Patrick M. Harding,[1] *B.S.; Ronald H. Laessig,*[2] *Ph.D.; and Patricia H. Field,*[3] *Ph.D.*

Field Performance of the Intoxilyzer 5000: A Comparison of Blood- and Breath-Alcohol Results in Wisconsin Drivers

REFERENCE: Harding, P. M., Laessig, R. H., and Field, P. H., **"Field Performance of the Intoxilyzer 5000: A Comparison of Blood- and Breath-Alcohol Results in Wisconsin Drivers,"** *Journal of Forensic Sciences*, JFSCA, Vol. 35, No. 5, Sept. 1990, pp. 1022–1028.

ABSTRACT: Intoxilyzer® 5000 and blood-alcohol results from drivers arrested for operating a motor vehicle while intoxicated and for related offenses were compared during a two-year period. Three hundred and ninety-five pairs of results were studied. The breath- and blood-alcohol specimens in this study were collected within 1 h of each other. The mean blood-alcohol concentration obtained was 0.180 g/dL, with a range from zero to 0.338 g/dL. By comparison, the mean Intoxilyzer 5000 result was 0.16 g/210 L with a range from zero to 0.32 g/210 L. Compared with the blood-alcohol result, Intoxilyzer 5000 results were lower by more than 0.01 g/210 L 67% of the time, within 0.01 g/210 L 31% of the time, and higher by more than 0.01 g/210 L 2% of the time.

KEYWORDS: toxicology, intoxication, breath-alcohol testing device, Intoxilyzer

The use of breath-alcohol[4] testing instruments based on infrared absorption technology has been displacing older, wet chemical devices like the Breathalyzer™. The Intoxilyzer™ 5000[5] is an infrared absorption-based, microprocessor-controlled, breath-alcohol analyzer used by numerous law enforcement agencies in this and other countries. The *in-vitro* performance of these instruments has been documented [*1*]. Inherent in the calibration of the instrument is the use of a 2100 : 1 blood-to-breath-alcohol ratio, regardless of whether the results are expressed in units of blood-alcohol concentration (BAC) or in breath-alcohol concentration (BrAC) units of grams of alcohol per 210 L of breath (g/210 L).

Since January of 1986, the Intoxilyzer 5000 has been the sole evidential breath-alcohol testing instrument used in Wisconsin for testing drivers arrested for operating a motor vehicle while intoxicated (OMVWI) and related offenses. The instrument's programmable, automated test sequence provides rapid, operator-independent results. To conduct an analysis, the operator need only perform a required pretest 20-min observation to ensure the absence of mouth alcohol and instruct the subject on how to provide an acceptable breath sample to the device.

Received for publication 30 May 1989; revised manuscript received 11 Sept. 1989; accepted for publication 26 Sept. 1989.

[1]Chemist, Toxicology Section, State Laboratory of Hygiene, University of Wisconsin, Madison, WI.

[2]Director, State Laboratory of Hygiene, University of Wisconsin, Madison, WI.

[3]Chief, Toxicology Section, State Laboratory of Hygiene, University of Wisconsin, Madison, WI.

[4]The unmodified term "alcohol" in this paper refers to ethanol.

[5]CMI/Federal Signal, Minturn, CO.

There are numerous, mostly theoretical, allegations in the literature predicting potentially large errors associated with breath alcohol testing. Frequently cited are error predictions based on the physiological variables that affect a conversion from a BrAC to a coexisting BAC [2–5]. In addition, the relative lack of specificity of infrared BrAC instrumentation [6,7] and the possibility of residual mouth alcohol contributing to a BrAC result [8] have been noted.

An empirical comparison of breath- and blood-alcohol results obtained during the routine processing of drivers arrested for OMVWI should reveal the magnitude and incidence of falsely elevated BrACs in a population relevant for forensic science purposes. A previous study in our laboratory compared Breathalyzer 900 or 900A results with BAC results in 404 arrested drivers and found no evidence of falsely elevated BrACs [9]. Other studies have examined the Lion Laboratory's Intoximeter 3000 [10] and Intoxilyzer 4011A [11] infrared analyzers under field conditions.

