STATISTICAL ESTIMATION OF HIGH ALCOHOL CONCENTRATIONS DETERMINED IN BREATH AND IN BLOOD

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ABSTRACT: In the study an attempt was made to compare the blood alcohol concentrations obtained from the analysis of breath and from direct blood investigation. Blood samples were taken from those patients of the Sobering Chamber in Cracow in whom blood alcohol concentration determined by the analysis of breath exceeded 3‰. 56 results of simultaneous determinations of alcohol in blood samples and in breath were taken for the comparison. Breath alcohol concentrations were determined using Alcomat V5, which utilises selective absorption in the IR region. Blood alcohol investigations were carried out by means of gas chromatography with the use of headspace technique. The results of breath-alcohol analysis differed from –0.83‰ to 1.37‰ in comparison with the results of direct blood investigation. The relative difference between these two variables ranged from 18.6% to 54.8% for particular patients.The correlation between the results of breath- and blood-alcohol analyses were evaluated. The correlation coefficient amounted to 0.242 and was statistically insignificant ($p > 0.05$). Furthermore, the slope and the intercept of the straight line adjusted to the experimental data were significantly different from the expected values ($t_{b0} = 11.35$, $t_{b1} = 11.16$, whereas $t_{0.05,54} = 1.98$). This might indicate a very low precision of the results of breath analyses at high alcohol concentrations. Moreover, the blood/breath ratios were calculated for each patient. The mean value of this coefficient for the investigated group amounted to 2063:1 ± 230 (1 standard deviation), and the coefficient of variation amounted to 11.2%. Although the mean value of the blood/breath ratio is nearly the same as the one used in Alcomat, it varies depending on the patient from 1357:1 to 2580:1. The results of the study show that there is no justification for continuation of the current practice which consists in treating alcohol blood concentrations obtained by the analysis of breath as equivalent to alcohol concentrations determined in the direct analysis of blood samples.

KEY WORDS: Ethanol; Breath analysis; Blood analysis.

Problems of Forensic Sciences, vol. XLII, 2000, 209–214
Received 9 September 1999; accepted 16 May 2000

INTRODUCTION

A system of evidential breath-alcohol analysis was developed and set into medicolegal practice in the United States and has now spread to many countries in Europe, including Poland [7].

Breath alcohol analysis has several advantages over direct blood alcohol analysis, including the fact that it is a non-invasive method, and the breath yields immediate information whether a person was breaking the law by driving with BAC above the legal limit. The basic principle governing the design of breath-alcohol instruments is that a physiological relationship exists between the concentration of alcohol in the expired air and in the blood.

According to Polish law, breath alcohol analysis has evidential value [9], but despite this fact, it is still used as an indirect method of blood analysis. Unfortunately, even if a breath analyser is working perfectly and measurement conditions like temperature or humidity of the room are standard, the differences between the results of breath- and direct blood analysis are observed. This might be caused by differences in a persons body temperature, breathing pattern, volume of sample delivered, alteration of breathing style prior to delivery, phase of alcohol metabolism or uncertainty in the analytical methods [3, 6]. These differences are especially significant for high alcohol levels.

Therefore the aim of the study was to estimate the reliability of breath alcohol testing devices in the case of high alcohol concentrations.

MATERIAL AND METHODS

The subjects in the study were patients admitted to the Sobriety Chamber in Cracow in whom BAC was determined to be in excess of 3 promilles by the analysis of breath. 56 results of simultaneous determinations of alcohol in breath and in blood samples were taken for comparison.

The concentrations of alcohol in breath were determined by Siemens Instrument Alcomat V5 that utilizes selective absorption in the infrared region. The analyser shows the alcohol concentration in blood by the multiplication of alcohol content in breath by the factor 2100.

Blood alcohol determinations were carried out using gas chromatography with the use of the headspace technique. The Perkin Elmer Auto System chromatograph with the HS-40 autosampler was utilized. Separation was performed with the 0.2% Carbowax 1500 on Graphpack packed column.

RESULTS

The first step of the statistical analysis was to calculate the differences between the indications of breath analyser and the results of chromatographic analysis.

