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The Comparison of Alcohol Concentrations in Postmortem Fluids and Tissues

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ABSTRACT: Fluid-tissue/blood alcohol ratios were calculated for a number of cases. The use of such factors to determine the blood alcohol concentration (BAC) becomes important when a blood specimen is not available or is contaminated. It was shown that estimates of blood alcohol concentrations derived from other physiological fluids or tissues can only be expressed as lying within a wide concentration range. Estimations of the BAC can be improved by using the stomach alcohol concentrations to determine if the deceased was in an absorption or postabsorption phase at the time of death.

KEY WORDS: toxicology, alcohol, postmortem examinations

Blood alcohol determination is one of the most frequently requested tests in forensic toxicology. However, there are instances when a blood specimen is not available for analysis (such as traumatic injuries) or when the blood sample may be contaminated. In light of these facts considerable effort has been made to find correlations between the blood alcohol concentration (BAC) and other body fluids and tissues [*1-9*].

It was the purpose of this study to determine the postmortem distribution ratios of ethanol in various fluids and tissues and to determine which fluid or tissue, when blood is unavailable or contaminated, can best be used with a conversion factor for estimating the BAC.

Materials and Methods

Specimen Collection

The following fluids or tissues were obtained incident to medicolegal autopsy examinations as mandated by the State of West Virginia Medical Examiner's Law (West Virginia Code, 61-12-10). All blood samples were drawn directly from the heart. Urine collection was obtained directly by needle puncture of the urinary bladder. The brain specimens represented frontal lobe tissue removed at autopsy without fixation. The pericardial sac

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fluid, spinal fluid, gastric contents, and vitreous humor were obtained from the appropriate organ or region. All specimens from the same autopsy case were analyzed simultaneously.

Gas Chromatography

A Perkin-Elmer Model 3920 gas chromatograph with a flame ionization detector was used under the following conditions: column, 0.2% Carbowax 1500 on Carbopack C packed in a 1.8-m (6-ft) glass column; operating temperatures, oven, 100°C; injection port, 150°C; and detector, 150°C; and carrier gas, nitrogen at a flow rate of 20 ml/min.

The gas chromatographic procedure was that of Jain [*10*]. Tertiary butyl alcohol was used as an internal standard. Brain specimens were first steam-distilled and then an aliquot of the distillate was subjected to gas chromatography.

Results

Table 1 shows the average brain/blood alcohol ratios obtained. In the calculation of these ratios, blood alcohol values were adjusted to weight/weight, assuming an average blood specific gravity of 1.054. Linear regression analysis was performed and the standard error of the estimate for each is shown in Table 2.

Table 2 shows that predictions of the BAC from other body fluids within a 95% confidence limit, that is, ±2 times the standard error of estimate, can only be expressed as lying within a broad concentration range. In an attempt to make better estimates of BAC, the ratios were recalculated by separating the cases into two groups, those with stomach alcohol concentrations less than 0.5 g/100 ml and those with more. These data are shown in Tables 3 and 4. Tables 5 and 6 show the standard error of the estimate for those cases with stomach alcohol concentrations less than 0.5 g/100 ml and those in which the concentration was greater, respectively. It was found that, with the exception of bile/blood alcohol ratios, the fluid-tissue/blood alcohol ratio was considerably more accurate when used to estimate BAC in those cases in which the stomach alcohol concentration was less than 0.5 g/100 ml than in those cases in which the stomach alcohol

TABLE 1—*Average tissue-fluid/blood alcohol ratios of human cadavers.*

	Cases, *n*	Blood Alcohol Range, g/100 ml	Average Ratio	Ratio Range
Vitreous/blood	110	0.046-0.697	1.05	0.48-1.72
Brain/blood	33	0.072-0.388	0.86	0.64-1.20
Bile/blood	89	0.046-0.697	0.99	0.48-2.04
Spinal fluid/blood	54	0.046-0.697	1.14	0.79-1.64
Urine/blood	92	0.046-0.697	1.16	0.53-2.17

TABLE 2—*Linear regression analysis of alcohol ratios.*

	Cases, *n*	Correlation	*m*	*b*	Standard Error of Estimate
Vitreous/blood	110	0.92	0.96	0.029	±0.051
Brain/blood	33	0.91	0.86	0.000	±0.035
Bile/blood	89	0.92	0.99	0.005	±0.048
Spinal fluid/blood	54	0.96	1.03	0.028	±0.041
Urine/blood	92	0.88	0.91	0.029	±0.063

TABLE 3—*Alcohol ratios in cases with stomach alcohol concentrations less than 0.5 g/100 ml.*

	Cases, *n*	Average Ratio	Theoretical[a] Ratio	Ratio Range
Vitreous/blood	37	1.19	1.27	0.86-1.72
Brain/blood	10	0.91	1.00	0.68-1.12
Bile/blood	29	0.99	1.00	0.58-1.35
Spinal fluid/blood	21	1.16	1.27	0.86-1.64
Urine/blood	30	1.32	1.33	0.92-2.13

[a] Water distribution ratio at equilibrium.