Method

The data used in this study were retrospectively compiled from analytical results obtained during the routine processing of Wisconsin drivers arrested for OMVWI and related offenses. The subjects were not preselected, and neither the subjects nor the Intoxilyzer operators were informed of their participation in the study. Under Wisconsin's "implied consent" statute, either the arresting officer or the driver may request that a blood specimen be obtained and analyzed after the BrAC test has been completed. The BAC analysis is provided free of charge by our laboratory. Breath- and blood-alcohol results are reported on standardized blood analysis request forms accompanying blood specimens submitted to the laboratory for analysis. These forms provide space for the Intoxilyzer operator to record the date, time, and result of the breath-alcohol test as well as space for the phlebotomist to record the date and time of blood collection. This information, along with the laboratory's BAC result, were used in this study.

Only results obtained from breath and blood specimens collected within 1 h of each other were included in this study. The 1-h period was chosen to provide a sufficient number of data pairs while reasonably limiting the variation between pairs of results attributable to physiological changes in alcohol concentration during the elapsed time between the collection of the two specimens.

Breath Analysis

Breath analyses were conducted by law enforcement officers operating Intoxilyzer 5000 instruments located in police agencies throughout Wisconsin. Administration of the breath-alcohol testing program is provided by the Chemical Test Section (CTS) of the Department of Transportation, Division of State Patrol. The CTS is responsible for all instrument maintenance and certification as well as the training and certification of the operators. Ethanol/water solutions used as controls and calibrators for breath-alcohol testing equipment are prepared by the CTS and certified by the State Laboratory of Hygiene. Operators must successfully complete a 24-h training course in order to obtain a breath testing permit, which is valid for two years, after which the satisfactory completion of recertification testing is required for renewal.

The Intoxilyzer 5000 employs two analytical wavelengths, 3.48 and 3.39 μm, as well as a 3.80-μm reference wavelength in determining BrAC. Analysis of deep lung air is ensured by the microprocessor-controlled monitoring of the breath pressure, duration of exhalation, and rate of change of the BrAC during exhalation. The instruments used in Wisconsin are equipped with a breath-alcohol simulator and data entry keyboard. The keyboard allows the entry, storage, and subsequent printing of information related to the driver and the offense. The test results are obtained independent of the data entry

system. Once the "START TEST" button is pressed, the instrument employs visual LED displays and audible tones to guide the operator and subject through the testing procedure.

The analytical test sequence employed throughout this study consisted of the analysis of a single breath specimen as well as a "control" analysis of the water-saturated alcohol vapor generated from a heated breath-alcohol simulator. Each of these analyses is preceded and followed by a system purge and blank analysis of room air, which sets the analytical baseline. Analytical results are displayed and printed to three decimal places expressed in BrAC units of grams per 210 L. The subject's breath test result is truncated to two decimal places for use as the reported value in any subsequent legal or administrative proceedings. In order for a test result to be valid, the room air blank analyses must show no alcohol to be present and the result of the simulator vapor analysis must fall within 0.10 ± 0.01 g/210 L.

Blood Analysis

The blood-alcohol analysis method used in this laboratory has been previously described in detail [*9*]. Preserved blood specimens were analyzed using a direct-injection gas chromatographic method employing *n*-propyl alcohol as an internal standard [*12*]. Results are given to three decimal places and expressed in grams of alcohol per decilitre of whole blood (g/dL). Quality assurance procedures include the analysis of aqueous ethanol standards to establish instrument response to a given ethanol concentration, as well as the analysis of spiked blood controls within each run [*13*]. The standard and control results must fall within 5% of their target values for the run to be valid. The overall analytical performance is monitored by participation in external proficiency testing programs, including Wisconsin's monthly program [*14*]. Blood-alcohol analyses conducted by eight different laboratory analysts are included in this study.

Results

A total of 395 pairs of blood- and breath-alcohol results met the 1-h criterion and were included in this study. An additional pair of results met this criterion but was excluded as a statistical outlier (BrAC = 0.04 g/210 L, BAC = 0.258 g/dL). The mean elapsed time between the breath and blood sampling was 36.6 min. Breath was sampled prior to blood in all but 5 cases. The elapsed times ranged from 9 to 60 min. The request for an alternative alcohol test was made by the subject in 299 cases (76%), by the arresting agency in 84 cases (21%), and jointly in 12 cases (3%).

The mean BrAC obtained was 0.16 g/210 L, with a range from 0 to 0.32 g/210 L. The mean BAC obtained was 0.180 g/dL, with a range from 0 to 0.338 g/dL. Paired *t*-test analysis shows that the difference between these two means is significant ($P < 0.001$). Figure 1 shows that the distribution of BACs approximates a normal distribution about the mean. Differences between data pairs were calculated by subtracting the two-digit Intoxilyzer 5000 result from the three-digit BAC. The Intoxilyzer 5000 BrAC result ranged from 0.021 higher to 0.074 lower than the corresponding BAC. The mean difference was 0.018.

