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Any test conducted by a breath-alcohol analyzer on a human subject involves the analysis of a sample of breath in contact with the subject's circulating pulmonary blood. The fundamental premise of such an analysis is that it is supposed to produce a result that reflects the corresponding blood-alcohol concentration (BAC) of the individual providing the sample, assuming that the test is conducted in a jurisdiction where results are reported in terms of BAC.

Thus, breath-alcohol analysis is an indirect measure of a subject's BAC, and this type of testing, therefore, necessarily requires that the measured breath-alcohol concentration (BrAC) be transformed into an associated BAC. Such a transformation entails the use of a conversion factor that is uniformly applied to all test subjects in a given jurisdiction. Problems stemming from the uniform application of that factor are addressed in this article.

Introduction
The variability of the ratio of BAC to BrAC — a ratio hereinafter termed "BBR" and central to the conversion of a measured BrAC into a corresponding, estimated BAC via the equation BAC = BBR x BrAC where, in the United States, BBR is 2100:1, or simply, 2100 — has been addressed extensively in both the legal and scientific literature. Nevertheless, information relevant to this issue appearing in various documented court cases has not always been entirely accurate and/or thorough. Consequently, the use of such information in the legal arena might lead to conclusions that are inconsistent with documented scientific data and their associated statistical analyses. Relevant clarifications in this regard are provided in this commentary within the context of the following information stemming from two cases1 that, although based in New York County, certainly have national implications concerning breath-alcohol analysis.
Leading researchers have … learned … that the mean population [BBR] is about 2,300:1. … Dr. Kurt W.[2] Dubowski, a noted authority, places [BBR] differences between 1,555:1 and 3,005:1. … He concludes that the breathalyzer[3] with its fixed ratio of 2,100:1 understates the blood alcohol of 86 percent of the population and overstates it for 14 percent of those tested. … Other experts assert that for 95 percent of the population the [BBR] of 2,100:1 results in a blood alcohol reading that is either accurate or understated.
People v. Nieves4
As conceded by the People, however, it is also widely accepted among authorities in this field that the ratio of 2,100 to 1 is a statistical "mean" and that the actual [BBR] applicable to the population-at-large, and to any one person, varies depending upon, among other things, the unique body chemistry of each individual.
People v. Singh5

The Issue of the 2300:1 BBR
With regard to the statement in People v. Nieves that "the mean population [BBR] is about 2,300:1," a mean BBR of 2280:1 — which is obviously consistent with the mean BBR of "about" 2300:1 cited — was initially documented in a brief report by Dubowski and O'Neill6 and subsequently addressed within the context of a detailed statistical analysis presented by Dubowski.7 It should be noted that more recent studies have reported mean postabsorptive BBRs higher than Dubowski's mean BBR of 2280:1 (by approximately 10 percent or less). These include, for example, the work of Jones and Andersson8 and Gainsford et al.9 Dubowski's data, however, are preferable because the Jones/Andersson and Gainsford et al. studies did not involve essentially simultaneous sampling of breath and blood, a condition that unequivocally characterizes the Dubowski data.10 This is certainly a critical issue when considering the BBR, since this ratio necessarily reflects the relationship between coexisting BAC and BrAC.11

The 2280:1 BBR characterizes only those individuals in the fully postabsorptive state of alcohol metabolism, as Dubowski12 emphasizes. Moreover, he stresses that "significant variations from this population mean [i.e., 2280:1] exist during active alcohol absorption and in some individuals even in the postabsorptive phase."

Dubowski adds that his data have a Gaussian distribution (also called a normal distribution), which means that the distribution of the data is characterized by the standard "bell-shaped" curve. Thus, given that Dubowski's mean postabsorptive BBR is 2280:1 and that the associated standard deviation (SD) he reported is 241.5, the confidence ranges listed in Table 1 apply to his data, based on established statistical analysis involving the Gaussian distribution.

