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Significance of variations in blood: breath partition coefficient of alcohol

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Summary

A helium-neon laser was used to measure the alcohol content of breath from six volunteers at regular intervals over up to four hours. The corresponding blood values were calculated with a blood:breath partition coefficient of 2100. When these values were compared with those obtained by direct measurement it was obvious that substantial variations occurred from one person to another in the derived values and that even in the same person the use of the partition coefficient of 2100 led to significant differences between the direct and derived values for blood, and these differences changed with time. Thus the assertion that a constant partition coefficient of 2100 exists between alcohol in blood and that in breath is not supported by the evidence. Accordingly the use of such a partition coefficient to derive blood alcohol values for law enforcement is not justified.

Introduction

The possibility that accurate blood alcohol values can be derived from measuring alcohol in breath has important implications in law, particularly in the United Kingdom in relation to the proposed revision of the relevant sections of the Road Traffic Act 1972.¹ But before breath analysis can be accepted as a substantive test in the courts two vital questions need to be answered. Firstly, are techniques available that will allow the alcohol content of breath to be accurately determined? Secondly, can an accurate determination of the alcohol content of blood be obtained from breath analysis by using of a universally applicable conversion factor? We describe here experiments carried out in an attempt to answer these questions.

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Method

Breath was analysed with a helium-neon infrared analyser designed and built by Powell² and modified specifically for measuring alcohol vapour in breath by Alobaidi.³ The apparatus has been described in detail elsewhere.⁴

Calibration ethanol-air mixtures were generated by a slow injector system⁵ over the range of 5 to 28 000 parts per million (ppm) by volume (0.022-116.3 $\mu\text{mol/l}$ (1.0-5356 $\mu\text{g/l}$)) at 20°C and 760 mm Hg. Initially, the slow injector output was verified with the aid of a manometric mixing technique and a flame ionisation detector gas chromatograph with oxygen as an internal standard.³ These known ethanol-in-air concentrations were used to calibrate the analyser before and after analysing each batch of breath samples.

Six volunteers, five men and one woman aged 20 to 58 years and weighing 57 to 76 kg were studied. On arrival in the laboratory they had fasted and abstained from alcohol for at least 12 hours and had taken no soft drinks for at least four hours. Breath and venous blood samples were obtained as previously described.⁶ Five volunteers chose to drink whisky 70° proof 100 ml diluted with 100 ml of water; the sixth preferred gin 70° proof diluted with 100 ml of tonic water. Up to three minutes was allowed for drinking, and in some cases this was followed by two minutes' mouthwashing. The length of each experiment varied but the average was three hours.

During the first two hours after drinking batches of three breath samples were taken in rapid succession at five- to 10-minute intervals and then at 15-minute intervals. The mean value of the three results in each batch was calculated and recorded. Blood samples were withdrawn immediately after the third breath sample in each batch and stored in plastic pots (0.3 ml) or glass phials (1 ml). Only one type of container was used for each volunteer. The samples were stored in a domestic refrigerator until analysed by the method of Curry *et al.*⁷ All analyses were done in duplicate and many in triplicate.

The measured blood alcohol concentrations were compared with the calculated values derived from the measured breath concentrations. For this purpose the partition coefficient of 2100:1, recommended by the British Medical Association,⁸ was used. The actual partition coefficients were also calculated for each volunteer from paired breath and blood alcohol concentrations at regular intervals.

Results

CALIBRATION STUDIES

The results in table I indicate that a high degree of reproducibility was achieved at all three speeds over the range 205 to 1226 ppm. On the basis of calibration with such alcohol vapour mixtures the laser infrared analyser response was linear within $\pm 5\%$ over the range 0-12 000 ppm of ethanol vapour by volume (0 to 49.8 $\mu\text{mol/l}$ (0-2296 $\mu\text{g/l}$)) at 20°C and 760 mm Hg. Over the range of interest of 0-500 ppm (0 to 2.08 $\mu\text{mol/l}$ (0-96 $\mu\text{g/l}$)) at 20°C and 760 mm Hg) ethanol vapour

TABLE I—Chromatographic calibration results from three slow injector speeds

Liquid sample injection speed (cm/min)	Gas flow rate (l/min)	Average peak height ratio vapour: oxygen	Standard deviation	No of samples	Concentration (ppm v/v)
0.22	0.1	10.371	0.305	20	1226
0.00909	0.1	3.875	0.125	19	449
0.00372	0.1	1.732	0.041	31	205
0.00372	0.5	3.427	0.0848	11	402

NB A maximum coefficient of variation of 3.22% at the 449 ppm v/v level was produced.

concentrations could be measured with a precision of $\pm 3\%$ when calibration checks were performed immediately before and after each batch of analyses.