Breath- and blood-alcohol results were considered to be in agreement if they differed by 0.01 or less. Using this criterion, it was found that 264 (67%) of the Intoxilyzer 5000 BrAC results were lower than the corresponding BAC, 123 (31%) were in agreement, and 8 (2%) were higher than the corresponding BAC. Table 1 lists the 8 pairs of results in which the BrAC result was higher than the corresponding BAC by more than 0.01. The elapsed time between specimen collections is noted in the right column.

Intoxilyzer 5000 results were plotted as the dependent variable versus the corresponding BAC (Fig. 2). Linear regression analysis of the data yielded the following equation for

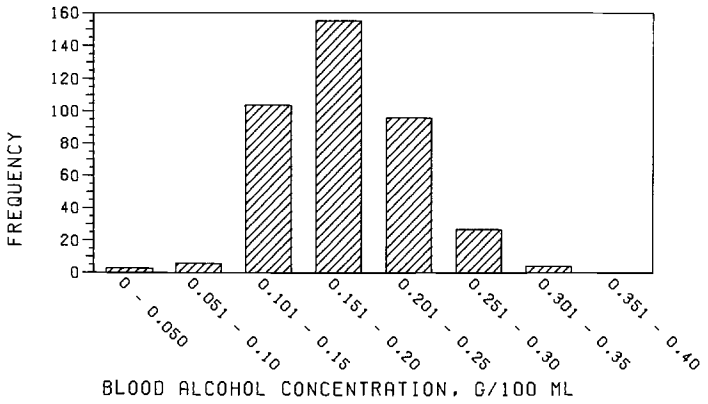

FIG. 1—*Distribution of blood-alcohol results attained by drivers in this study.*

TABLE 1—*Instances in which the Intoxilyzer 5000 breath-alcohol result exceeded the blood-alcohol result by more than 0.01.*

Intoxilyzer 5000, g/210 L	Blood-Alcohol, g/dL	Difference	Elapsed Time,[a] min
0.28	0.262	0.018	58
0.15	0.129	0.021	53
0.31	0.298	0.012	31
0.21	0.198	0.012	41
0.19	0.169	0.021	50
0.16	0.149	0.011	58
0.15	0.133	0.017	48
0.10	0.082	0.018	34

[a]Elapsed time between breath and blood sampling.

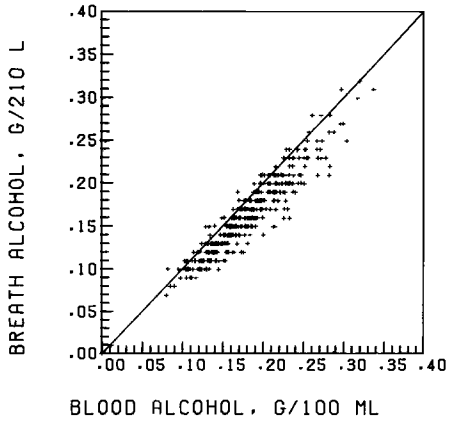

FIG. 2—*Scatter plot of Intoxilyzer 5000 versus blood-alcohol results. The line of 1:1 correlation is shown for reference.*

the line: BrAC = 0.8852 (BAC) − 0.0025. The data were significantly correlated (r = 0.9454). The slope of the regression line indicates a significant, systematic underestimation of 11.5% when the BrAC is used to estimate the coexisting BAC.

One would anticipate that the differences between paired results would be time dependent, with physiological changes in the alcohol concentration during the delay in collecting the second (blood) specimen influencing the magnitude of the difference. However, when the elapsed time between breath and blood sampling was compared with the differences between the 395 pairs of results, only a weak negative correlation was found (r = −0.2463), indicating that factors other than elapsed time are more important in explaining the observed difference.