An additional point in this regard is that, for all Gaussian distributions, the mean divides the bell-shaped curve in half. So for Dubowski's data, 50 percent of the drinking/driving population in the postabsorptive state has a BBR below 2280:1, and 50 percent has a BBR above this mean. The various confidence ranges listed in Table 1 expand on this point.

Note that the statement in Nieves, namely that "Dr. Kurt W.14 Dubowski, a noted authority, places [BBR] differences between 1,555:1 and 3,005:1," reflects the confidence range for 99.7 percent of the postabsorptive drinking/driving population listed in column 6 of Table 1 (i.e., Mean ± 3 SD, or 2280:1 ± 3 x 241.5) — and only for the postabsorptive population.

The Ratio of Underestimates To Overestimates in the Postabsorptive State — A Correction
As per Nieves, "He [Dubowski] concludes that the breathalyzer15 with its fixed ratio of 2,100:1 understates the blood-alcohol of 86 percent of the population and overstates it for 14 percent of those tested." This statement stems from an earlier Dubowski work published in 198216 in which he says, "The 2100:1 conversion tends to underestimate the actual BAC in about 86 percent of the population by a mean of about eight percent, since the functional partition ratio between blood and breath in healthy adult males was found to be 2.28 x 103 [i.e., 2280:1]." The reader should note that the "eight percent" factor in Dubowski's statement reflects the fact that 2100:1 differs from the mean of 2280:1 by about 8 percent.

Dubowski's conclusion concerning the issue of 86 percent underestimates — and by extension, 14 percent overestimates — is entirely inconsistent with the statistical analysis of his data, as Simpson17 demonstrated and Labianca18 verified. In fact, the use of standard statistical tables for the Gaussian distribution (refer, for example, to Table 3.3 in Barlow's text19) clearly confirms the following conclusion: Based on the following information, namely a postabsorptive mean BBR of 2280:1, the standard 2100:1 BBR used by breath-alcohol analyzers in the United States, and the fact that 2100:1 differs from 2280:1 by 0.75 SD (i.e., 2280 - 2100 = 180, and 180 ÷ 241.5 [Dubowski's SD] = 0.75), 23 percent (and not 14 percent) of the postabsorptive drinking/driving population is overestimated by breath-alcohol analysis. This represents nearly one out of every four drivers in the postabsorptive state. The corresponding percentage of underestimates is 77 percent (and not 86 percent).

The use of the same statistical table cited above20 demonstrates that, if breath-alcohol analyzers were calibrated at 2038:1 — obtained by reducing Dubowski's mean BBR of 2280:1 by one SD, in accord with the confidence range for 68 percent of the postabsorptive population, as listed in column 3 of Table 1 — then 84 percent of the drinking/driving population (which would agree reasonably well with Dubowski's 86 percent) would be underestimated, and 16 percent (also in good agreement with Dubowski's 14 percent) would be overestimated. The reality, however, is that breath-alcohol analyzers are calibrated at 2100:1 and not at 2038:1. Thus, the ratio of underestimates to overestimates in the postabsorptive state is, once again, 77:23, and not 86:14.

Incorrect Statistical Estimate Based on The 2100:1 BBR
Given the preceding analysis, which is mathematically definitive and, therefore, unequivocally correct, the following statement from Nieves has no basis in fact: "Other experts assert that for 95 percent of the population the breathalyzer ratio of 2,100:1 results in a blood alcohol reading that is either accurate or understated." Those individuals who would endorse this position have clearly failed to rely on established statistical analysis methodology. The "95 percent of the population" referred to by these "other experts," within the context of the 2100:1 BBR, indicates that these "experts" are, apparently, unaware of the statistical range

for 95 percent of the postabsorptive drinking/driving population listed in column 4 of Table 1 (i.e., 1797:1 to 2763:1). They also appear to be unaware of the ratio of underestimates to overestimates of 77:23 specified above.