VOLUNTEER STUDIES

A large signal, attributable to mouth alcohol, was recorded immediately after drinking, but this dropped steeply over the next 10 minutes. Thereafter the breath alcohol concentration rose steadily until a peak was reached between 18 and 85 minutes after drinking. The peak concentrations varied significantly between the volunteers over the range 0.0347 to 0.0890 mmol/l breath (0.16–0.41 mg/100 ml). Although these variations in peak times and peak concentrations were substantial they followed almost exactly the pattern of the corresponding blood alcohol concentrations, except in one volunteer (subject 1), who produced a series of breath alcohol values that did not correspond with the coincident blood values (table II). For example, 69 minutes after he had stopped drinking his maximum breath concentration was 1136 ppm by volume, equivalent to 106 mmol/l blood (488 mg/100 ml), when his measured blood alcohol concentration was only 8.84 mmol/l (40.75 mg/100 ml). There was no obvious explanation for this deviation from the normal pattern.

The quantitative data for breath and blood collected from each experiment are set out in tables II and III together with the derived partition coefficients. From these data it is clear that not only did the blood-breath partition coefficients vary from one person to another but also that they varied with time in the same person. Tables II and III also list the calculated blood alcohol concentrations obtained when the recommended partition coefficient of 2100:1 was used to convert the measured breath alcohol values.

Discussion

Over the range of immediate interest (65 to 1200 ppm) ethanol vapour concentrations can be measured with a precision of $\pm 3\%$ when calibration checks are carried out before and after analysing each batch. This corresponds with the degree of accuracy shown for the conventional Luft-type non-dispersive infrared gas analyser,⁶ but extends it over a greater range.

TABLE II—Breath and blood alcohol concentrations and corresponding partition coefficients obtained from volunteer (subject 1) who did not follow usual pattern. Values above short dividing lines were obtained before alcohol peaks were reached

Measured blood alcohol (mmol/l)	Breath alcohol (mmol/l)	Partition coefficient	Calculated blood alcohol (mmol/l) (breath value $\times$ 2100)
7.245	0.006 94	1043	14.58
8.473	0.005 36	1581	11.26
10.745	0.006 62	1624	13.90
9.826	0.007 57	1297	15.90
9.457	0.009 31	1016	19.55
8.413	0.010 09	834	21.19
8.843	0.050 51*	175	106.1
8.598	0.007 05	1219	14.81
8.719	0.008 27	1055	17.36
7.736	0.003 60	2148	7.57
7.122	0.004 25	1674	8.93
5.894	0.003 78	1561	7.93
6.508	0.003 45	1886	7.25

Conversion: SI to traditional units—Alcohol: 1 mmol/l $\approx$ 4.6 mg/100 ml.
*This exceptionally high breath alcohol value, obtained after regurgitation, was disregarded in all calculations.

TABLE III—Breath and blood alcohol concentrations and corresponding partition coefficients obtained during experiment in volunteers. Values above short dividing lines were obtained before alcohol peaks were reached

Measured blood alcohol (mmol/l)	Breath (mmol/l)	Partition coefficient	Calculated blood alcohol (mmol/l) (breath value $\times$ 2100)
<i>Subject 2</i>			
14.852	0.006 29	2358	13.21
17.762	0.008 98	1980	18.86
17.284	0.008 25	2096	17.33
16.707	0.005 97	2803	12.54
14.852	0.006 14	2420	12.89
14.467	0.006 14	2357	12.89
13.187	0.006 75	1955	14.18
13.250	0.006 90	1922	14.49
12.547	0.006 73	1874	14.13
10.627	0.005 40	1968	11.34
12.226	0.004 47	2730	9.39
11.395	0.004 79	2374	10.06
11.586	0.004 64	2492	9.74
8.834	0.003 60	2455	7.56
8.578	0.003 91	2200	8.21
7.298	0.003 60	2028	7.56
8.834	0.003 15	2806	6.62
9.858	0.003 15	3133	6.62
<i>Subject 3</i>			
2.02	0.001 80	1123	3.78
6.512	0.002 10	3103	4.41
7.860	0.003 60	2183	7.56
10.106	0.004 34	2323	9.11
10.781	0.004 49	2397	9.43
10.106	0.004 79	2105	10.06
10.556	0.005 12	2199	10.75
12.352	0.004 58	2691	9.62
9.433	0.004 19	2247	8.80
9.207	0.003 60	2559	7.56
7.187	0.003 91	1844	8.21
<i>Subject 4</i>			
3.168	0.002 13	1496	4.47
6.354	0.002 28	2799	4.78
7.704	0.002 73	2826	5.73
10.125	0.003 62	2787	7.60
12.310	0.005 29	2326	11.11
13.502	0.005 32	2541	11.17
11.753	0.005 29	2221	11.12
11.119	0.005 16	2148	10.84
10.086	0.003 82	2644	8.02
8.815	0.003 36	2624	7.06
8.020	0.002 82	2850	5.92
7.545	0.003 47	2169	7.29
<i>Subject 5</i>			
3.722	0.001 65	2256	3.46
5.291	0.003 60	1469	7.56
5.291	0.004 06	1306	8.53
8.229	0.004 34	1891	9.11
8.424	0.004 06	2080	8.53
6.875	0.003 15	2176	6.62
9.209	0.004 49	2050	9.43
7.250	0.003 67	1975	7.71
8.033	0.003 75	2142	7.88
7.053	0.003 21	2196	6.74
6.464	0.003 34	1938	7.01
5.290	0.002 84	1861	5.96
<i>Subject 6</i>			
1.447	0.001 02	1419	2.14
2.170	0.001 02	2128	2.14
4.101	0.001 65	2487	3.47
5.789	0.002 26	2575	4.75
6.104	0.002 69	2261	5.66
7.721	0.003 60	2146	7.56
6.514	0.002 99	2172	6.28
6.755	0.002 84	2373	5.98
7.239	0.003 29	2193	6.91
4.449	0.003 15	1414	6.62
5.425	0.002 69	2010	5.65