The systematic underestimation of BAC by the Intoxilyzer 5000 found in this study can be attributed to the instrument's calibration using a 2100 : 1 blood- to breath-alcohol ratio rather than a ratio that reflects the mean population ratio of approximately 2300 : 1 documented in recent literature [*15–17*]. This can be illustrated if the BrACs obtained in this study are multiplied by 2300/2100 and plotted against the corresponding BACs (Fig. 3). Linear regression analysis of these data yielded the following equation for the line: BrAC = 0.964 (BAC) − 0.0031. The slope of the regression line indicates that the Intoxilyzer 5000 would systematically underestimate BAC by only 3.6% if it were calibrated using a 2300 : 1 ratio, in comparison with the 11.5% underestimation exhibited with its present calibration. The mean BrAC from the adjusted results is 0.17 (0.177) g/210 L, compared with the mean BAC of 0.180 g/dL. Paired t-test analysis indicates that there is a significant difference between these two means ($P < 0.001$).

Discussion

Intoxilyzer 5000 results correlated well with blood alcohol concentrations, while demonstrating a low bias. The 11.5% overall systematic underestimation of BAC found in this study is consistent with the 11% low bias found when police officers operated Breathalyzer Models 900 and 900A under similar conditions [*9*]. This bias appears to be primarily due to physiological variables and could be substantially reduced if the instruments were calibrated using a blood/breath alcohol ratio of 2300 : 1 instead of the currently used 2100 : 1. This is an unlikely, and perhaps undersirable option from a forensic science point of view, however. In jurisdictions where breath-alcohol results are expressed as a

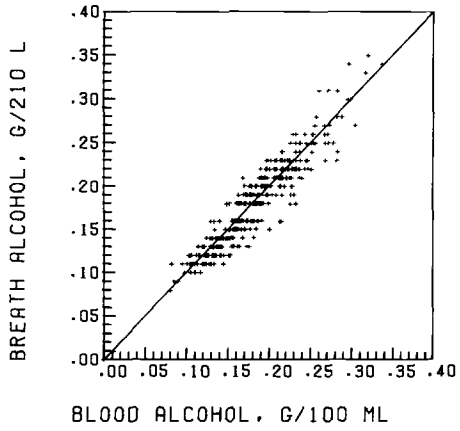

FIG. 3—*Scatter plot of Intoxilyzer 5000 results adjusted to a 2300:1 blood/breath alcohol ratio versus blood-alcohol results. The line of 1:1 correlation is shown for reference.*

coexisting BAC, it is far easier for a prosecutor to overcome a bias in favor of the defendant than to overcome the possibility of the converse.

The 1-h criterion used for the inclusion of data pairs in this study was deliberately chosen to minimize differences between BrAC and BAC that could be attributed to alcohol absorption and elimination. The chosen elapsed time between the breath and blood sampling did not appear to contribute significantly to the observed discrepancy between BrACs and BACs observed in this study.

The absorptive state of the subjects with regard to alcohol was not known in this study. It is likely, however, that the majority of the subjects were in a postabsorptive state or at least near to attaining a peak alcohol concentration by the time of the first (breath) test. This is due to the length of time necessary for completion of routine roadside arrest procedures, transportation to a breath testing site, and observation of the subject for 20 min prior to administering the breath test. After the breath tests had been administered and the subjects transported to a hospital or clinic for phlebotomy, it is likely that only a small fraction of them were not postabsorptive by the time that the blood specimen was drawn. Roadside arrest times were available in only a fraction of the cases in this study. These times, as well as information obtained from the sworn testimony of police officers in OMVWI trials, indicate that the elapsed time between the driving violations and the evidentiary breath test is rarely under 30 min and often over 1 h.

No evidence was found of falsely elevated BrAC results that could be attributed to unusually low individual blood- to breath-alcohol ratios, endogenous or exogenous interfering compounds in the breath, residual mouth alcohol, or electromagnetic interference. Overestimation of BAC by the Intoxilyzer 5000 was infrequent and of small magnitude. Indeed, most of the differences shown in Table 1 could be eliminated if the amount of alcohol theoretically eliminated in the time elapsed between the breath and blood specimen collection were added to the BAC.

Conclusion

It is clear from the data in this study that, in the context of a carefully controlled breath-alcohol testing program, the Intoxilyzer 5000 is likely to underestimate blood-alcohol concentrations in the driving population.

Acknowledgments

The authors wish to thank Cindy Schkirke for the many hours that she devoted to sorting and copying report forms.

Addendum

The Intoxilyzer 5000 is currently manufactured by CMI/MPD, Owensboro, Kentucky.

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Address requests for reprints or additional information to
Patrick Harding, Chemist
State Laboratory of Hygiene
465 Henry Mall
Madison, WI 53706