The Ratio of Underestimates To Overestimates in the Absorptive State

As noted previously, Dubowski21 expressed particular concern about the variability of the BBR in the absorptive state of alcohol metabolism. In fact, his concern mirrors a similar position he and Mason22 endorsed earlier, in 1974, when they emphasized that, “when blood and breath tests are available to a subject, the breath test can be discriminatory in yielding a higher result than a blood test during absorption.” Consistent with Dubowski’s position concerning significant deviations from his postabsorptive mean BBR of 2280:1 “during active alcohol absorption”23 — a position that would certainly be endorsed by Mason24 as well — Labianca and Simpson25 determined a mean absorptive state BBR of 1836:1, derived from lognormal statistical analysis of the data of Giguiere and Simpson.26 This mean is obviously significantly lower than 2280:1. Moreover, the logarithm-transformed data are normally distributed and generate an absorptive state BBR confidence range of 1259:1 to 2679:1 for 95 percent of the drinking/driving population and 1128:1 to 2989:1 for 99 percent, the latter percentage slightly more conservative than the 99.7 percent employed by Dubowski for the analysis of his data.27 The Labianca/Simpson absorptive state data reflect a ratio of underestimates to overestimates of 24:76.28 In contrast, the data from Jones29 for the absorptive state indicate a less pronounced, but nevertheless significant, ratio of underestimates to overestimates of 35:65.30

The Concept of Relative Error

The postabsorptive state BBR data of Dubowski31 can also be compared with the absorptive state BBR data of Labianca and Simpson32 within the context of relative error,33 which is expressed as a percentage and given by the equation in Figure 1 in which 2100:1 is the “Accepted BBR Value.”

The application of the equation in Figure 1 to the lower limit of Dubowski’s 99 percent BBR confidence range (column 5 of Table 1) yields a relative error of -21 percent, as demonstrated by the calculation shown in Figure 2 involving the equation in Figure 1.

It should be recognized that the 99 percent lower limit value of the BBR is selected for this calculation because a certainty of greater than 99 percent34 is an established standard for scientific evidence and consistent as well with the “beyond a reasonable doubt” standard of evidence in criminal proceedings, as emphasized by Rainey35 (refer to associated relevant explanation in note 34). Dubowski’s use of a 99.7 percent confidence range (column 6 of Table 1) is also consistent with this stipulation, although the 99 percent range is slightly more conservative, as indicated previously.

The negative sign preceding the “21 percent” result in Figure 2 means that, excluding any other source of error in a given breath-alcohol analysis, the percentage BAC of a DWI arrestee in the postabsorptive state should be reduced by 21 percent if that arrestee is to be given the benefit of the lower limit BBR of the corresponding 99 percent confidence range. This reduction is mathematically equivalent to multiplying the reported percentage BAC by the fraction, 1657/2100 — or, more generally, by the fraction BBR/2100, where “BBR” would be the statistical ratio of interest (1657 in this example) or the subject’s actual BBR at test time in the typically unlikely circumstance that it would be known — as demonstrated in Figure 3 for the example of a reported percentage BAC of 0.09 percent in a hypothetical case.

Note that “0.21” in the Figure 3 calculation is the decimal equivalent of 21 percent that is required when a percentage is involved in a calculation, and that the adjusted percentage BAC of 0.07 percent obtained in this case is a truncated result. Truncation means that all decimal places beyond the second are dropped without rounding. This protocol is in accord with Section 59.5e of the State of New York Department of Health Administrative Rules and Regulations and with the established, universal convention currently in place for law enforcement applications of breath- and blood-alcohol analysis.36

The application of the equation for relative error to the lower limit of Labianca and Simpson’s37 99 percent BBR confidence range for the absorptive state — that is, 1128:1, as noted previously — yields a relative error of -46 percent. So if the hypothetical arrestee in Figure 3 with a reported percentage BAC of 0.09 percent were to be afforded the benefit of an absorptive state BBR evaluation, a calculation similar to the one conducted for the postabsorptive state would give an adjusted, truncated percentage BAC of 0.04 percent.