Thus there is ample evidence from these experiments and from those of other workers using different types of equipment that the amount of ethanol present in a gas mixture can be measured with a substantial degree of accuracy.⁹⁻¹² It is reasonable therefore to conclude that techniques are available which will allow the alcohol concentration in breath to be accurately determined.

When breath alcohol measurements were used to calculate the amount of alcohol present in whole blood the derived values often differed substantially from those obtained by direct measurement. The validity of the conversion factor of 2100 must therefore be in doubt. This factor has already been questioned by Payne *et al*, who published data showing that the blood:breath partition coefficient was probably too low, that it gave wrong

results when applied universally, and that even in the same person there were significant discrepancies.⁶ Our findings confirm and amplify these earlier observations and those of other workers.¹³⁻¹⁶ In particular, Entiknap and Wright described similar disparities in a study of two volunteers.¹⁶ The relevant blood:breath ratios averaged 2475:1, which was not significantly different from the ratio of 2470 obtained from the 24 volunteers studied by Payne *et al.*⁶ Moreover, in both subjects significant changes in the ratio occurred for short periods during the experiment. Entiknap and Wright suggested that on balance a figure of 1:2370 for the breath:blood ratio "seems a reasonable guess." But "a reasonable guess" should not be used to obtain a conviction in a court of law.

In a later study similar values were reported by Jones, who obtained blood:breath ratios that averaged 2367 (range 2120-2950) in 15 volunteers.¹⁰ In each of his volunteers the ratios changed during the course of the experiment by as much as 24%. The pattern of these blood:breath ratios corresponds to the pattern that we found, although our ratio for five subjects at 2271 was slightly lower and our range of 1123 to 3100 considerably wider.

More recently Jones *et al.*¹² have attempted to reassess the value of breath analysis. According to their calculations the results derived from 78 comparisons of capillary blood values with breath values showed a line of best fit at a ratio of 2300:1, although no hard data were presented to allow an independent check. Clearly therefore the blood:breath ratio not only varies from person to person but also widely in the same person with time.

A possible explanation for these variations was suggested by Payne *et al.*,⁶ who pointed out that equilibrium between pulmonary blood and alveolar air can be achieved only when inspired air is perfectly distributed within the lungs relative to the pulmonary blood flow, that even in healthy people some degree of ventilation-perfusion inequality exists, and that such inequality is greater in the presence of established lung disease. Furthermore, even if equilibrium were reached between pulmonary blood and alveolar air it is unlikely that the mucus secretions of the bronchial tree would also reach equilibrium at

the same speed. Thus some exchange of alcohol vapour might be expected to take place between breath and mucus during passage along the bronchial tree, particularly during the early stages of absorption.

Accordingly, as has been argued,¹⁷ the blood:breath ratio should be regarded as nothing more than a statistical convenience suitable for defining the limits of a particular universe. Its use to derive individual blood alcohol levels from breath alcohol levels has little scientific justification, and, more particularly, its use in this way for law enforcement can only be deplored. We reiterate our view that breath analysis is not an acceptable method for accurately determining blood alcohol concentrations.

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Coagulation and fibrinolysis in intact hydatidiform molar pregnancy

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Summary

Tests of coagulation, fibrinolysis, and platelet function were performed in 17 patients with intact molar pregnancies. Women with intact molar pregnancies had higher fibrinogen, factor VIII, and fibrinogen degradation products, concentrations and lower prothrombin, factor X, plasminogen, and plasminogen activator concentra-

tions than controls with normal pregnancies. They also had reduced platelet counts and thromboelastographic values, which indicated hypocoagulability. These results suggest that intravascular coagulation occurs in intact hydatidiform molar pregnancies.

Introduction

Normal pregnancy is accompanied by changes in the coagulation as well as the fibrinolytic system. These changes occur in parallel with the period of gestation,^{1,2} being minimal in the first trimester and changing progressively thereafter.

Certain abnormal pregnancy states, such as eclampsia,³ pre-eclampsia,^{4,5} intrauterine death,^{6,7} amniotic fluid embolism,^{8,9} abruptio placentae,¹⁰ and septic abortion, are also accompanied by coagulation and fibrinolytic abnormalities.

Coagulation disorders have been suspected in hydatidiform molar pregnancies when there has been a previous serious

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