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Uncertainty in the Results of Breath-Alcohol Analyses

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I would like to address some of the points made by Robert Q. Thompson in his article "The Thermodynamics of Drunk Driving" (*1*). It is no trivial task to calculate from first principles the in vivo *postabsorptive* blood- to breath-alcohol ratio (hereinafter termed "blood/breath ratio", and denoting the ratio of blood-alcohol concentration [BAC] to breath-alcohol concentration [BrAC]) and its associated uncertainty for motor vehicle operators arrested for *d*riving *u*nder the *i*nfluence (DUI) of alcohol. Thompson is to be commended for his elegant analysis and development of this theoretical model. I do, however, have reservations concerning the limited scope and basis of some of Thompson's conclusions, and offer arguments in support of a broader perspective. These arguments address the impact of the state of alcohol absorption of DUI arrestees on the results of their breath-alcohol tests and statistical analysis of experimental blood/breath ratio data. Also considered is questionable scientific methodology characterizing some of the work cited by Thompson.

Blood/Breath Ratios and the State of Alcohol Absorption

Thompson's theoretical model assumes complete equilibration between BAC and BrAC. Therefore, the assumption of postabsorption necessarily applies to his model, and his comparisons between *calculated* and *experimental* blood/breath ratios are restricted to the postabsorptive state. Given this condition, Thompson initially states that a blood/breath ratio of 1880:1 should be employed by breath-alcohol analyzers instead of the standard 2100:1 currently utilized in the USA and elsewhere. His selection of 1880:1—which is the difference between his calculated mean blood/breath ratio of 2350:1 and 2.33 SD, where SD (standard deviation) is 200—is derived from normal, *one-tailed* error analysis involving 99% of the postabsorptive DUI population. He subsequently points out that normal, one-tailed error analysis of Dubowski's experimental postabsorptive blood/breath ratio data (number of blood/breath pairs: 393; mean: 2280:1; SD: 241.5) (*2*) "suggests" a lower limit blood/breath ratio of 1720:1, which, compared to 1880:1 and, more significantly, to 2100:1, would result in fewer DUI convictions stemming from *overestimates* of BAC.

One-Tailed vs Two-Tailed Normal Error Analysis

One of several points I would make concerning Thompson's position is that the lower limit blood/breath ratio he cited for Dubowski's postabsorptive data (*2*) should be about 3.5% lower, or 1660:1, based on a *two-tailed* normal error analysis. (A similar reduction can be considered in connection with Thompson's calculated lower limit ratio of 1880:1.) A ratio of 1660:1 is the minimum ratio derived from Dubowski's data that would characterize the *central* 99% of the postabsorptive DUI population. This level of confidence is consistent with the statistical approach and recommendation of Rainey for meeting the "beyond-a-reasonable doubt" requirement for convictions in criminal proceedings, and reflects standard clinical laboratory practice as well (*3*). It is also somewhat more conservative than the 99.9% level of confidence cited by Jones for direct BAC analyses in Sweden (*4*), which he also recommends for breath-alcohol analyses in all jurisdictions (*5*).

The following hypothetical scenarios reflect the significance of a two-tailed analysis of postabsorptive blood/breath ratios. In the first, a DUI arrestee has a BAC of 0.10%, based on a breath test administered in a jurisdiction whose "legal limit" is 0.08%. At 1720:1, this individual's adjusted, *truncated* BAC is an inculpatory 0.08%, whereas at 1660:1, it is an exculpatory 0.07%. (It should be noted that *truncation,* or deletion of the third decimal place, is the standard practice in law enforcement for reporting BACs [*6*].) In the second scenario, the test subject has an *actual,* inculpatory BAC of 0.11% in a jurisdiction with a legal limit of 0.10%. However, at a blood/breath ratio of 2900:1, which is the upper limit of the 99% level of confidence derived from Dubowski's postabsorptive data (*2*), the adjusted BAC would be an exculpatory 0.07%.