TABLE 4—*Alcohol ratios in cases with stomach alcohol concentrations greater than 0.5 g/100 ml.*

	Cases, *n*	Average Ratio	Theoretical[a] Ratio	Ratio Range
Vitreous/blood	23	0.89	1.27	0.48-2.00
Brain/blood	11	0.82	1.00	0.64-1.20
Bile/blood	15	0.96	1.00	0.57-1.30
Spinal fluid/blood	6	1.02	1.27	0.79-1.27
Urine/blood	16	0.92	1.33	0.53-1.33

[a] Water distribution ratio at equilibrium.

TABLE 5—*Linear regression analysis of alcohol ratios in cases with stomach alcohol concentrations less than 0.5 g/100 ml.*

	Cases, *n*	Correlation	*m*	*b*	Standard Error of Estimate
Vitreous/blood	37	0.93	1.14	0.010	±0.032
Brain/blood	10	0.95	0.97	−0.008	±0.027
Bile/blood	29	0.89	1.06	−0.007	±0.045
Spinal fluid/blood	21	0.95	1.11	0.014	±0.030
Urine/blood	30	0.87	1.18	0.037	±0.042

TABLE 6—*Linear regression analysis of alcohol ratios in cases with stomach alcohol concentrations greater than 0.5 g/100 ml.*

	Cases, *n*	Correlation	*m*	*b*	Standard Error of Estimate
Vitreous/blood	23	0.89	0.95	−0.001	±0.063
Brain/blood	11	0.85	0.83	−0.003	±0.047
Bile/blood	15	0.96	1.06	−0.015	±0.043
Spinal fluid/blood	6	0.93	0.95	0.043	±0.056
Urine/blood	16	0.89	0.85	0.047	±0.076

concentration was greater. In the case of the bile/blood alcohol ratio, there was an insignificant difference in the ratio regardless of the stomach alcohol concentration.

Discussion

Tables 1 and 2 show that any estimate of the blood alcohol concentration from another physiological fluid or tissue can only be expressed as lying within a wide concentration

range. The formula for calculating the blood alcohol concentration from the alcohol concentration in another fluid or in tissue is

$$\frac{a - b}{m}$$

where

a = measured concentration,
m = slope of the linear regression line, and
b = y intercept of the linear regression line.

Twice the standard error of the estimate must be added to or subtracted from the calculated BAC to achieve a 95% confidence level. A sample calculation using the data from Table 2 and a given vitreous humor alcohol concentration of 0.20 g/100 ml would be

$$\frac{0.20 - 0.029}{0.96} = 0.17$$

$$2 \times 0.05 = 0.10$$

Therefore,

$$\text{BAC} = 0.17 \pm 0.10$$

In actual cases only a few stomach alcohol levels exceed 5 g/100 ml of stomach contents. This fact indicates that alcohol absorption from the stomach is very rapid and gives support to the theory that the phase of alcohol absorption can be predicted from the alcohol level in the stomach. In our study, the alcohol level of 0.5 g/100 ml was chosen arbitrarily as the median between the absorption and postabsorption phases. Cases with alcohol concentrations less than 0.5 g/100 ml of stomach contents were considered to be in the postabsorption phase and the others were considered to be in an absorption phase. Examination of Tables 3 and 4 reveals that the theoretical alcohol distribution values, in most instances, were much closer to the actual values when the stomach alcohol concentration was less than 0.5 g/100 ml. Recalculation of the estimates of BAC from brain, vitreous humor, spinal fluid, and urine significantly improved the standard error of the estimate for cases in which the stomach alcohol concentration was less than 0.5 g/100 ml (Tables 5 and 6). The reliability of bile alcohol concentrations in estimating BAC was the same for absorption and postabsorption phases. Coe and Sherman [*4*] discussed the absorption phase of the alcohol as an explanation for different conversion factors being reported in various studies [*3,6,7*] to estimate the BAC from the vitreous humor alcohol concentrations. Felby and Olsen [*3*] excluded those cases in which the vitreous humor alcohol values were lower than the blood alcohol values, therefore limiting their cases to those that were most likely postabsorptive.

It was concluded that in the absence of blood for analysis, when the stomach alcohol concentration was less than 0.5 g/100 ml, brain, spinal fluid, or vitreous humor could be used equally well to estimate the actual BAC. As the advantages of vitreous humor are already well established (more readily available, less chance of bacterial contamination, and good stability of alcohol [*3,4,6,7*]), it was thought that this specimen would be the most reliable one to use for estimating BAC in those cases in which the stomach alcohol concentration is less than 0.5 g/100 ml. When the stomach alcohol concentration is unavailable or is greater than 0.5 g/100 ml, it would be better to use bile for BAC estimates. The standard error of the estimate for converting bile alcohol concentrations to BAC

changed very little whether the deceased was in an absorption or postabsorption phase at the time of death (Tables 5 and 6), and bile had the smallest error of the estimate when the stomach alcohol concentration was greater than 0.5 g/100 ml (Table 6).

Summary

Estimations of BAC derived from other physiological fluids or tissues can only be expressed as lying within a wide concentration range. The determination of the alcohol concentration in stomach contents can serve to improve the accuracy of blood alcohol estimates as derived from other fluids or tissues.

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