Letter to the Editor

Considering Measurement Variability When Performing Retrograde Extrapolation of Breath Alcohol Results

To the Editor:

The computational practice of retrograde extrapolation is frequently encountered in the forensic interpretation of breath alcohol analysis. The process involves retrograde estimation (with respect to time) of an individual's breath alcohol concentration (BrAC) based upon knowledge of their BrAC measured at some point in time. In addition, several assumptions are included, such as metabolic elimination rates, drinking pattern and times, and existence of post-absorptive state. The accuracy of the retrograde estimation relies largely on the validity of the assumptions and knowledge of the underlying mechanisms that define ethanol kinetics in humans. In most cases, the computation is performed in order to establish a reasonable estimate of the BrAC at the time of driving in driving-while-intoxicated litigation.

Typically, the retrograde estimation begins with the measurement result at the time of analysis and projects backward to the time of the driving incident. In most cases, the known measurement result is assumed to be the beginning point without any regard to its uncertainty or variability. It should not be assumed that the BrAC measurement is a fixed constant with no uncertainty. In fact, a person's BrAC is reasonably considered a continuous random variable sampled at one point in time from a normally distributed population of values. Figure 1 illustrates this concept with the normal distribution. The assumption of normality is generally reasonable and justified (1).

Jurisdictions that perform duplicate breath alcohol analyses have the ability to estimate the variability of single determinations based on a large number of duplicates and can better address the uncertainties and limitations associated with retrograde extrapolation. Duplicate analyses have the advantage of demonstrating total method variability by combining both analytical and biological factors (2). Where duplicates are performed, the mean should be the value from which extrapolation is projected because it better estimates the individual's true BrAC by minimizing random error. The mean should also be corrected for any known systematic error or bias. Those jurisdictions measuring only one breath sample have no way of evaluating the variability of the BrAC distribution or of knowing whether their single result is high, low, or equal with respect to the distribution mean. Extrapolating from a single measurement, therefore, introduces further uncertainty.

Where duplicate analyses within acceptable agreement are available, they can be used to determine the minimum time interval, back to which an estimation can begin, based upon the measurement variability. Only prior measurements expected to exceed the variability of the BrAC distribution (as estimated from duplicates) can be reported as significantly different because of some non-random factor such as metabolism. Employing the method of delta checks (Scr) can be useful in this regard (3). The metabolism of ethanol over short time intervals (20 to 30 minutes) is not expected to yield measurably different results beyond the normal random error associated with breath alcohol measurement (4). Therefore, sufficient time must be allowed before meaningful estimation can be made.

In addition to measurement variability, the assumed elimination rate (Widmark's $\beta$) must also be considered in determining how soon a retrograde estimation can occur. Smaller $\beta$ values will increase the time necessary for estimation, whereas larger values will decrease the time.

$$\delta_{cr} = K \times CV_T$$
$$2.77 \times (0.053) \bar{x} = \beta t$$
$$0.019 = 0.013t$$
$$t = 1.5 \text{ h}$$

Figure 1. Estimation of the time necessary to allow for retrograde extrapolation in view of measurement variability.
Combining the factors of measurement variability and assumed elimination rate allows one to estimate the smallest time interval over which a retrograde estimation can occur. Figure 1 illustrates an assumed normal distribution of BrAC values from which duplicates (e.g., 0.12 and 0.14 g/210 L) have been randomly sampled at time $t_2$. Based on a large number of field duplicates ($n = 15,493$) performed on BAC Verifier Datamaster breath alcohol instruments (National Patent Analytical Systems, Mansfield, OH), the standard deviation (SD) for single determinations was calculated at each concentration and reported previously (5). Employing a large body of field data allows for a better upper limit estimation of method variability for a particular measuring system. The estimated SD for a concentration of 0.130 g/210 L is 0.0069 g/210 L. The relevant information then becomes $\bar{x} = 0.130$ g/210 L, $SD = 0.0069$ g/210 L, and the coefficient of variation (CV) = 5.3%. Next we compute the critical difference or delta value ($\delta_{cr}$) beyond which it can be assumed that a real or significant difference has been measured and not accounted for by random variability. The critical difference is computed from $\delta_{cr} = K \times CV$, where $K = 2.77$ and minimizes the probability of false rejection to less than 5% (6,7). Based on the above data, the critical difference becomes $\delta_{cr} = 2.77 \times 0.053 = 0.147$, which is the proportional change necessary to conclude a real difference. The time necessary to estimate a real difference based on an assumed $\beta$ for breath alcohol elimination ($\beta = 0.013$ g/210 L/h because BrAC is typically less than the corresponding blood alcohol concentration) is then computed by

\[
\delta_{cr} \times \bar{x} = \beta t \\
0.019 = 0.013 t \\
t = 1.5 \text{h}
\]

Therefore, one could not estimate an extrapolated value in less than 1.5 hours (back to $t_1$ in Figure 1) given this set of data. If the driving incident occurred only one hour prior to breath alcohol analysis, and all of the other relevant assumptions are valid, then one would expect the BrAC at the time of the incident to be measurably the same as the BrAC at the time of analysis. Their values would be considered random variables from the same distribution. Different values for $\beta$ or SD will yield differing results; one could, for example, compute a range of times based on a range of $\beta$ values. Even when the duplicates agree to two decimal places, the same approach is used because random variability is still present in the method. Presumably, one could extrapolate blood alcohol results in shorter times because the SD would be reduced. Further, jurisdictions would be well-advised to estimate the appropriate SD based on their own system of replicate measurement.

Finally, BrAC measurements should be considered random variables drawn from assumed normal distributions possessing variability. The magnitude of this variability is best estimated from a large number of duplicate analyses collected while the system is assumed to be in statistical control. Appropriate consideration of total method variability may preclude extrapolation in short time intervals.

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References