Body Mass Index and Blood-Alcohol Calculations*

To the Editor:

Alcohol tops the list of psychoactive substances encountered in police investigations of crimes such as mugging, murder, sexual assault, and especially impaired driving (1). Accordingly, the need often arises to interpret a person’s blood-alcohol concentration (BAC) in relation to the degree of alcohol influence and the amount of alcohol consumed (2). Such calculations are usually done with the aid of so-called “know your limit” or blood-alcohol charts, and more recently, several computer programs have been developed for this purpose (3).

Two pharmacokinetic parameters of ethanol are important in forensic science and legal medicine when expert witnesses and others engage in making various blood-alcohol calculations, such as retrograde extrapolation or relating a person’s BAC to the number of drinks consumed (4). These parameters are the disappearance rate of ethanol from the bloodstream and the volume of distribution of alcohol (V_d). This latter parameter expresses the ratio between the concentration of alcohol in the body as a whole and the prevailing BAC and is an important concept introduced in the 1930s. The lean body mass (LBM) of the average person has changed considerably since the distribution volume of ethanol was first determined.

Ethanol distributes into the total body water (TBW) compartment without binding to plasma proteins and solubility in fat and bone is negligible (1). The V_d for ethanol depends on the person’s age, gender, and body composition, especially the proportions of fat to LBM (4,7). Indeed, total body water (TBW) can be determined fairly reliably using ethanol as a biomarker, and the results of such experiments show good agreement with values determined by isotope dilution (3H_2O and 2H_2O) methods (8).

Many equations commonly used for blood-alcohol calculations assume population average values for V_d such as 0.7 L/kg for men and 0.6 L/kg for women (2,3). Sex-related differences in V_d stem from differences in body composition between men and women especially degree of adiposity (4). Instead of using population averages, a better approach would be to estimate TBW using anthropometric data, such as age, height, and weight (9). From the percentage of TBW a more appropriate value of V_d for ethanol can be derived from knowledge about the blood-water content, which is close to 80% w/w (~85% w/v) on average (1 mL blood = 1.06 g). Others have devised nomograms incorporating the person’s body mass index (BMI) as an indirect way to estimate V_d, although empirical studies demonstrating the strength of this relationship have not been published (10).

During experiments on the clinical pharmacokinetic of ethanol (7,11), two of the volunteers had widely different BMI and correspondingly large differences in V_d for ethanol. The intravenous route of administration was used to avoid problems caused by first-pass metabolism and to guarantee 100% bioavailability of the dose (11). Figure 1 shows the resulting concentration-time profiles of ethanol in a healthy male (BMI = 19.1) and female subject (BMI = 31.6) who received 0.40 g ethanol/kg body weight by constant rate intravenous infusion (10% w/v in glucose) over 30 min. Specimens of venous blood were taken at 5-min intervals from indwelling catheters and the concentrations of ethanol were determined by headspace gas chromatography, a method with high analytical precision and a coefficient of variation of about 1% (12).

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Figure 1. Concentration-time profiles of ethanol in a healthy male (BMI = 19.1 kg/m^2) and female (BMI = 31.6 kg/m^2) after intravenous administration of ethanol (0.4 g per
The dashed diagonal lines in Figure 1 were obtained by least-squares linear regression using selected concentration-time points on the post-absorptive phase. The $V_d$ for ethanol was then derived as ratio of dose (g/kg) to $C_0$ (g/L), where $C_0$ represents the BAC expected if absorption and distribution of the entire dose had occurred instantaneously without any metabolism taking place. The female subject had a $V_d$ of 0.45 L/kg, compared with the man’s $V_d$ of 0.70 L/kg, and the corresponding rates of alcohol elimination from blood (slopes of the diagonal lines) were 0.15 g/L/h for the woman and 0.11 g/L/h for the man.

The woman’s BMI was 31.6 kg/m², which is in the range for clinical obesity class I, and the $V_d$ for ethanol was abnormally low (0.45 L/kg), being 25% less than the value of 0.6 L/kg used in many blood-alcohol charts and computer programs (2,3).

Using a $V_d$ of 0.6 L/kg in blood-alcohol calculations instead of the correct value of 0.45 L/kg obviously impacts on the reliability of the results if and when a person’s BAC is compared with information about the number of drinks consumed. The man’s $V_d$ was 0.7 L/kg (BMI = 19.1 kg/m²), which is in good agreement with the population average value for men incorporated into many blood-alcohol charts.

This preliminary report confirms that $V_d$ for ethanol is likely to be abnormally low for people who are clinically obese, which calls for caution when making blood-alcohol calculations for teaching, research, or legal purposes. It would be much more acceptable to use subject-specific values for $V_d$ based on information about TBW, BMI, or LBM for the individual concerned. Use of inappropriate values of $V_d$ will have consequences in litigation concerning driving under the influence of alcohol, for example when a person’s BAC is compared with information about prior consumption of alcohol.

Obesity has become a major public health concern along with binge drinking and drunkenness (13,14). Besides the importance of BMI in blood-alcohol calculations, obesity is also a concern in connection with the pharmacokinetics and pharmacodynamics of therapeutic drugs (15). The relationship between BMI and $V_d$ for ethanol needs to be investigated in many more individuals of different ages, ethnicity, and body composition, including those underweight for height, emaciated, and morbidly obese.

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References