The Absorptive and Postabsorptive States

Thompson's model is predicated on postabsorption, but, in fact, any particular DUI arrestee is not necessarily postabsorptive at the time of the breath test. Therefore, Thompson's suggestion that DUI arrestees should be evaluated on the basis of the "lower fixed [blood/breath ratio] value of 1720"—which, as noted above, is derived from Dubowski's data (*2*)—can be discriminatory. In this regard, Labianca and Simpson (*7*) have emphasized that the magnitude of the blood/breath ratio is dependent on the time elapsed after the end of drinking (*2, 8–10*) and the *absorptive* state, which is characterized by significant deviations from Dubowski's postabsorptive mean blood/breath ratio (*2*), is distinguished by a widely varying time frame. For fasting subjects, for example, the time-to-peak BAC typically ranges from 0.5 to 2.0 h, with an average of 0.75 to 1.35 h, depending on dose and time of last meal—whereas for nonfasting subjects, the range is 1.0 to 6.0 h, and the average is 1.06 to 2.12 h (*11*).

Based on lognormal statistical analysis of the data of Giguiere and Simpson (*12*), Labianca and Simpson (*7*) determined a *mean* absorptive state blood/breath ratio of 1836:1, with a statistical range of 1128:1 to 2989:1 for 99% of the population. These data, coupled with the results of Heifer (*10*), which are also consistent with the conclusions of Normann et al. (*13*), demonstrate unequivocally that DUI arrestees in the absorptive state are at a significantly greater disadvantage than postabsorptive arrestees when undergoing breath-alcohol analysis. Furthermore, this conclusion reinforces similar arguments put forth by Dubowski (*2*) and Simpson (*14–16*).

An additional point for consideration involving Thompson's assumption of postabsorption for DUI arrestees is his determination that, based on the calculated postabsorptive blood/breath ratio of 2350:1 (SD: 200) cited above, 11% of the drinking/driving population undergoing breath-alcohol analysis would be characterized by overestimated BACs. Thompson appropriately based this determination on a *one-tailed*, normal error analysis because, in this case, those DUI arrestees whose blood/breath ratios are *below* 2100:1 constitute the sole consideration. They would comprise that portion of the postabsorptive drinking/driving population whose BACs would be overestimated by breath testing. Thompson's 11% estimate, however, is in contrast to the percentage arrived at by Simpson (*15, 17*), who, using the same straightforward statistical approach employed by Thompson, showed that 23% of postabsorptive subjects would have actual BACs overestimated by breath testing, based on Dubowski's postabsorptive blood/breath ratio data (*2*).

It is interesting in this regard that, at the time Simpson documented his conclusions, members of the forensic science community were critical of his mathematical approach to calculating the percentage of overestimates for test subjects in the postabsorptive state (*18, 19*). I would hasten to add, however, that it is particularly noteworthy that, in addition to Simpson's sound scientific rebuttals of these criticisms (*20, 21*), Thompson independently applied the same mathematical approach in his work. This situation suggests that published work focusing on forensic alcohol analysis must be carefully scrutinized to ensure that proper scientific methodology was used to arrive at the documented conclusions. Some examples in this regard are addressed below within the context of Thompson's work.

Questionable Scientific Methodology

Apparently, Thompson was unaware of instances of inappropriate scientific methodology involving certain of the peer-reviewed literature he cited. One instance involves the work of Jones and Andersson (*22*), who reported a mean time-adjusted blood/breath ratio ± SD of 2407 ± 213, based on a study of 799 DUI arrestees *assumed* to be postabsorptive. A fundamental flaw of this work is that the *single* evidential breath test for each subject was *aborted* for unexplained reasons. The possibility cannot be ruled out, therefore, that the aborted breath tests generated artificially *low* data, so that the reported blood/breath ratios are falsely *high*.

In addition, Jones and Andersson's claim that the use of modern breath-alcohol analyzers may account, in part, for postabsorptive blood/breath ratio data differing from corresponding data obtained with older instruments, is unsupportable because instrumental and calibration errors are insignificant compared to blood/breath ratio variability and other sources of error (*16, 17, 23*).

The single evidential breath test characterizing Jones and Andersson's work (*22*) is also problematic because it is inconsistent with Jones' own recommendation for duplicate sampling (*5, 24*) and with the recognized quality assurance practice of duplicate sampling endorsed by the National Safety Council Committee on Alcohol and Other Drugs (*6*).