The results show that the alcohol concentrations indicated by breath analyser could be higher as well as lower that the results of direct blood analysis. Only 22% of the breath test results agreed with the corresponding blood test. Two tests were considered to agree

when there was a difference of 0.1 promille or less. In 28% of the cases the result of breath analysis was underestimated and in 50% of the cases it was overestimated. The range varied in 2.2 promilles. Although the differences look substantial, one must remember that we operate with very high alcohol levels.

The relative difference between these results was calculated for each person. In the majority cases, the relative difference did not exceeded 10%. Unfortunately, in an extreme case this difference exceeded 50%. From a statistical point of view these extreme cases are not important, but in forensic science and medical practise we must take these individuals situation's into consideration.

We must be sure that the result of breath alcohol analysis accurately reflects the concentration of alcohol in a person's blood, that is the concentration which reflects his or her state of impairment.

The next step was to estimate the correlation between the results of breath- and direct blood-alcohol analysis by GC. The results obtained by breath testing were plotted against the results obtained by chromatographic analysis. The scatter plot of relationship between breath- and blood-alcohol concentration is presented in Figure 1.

In the absence of errors a straight regression line should be obtained with a slope equal to 1, a zero intercept and a correlation coefficient equal to 1. Of course this is an ideal situation since, even in the absence of systematic errors, a scatter of the results around the best-fit line will always be observed. One must be able to decide if the experimental estimates of the regression coefficients in the line equation: slope and intercept, are significantly different from 1 and 0, respectively, and this can be

Fig. 1. Scatter plot of relationship between breath- and blood-alcohol concentrations.

performed using the Student's t-test [8].

The values obtained for the slope and intercept coefficients differ from the expected ones (1 and 0, correspondingly) and these differences are shown to be statistically significant. The regression coefficients indicate that the results of breath tests do not

correlate with the results of direct blood analysis for high alcohol concentrations. This is confirmed by a low value of the correlation coefficient equal to 0.25.

Moreover, we estimated a value of blood/breath ratio for alcohol for the examined group. The concentrations of alcohol in blood indicated by Alcomat device (in promilles) were recalculated for the concentrations in breath (in mg/dm^3). Next the results of GC analysis were divided by calculated contents of alcohol in breath. The frequency distribution of blood/breath ratios for the examined group is presented in Figure 2.

The mean value of the blood/breath ratio amounted to 2063:1 and median amounted to 2046:1. The range of the ratio varied from 1357:1 to 2580:1. The standard deviation was 230.3 and the coefficient of variation was 11.2%.

CONCLUSIONS

The results of the study indicate that the use of breath testing as an indirect method of

Fig. 2. Frequency distribution of blood/breath ratios.

blood analysis in cases of high alcohol levels should not to be advised. Although the mean value of blood/breath ratio is nearly the same as the one used in Alcomat device, it varied substantial between patients. This fact confirms the occurrence of considerable individual variability. For high alcohol concentrations, the results of breath-alcohol analyses do not correlate with the results of gas chromatographic analysis.

The results of our study differ from the results of the research carried out on volunteers or on drunk drivers which showed that the blood/breath factor should be closer to 2300:1 rather than to 2100:1 to obtain unbiased estimates of BAC during the postabsorptive phase [1, 2, 4, 5]. If we used for example a breath analyser, which utilises the 2300:1 factor, 86% of the cases would be overestimated. On the other hand the

results confirm the suggestions of some authors that the value of the blood/breath coefficient falls with the growth of alcohol concentration. It might be caused by disturbances in partition process of ethanol between the pulmonary blood and alveolar air in the lungs. Henry's law, which describes this process, is defined (obeyed) for an ideal diluted solute. Probably, for high alcohol concentrations these conditions are not fulfilled.

Breath alcohol analysis is the most convenient and economical method for the police and the least embarrassing and painful for the examined person. The breath alcohol method is highly practical to screen drunk drivers at the roadside. But, it seems that if a conclusion can have serious consequences, it would be preferable to make it on the basis of a direct blood measurement.

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