The concept of relative error is, obviously, also applicable to the upper limit of the 99 percent BBR confidence ranges of the data of Dubowski38 and of Labianca and Simpson.39 A sample calculation for the determination of the relative error using Dubowski's upper confidence limit of 2903:1 (column 5 of Table 1) produces a result of +38 percent, as shown in Figure 4.

The positive sign preceding "38 percent" in Figure 4 simply means that, excluding any other source of error, a DWI arrestee in the postabsorptive state could have an actual percentage BAC that is 38 percent higher than the reported breath-test result. That higher result, as demonstrated in Figure 5 for the hypothetical case described previously involving a reported percentage BAC of 0.09 percent, can be determined either by increasing 0.09 percent by 38 percent — using the corresponding decimal equivalent of 0.38 in the calculation — or by multiplying 0.09 percent by the fraction 2903/2100.

Similar calculations for the upper limit of the 99 percent BBR confidence range of Labianca and Simpson40 that was cited previously, namely 2989:1, produces a relative error of +42 percent and a truncated, adjusted percentage BAC of 0.12 percent for the hypothetical case involving the reported test result of 0.09 percent. Note that the truncated result of 0.12 percent obtained from the Figure 5 calculation is identical to the truncated result obtained from the calculation involving Dubowski's upper limit BBR of 2903:1 because the latter differs minimally (less than 3 percent) from the Labianca/Simpson upper limit BBR of 2989:1.

A summary of the relative error ranges addressed above is provided in Table 2.

A final point of consideration is that the concept of relative error allows for further elaboration of an issue considered in a previous section, namely that some experts believe that the use of the 2100:1 BBR in breath-alcohol analysis affords 95 percent of test subjects accurate or understated test results (as per Nieves). Certainly, for the 95 percent confidence range characterizing Dubowski's postabsorptive state data (1797:1 to 2763:1, column 4 of Table 1), the relative error is -14 percent to +32 percent; for the 95 percent confidence range cited previously for the Labianca/Simpson absorptive state data (1259:1 to 2679:1), the relative error is -40 percent to +28 percent. Therefore, if test subjects undergoing breath-alcohol analysis are afforded the benefit of the doubt within the context of the BBR, the use of the lower limit BBRs of the 95 percent confidence ranges listed above — instead of the lower limit BBRs associated with the corresponding 99 percent confidence ranges that would, as noted previously, be consistent with the standard for scientific certainty43 — means that postabsorptive state subjects would be entitled to a 14 percent reduction in test results, and absorptive state subjects, a 40 percent reduction. Thus, once again, the "95 percent argument" of the experts referred to in Nieves is simply inconsistent with the analysis provided in this commentary.

Conclusion

The message of this commentary is unequivocal: The application of a 2100:1 BBR to all test subjects undergoing breath-alcohol analysis fails to take into account the significant variability of the BBR among various drivers who have ingested alcohol. In this regard, the statement in Singh, namely that "it is … widely accepted among authorities in this field that the ratio of 2100:1 is a statistical 'mean,'" is, in fact, inaccurate and misleading. Given the above presentation, a BBR of 2100:1 is certainly not "a statistical 'mean.'"

The reality, once again, is that the BBR varies significantly as a function of the state of alcohol absorption of the individual drinker at the time of the arrest and/or breath-alcohol analysis. Moreover, this state of absorption is frequently unknown in a given case, so the defendant in such a case would be entitled to a BBR-based evaluation involving the absorptive state data cited above. Consistent with this position is another argument offered in Singh that is, in contrast to the one cited previously, scientifically valid, namely "that the actual blood/breath conversion ratio applicable to the population at large, and to any one person, varies depending upon, among other things, the unique body chemistry of the individual."