Timing of Blood and Breath Sampling

Another questionable aspect of the experimental protocol of Jones and Andersson (*22*) is that venous blood was sampled an average of 30 min (range: 6 to 60 min) after the single exhalation breath test in each case. Given that BAC $\propto$ BrAC and that the proportionality constant at any given time is the blood/breath ratio, denoted by BBR, then in order for the equation BAC = BBR $\times$ BrAC to accurately reflect the relationship between BrAC and coexisting BAC, the latter two concentrations must be measured essentially simultaneously (*8, 10, 12, 25*).

Rates of Alcohol Elimination and Absorption

Jones and Andersson's use of a mean rate of alcohol elimination of 0.019%/h (*22*) to correct for the time difference between breath and blood sampling is also questionable. This mean (SD: 0.0049%/h) is based on the analyses of two blood samples taken from more than 1000 individuals (*26*). Samples were taken an average of 68 min apart (range: 30 to 120 min), with 75% of the double samples taken between 47 and 84 min apart. Such protocol is in contrast to the pioneering work of Widmark with alcohol elimination rates, which involved both the analysis of at least nine blood samples taken over a 230-min postabsorptive period and the application of the method of least squares to the data (*27*). Moreover, broader elimination rate ranges and greater SDs than those of Jones and Andersson (*26*) were cited by Dubowski (*2*) for studies also involving the testing of two samples. One of these studies, for example, reported a range of elimination rates of 0.001%/h to 0.08%/h for 1512 subjects, with a mean and SD of nearly 0.02%/h and 0.01%/h, respectively.

The assumption of postabsorption by Jones and Andersson (*22*) for the DUI suspects they evaluated is another of the problems they failed to address (*22, 26*). If a DUI suspect is in the absorptive phase of alcohol metabolism, then the hourly rate of elimination used by Jones and Andersson (*26*) fails to take into account substantial changes in BAC that can occur during active alcohol absorption. On an empty stomach, for example, Jones et al. (*28*) found the *rise* in BAC to average 0.10%/h (range: 0.03%/h to 0.30%/h). Moreover, analysis of data reported by Dubowski (*2*) shows a range of absorption rates of about 0.05%/h to as high as 0.60%/h and an *average* of about 0.15%/h, the latter having also been determined by Simpson (*29*).

Rates of alcohol absorption on a full stomach, on the other hand, tend to be lower but are, nevertheless, significant. Analysis of the data of Jones and Neri (*30*), derived from their study of subjects who ingested mixed drinks with a meal, reveals absorption rates ranging from approximately 0.02%/h to 0.08%/h, with a mean of about 0.05%/h.

Conclusion

It must be emphasized that Thompson's work is a step in the right direction. Of particular significance, however, is that any discussion of error in breath-alcohol tests cannot be restricted solely to a consideration of postabsorptive error; *all* sources of error must be considered. Certainly, with regard to a key source of error addressed in this article (the variability of the blood/breath ratio), it is typically not known in a DUI case if equilibrium, and therefore postabsorption, exists at the time of the breath test. Unless the existence of equilibrium can be established by objective means for each test subject, it can only be assumed that the subject is still absorbing alcohol. That assumption is required if strict adherence to a fundamental tenet of American jurisprudence is to be maintained, namely, that defendants must be afforded the benefit of the doubt in criminal proceedings. This means that the correction factor for 99% confidence limits is 46% (*7*) rather than the 18% consistent with the use of the lower limit blood/breath ratio of 1720:1 stemming from Dubowski's postabsorptive data (*2*) and cited by Thompson (*1*), or the 21% associated with the corresponding adjusted blood/breath ratio of 1660:1 stemming from the two-tailed analysis described previously.

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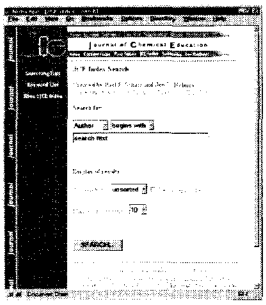

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