd's original study of children makes her equation particularly appropriate in the pediatric and neonatal population.

An exact, reliable means of determining patient blood volume still eludes us. Allen's work (4) is most notable to perfusionists because his formulas are used by Medtronic Hemotec's protamine titration instrument. While weight referenced constants, such as 65 ml/kg, are convenient to use, some investigators have studied additional factors such as height, gender, and adiposity to further lend accuracy to their equations (5). Nadler (6) studied hospital workers and prison inmates, and then modified the existing formulas of Allen and Baker using a linear regression model.

The hematocrit dilution method for prediction of EBV involves measuring the change in hematocrit following initiation of CPB (hemodilution) with a known volume (pump prime). Acsell, Riley, and Ecklund compared this method to eight morphology based formulas in 67 adult patients using the Student's t-test and regression analysis (7). They concluded that none of the eight equations (independent variables) were adequate predictors of EBV as determined by the hematocrit dilution method (dependent variable). Though simple, the hematocrit dilution method for determining EBV is impractical, at least in my institution, for two reasons: 1) prediction of post-dilution hematocrit, and thus the potential need for transfusion, requires knowing the EBV *before* initiation of CPB, and 2) patient EBV is frequently used to calculate initial heparin dosing.

The formula used in the EBV nomogram is a modification of Allen's equations. Specifically, the constants used for height and weight fall between those originally published by Allen for adult men and women. Fletcher (8) used this same modified formula in his model for estimating post-dilution hematocrit. In proportion to height and weight, Allen states that "...the blood volume is similar in men, boys and also young girls. Comparatively less blood occurs in adult women except during pregnancy, when there is present 1 L more blood than in men of similar sizes." Keep in mind, Allen's studies were conducted on healthy Chinese subjects.

Computerized spreadsheet software makes comparison of this modified formula to Allen's original male and female formulas quick and easy. For an average sized male, the modified formula underestimates the blood volume by 400 ml as compared to the original male equation. For an average sized female, the modified formula overestimates by this same amount. In terms of calculating post-dilution hematocrit or initial heparin dose however, this difference is insignificant.

One need only to look at the accompanying references to see that studies in body surface area and blood volume estimation have ceased for many years. Further research more applicable to patients with cardiovascular disease is welcomed. In the meantime, our use of various constants, nomograms, equations, and "fudge factors" should continue, realizing that the results are at best ballpark estimations.

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