Notes

1. Pertinent citations have been omitted from the quoted case information, but these are readily accessible via reference to the specific cases cited.
2. The initial "W" in Dubowski's name should be "M."
3. Since all breath-alcohol analyzers used in the United States rely on a BBR of 2100:1, the term

"breathalyzer" is synonymous with any of these instruments within the context of the BBR. This argument applies both to instruments that generate results in terms of percentage BAC and those that generate results in terms of BrAC, the latter denoting breath-alcohol concentration, which typically has the concentration unit "gram (g) of alcohol per 210 liters (L) of breath" (g/210 L). For the latter instruments, the 2100:1 BBR is necessarily involved, as stated explicitly by Jones (A. W. Jones, Physiological Aspects of Breath-Alcohol Measurement, 6(2) ALCOHOL, DRUGS AND DRIVING 1-25 [1990]) and demonstrated unequivocally by Labianca and Simpson via a simple mathematical proof (D. A. Labianca & G. Simpson, Medicolegal Alcohol Determination: Variability of the Blood-to Breath-Alcohol Ratio and Its Effect on Reported Breath-Alcohol Concentrations, 33 EUR. J. CLINICAL CHEM. & CLINICAL BIOCHEM. 919-925 [1995]).
4. People v. Nieves, 541 N.Y.S.2d 1008, 1010 (N.Y. Crim. Ct. 1989).
5. People v. Singh, 542 N.Y.S.2d 1018, 1023 (N.Y. Crim. Ct. 1989).
6. K. M. Dubowski & B. O'Neill, The Blood/Breath Ratio of Ethanol, 25 CLINICAL CHEM. 1144 (1979). Additional details of this study appear in Dubowski's 1985 work cited in note 7, which is why the 2280:1 ratio listed in that work and the associated statistical analysis provided have been attributed to Dubowski in this commentary. Nevertheless, the reader is reminded that O'Neill also contributed to the "Dubowski Study," as per the citation at the beginning of this note.
7. K. M. Dubowski, Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects, 10 J. STUD. ALCOHOL (Supp.) 98-108 (1985).
8. A. W. Jones & L. Andersson, Variability of the Blood/Breath Ratio in Drinking Drivers, 41 J. FORENSIC SCI. 916-921 (1996).
9. A. R. Gainsford, D. M. Fernando, R. A. Lea & A. R. Stowell, A Large-Scale Study of the Relationship Between Blood and Breath Alcohol Concentrations in New Zealand Drinking Drivers, 51 J. FORENSIC SCI. 173-178 (2006).
10. See Dubowski & O'Neill, supra note 6.
11. D. A. Labianca, Uncertainty in the Results of Breath-Alcohol Analyses, 76 J. CHEM. EDUC. 508-510 (1999).
12. See Dubowski, supra note 7.
13. Id.
14. See supra note 2.
15. See supra note 3.
16. K. M. Dubowski, Alcohol Analysis: Clinical Laboratory Aspects. Part I, LAB. MGMT. 43-54 (March 1982).
17. G. Simpson, Accuracy and Precision of Breath-Alcohol Measurements for a Random Subject in the Postabsorptive State, 33 CLINICAL CHEM. 261-268 (1987).
18. D. A. Labianca, Uncertainty in the Results of Breath-Alcohol Analyses, 76 J. CHEM. EDUC. 508-510 (1999); D. A. Labianca, The Flawed Nature of the Calibration Factor in Breath-Alcohol Analysis, 79 J. CHEM. EDUC. 1237-1249 (2002).
19. R. J. BARLOW, STATISTICS: A GUIDE TO THE USE OF STATISTICAL METHODS IN THE PHYSICAL SCIENCES 39 (1989).
20. Id.
21. See Dubowski, supra note 7.
22. M. F. Mason & K. M. Dubowski, Alcohol, Traffic, and Chemical Testing in the United States: A Résumé and Some Remaining Problems, 20 CLINICAL CHEM. 126-140 (1974).
23. See Dubowski, supra note 7.
24. See Mason & Dubowski, supra note 22.
25. D. A. Labianca & G. Simpson, Statistical Analysis of Blood- to Breath-Alcohol Ratio Data in the Logarithm-Transformed and Non-Transformed Modes, 34 EUR. J. CLINICAL CHEM. CLINICAL BIOCHEM. 111-117 (1996).
26. W. Giguiere & G. Simpson, Medicolegal Alcohol Determination: In Vivo Blood/Breath Ratios as a Function of Time, I in PROCEEDINGS OF THE 27TH MEETING OF THE INTERNATIONAL ASSOCIATION OF FORENSIC TOXICOLOGISTS, Oct. 19-23 (1990), Perth (Australia); V. J. McLinden & D. J. Haney, eds., International Association of Forensic Toxicologists: Perth, 1992; pp. 494-506.
27. See Dubowski, supra note 7.
28. D. A. Labianca, The Flawed Nature of the Calibration Factor in Breath-Alcohol Analysis, 79 J. CHEM. EDUC. 1237-1249 (2002).
29. A. W. Jones, Variability of the Blood: Breath Alcohol Ratio in Vivo, 39 J. STUD. ALCOHOL 1931-1939 (1978).
30. G. Simpson, Assessing Breath Test Estimation of Blood Alcohol Concentration, 13 J. ANALYTICAL

TOXICOLOGY 242-244 (1989).
31. See Dubowski, supra note 7.
32. See Labianca & Simpson, supra note 25.
33. D. A. SKOOG, D. M. WEST & F. J. HOLLER, FUNDAMENTALS OF ANALYTICAL CHEM. 14 (7th ed. 1996).
34. The reader should note that the usual protocol concerning the 99 percent statistical range of a Gaussian distribution is to specify that this range is characterized essentially by “Mean ± 2.58 SD” (column 5 of Table 1, and p. 38 of Barlow, supra note 19). Actually, the range is explicitly defined by “Mean ± 2.576 SD” (p. 37 of Barlow, supra note 19). Therefore, since 2.58 SD is greater than 2.576 SD, the calculation presented is, in effect, consistent with the standard of “greater-than-99 percent-certainty” for scientific evidence emphasized by Rainey (note 35). Perhaps the essence of this standard can be better appreciated by considering the following example. If an individual is characterized by an unbearably intense headache, and if the only means available to quell the pain is a bottle of 100 pain-reliever capsules, 99 of which are cyanide-free and one of which contains enough cyanide “to kill an elephant,” would that individual ingest a capsule from that bottle or, instead, decide to let the headache run its course? If the individual chooses to ingest a capsule, she would, in effect, be 99 percent certain that there would be no fatal consequence of her action. On the other hand, if she chooses to “live” with the headache, she would be requiring a standard of “greater-than-99 percent-certainty” and would, in effect, be exercising reasonable doubt concerning the fatal outcome of potentially ingesting a tainted capsule. Clearly, this argument would be even more telling if a standard of 95 percent certainty was in place because, under that condition, our example would involve a tainted bottle containing 95 cyanide-free capsules and five cyanide-laced capsules.
35. P. M. Rainey, Relation Between Serum and Whole-Blood Ethanol Concentrations, 39 CLINICAL CHEM. 2288-2292 (1993).
36. K. M. Dubowski, Alcohol Analysis: Clinical Laboratory Aspects. Part II, LAB. MGMT. 27-36 (April 1982); K. M. Dubowski, Quality Assurance in Breath-Alcohol Analysis, 18 J. ANALYTICAL TOXICOLOGY 306-311 (1994).
37. See Labianca & Simpson, supra note 25.
38. See Dubowski, supra note 7.
39. See Labianca & Simpson, supra note 25.
40. Id.
41. See Dubowski, supra note 7.
42. See Labianca & Simpson, supra note 25.
43. See supra notes 34 and 35.

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