

ARTICLES

A SIMULATION OF THE EFFECT OF BLOOD IN THE MOUTH ON BREATH ALCOHOL CONCENTRATIONS OF DRINKING SUBJECTS.

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ABSTRACT

After consuming lunch, twenty-six male subjects ingested alcohol *ad libitum* over approximately one hour. At least 1.5 hours after drinking ceased, the subjects provided breath samples into a Breathalyzer® Model 900 or 900A. Immediately after providing the breath samples, blood was collected from the cubital vein using a sterile disposable plastic syringe. Part of the blood sample (3-10 mL) was placed into a blood tube containing 1 % sodium fluoride and 0.5 % sodium citrate and was analysed for alcohol by headspace gas chromatography. The remaining blood (3-10 mL) was placed in the subject's mouth for up to 30 seconds and then swallowed or expectorated. A second Breathalyzer test was conducted within ten minutes of the first. The blood alcohol concentrations of the subjects averaged 0.095 g/dL and ranged between 0.044 to 0.168 g/dL. The untruncated Breathalyzer results were significantly lower after introducing blood into the mouth ($p=0.017$). When these Breathalyzer results were truncated to two decimal places, however, these slight differences were eliminated. In addition, when the initial Breathalyzer results were compared to the blood alcohol concentrations the apparent blood breath ratios averaged 2319, with a range of 1947:1 to 2654:1. We conclude that blood in the mouth does not lead to an overestimation of the breath alcohol concentration of drinking subjects.

RÉSUMÉ

Après le repas du midi, on a demandé à 26 sujets mâles de consommer de l'alcool *ad libitum* durant une période approximative d'une heure. Des échantillons d'haleine ont été obtenus de ces sujets après au moins une heure et demie suivant la fin de la période de consommation d'alcool et ont été analysés à l'aide d'instruments de type Breathalyzer® modèle 900 ou 900A. Immédiatement après l'obtention des ces échantillons d'haleine, du sang a été prélevé de ces sujets à l'aide d'une seringue de plastique stérile à usage unique. Une partie des échantillons de sang (3-10 mL) a été transférée à un tube qui contenait du fluorure de sodium à 1% et du citrate de sodium à 0.5%. La concentration d'alcool de ce sang a été déterminée par chromatographie en phase gazeuse à espace de tête. La quantité résiduelle de sang (3-10 mL) a été placée dans la bouche du sujet pour une durée de temps d'au moins 30 secondes et , par la suite, a été avalée ou

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expectorée. Une deuxième analyse d'alcool a été faite à l'aide du **Breathalyzer®** durant les dix prochaines minutes après la première analyse. La concentration moyenne d'alcool dans le sang était de 0.095 g/dL avec un écart de concentrations de 0.044 à 0.168 g/dL. Les résultats non tronqués obtenus avec le **Breathalyzer®** étaient significativement inférieurs après l'introduction du sang dans la bouche ($p=0.017$). Cependant, après que ces mêmes résultats ont été tronqués jusqu'à la deuxième décimale, ces différences minimales ont été éliminées. De plus, une comparaison des résultats initiaux provenant du **Breathalyzer®** avec les concentrations sanguines d'alcool a révélé un rapport de la concentration d'alcool du sang à l'haleine de 2319 avec un écart de 1947:1 à 2654:1. On arrive donc à la conclusion que du sang dans la bouche ne résulte pas en une surestimation de la concentration d'alcool présente dans l'haleine des sujets.

INTRODUCTION

The potential of residual alcohol in the oral cavity (mouth alcohol effect) leading to elevated breath alcohol test results has been studied since 1867 (1). Since then, the effect of numerous alcohol-containing compounds have been tested such as mouthwashes, breath sprays, asthma inhalers, cough medicine, and liquor-filled chocolates (2-6). This has led to the development of procedural and instrumental safeguards to reduce or prevent the reporting of mouth alcohol as a blood alcohol concentration. These safeguards include deprivation times of fifteen to twenty minutes, duplicate breath alcohol testing and mouth alcohol detectors.

An unusual aspect of the mouth alcohol effect has been raised in Criminal Courts in Canada (7,8) and Australia (9) regarding the influence that blood in the mouth has on breath alcohol concentration (BrAC). It has been argued that a breath alcohol test being conducted by the police on a drinking suspect would be falsely elevated if the suspect had blood in the oral cavity, as a result of periodontitis, cuts to the mouth received in an automobile accident, or dental work prior to being arrested. Since it is known that blood contains approximately 2,300 times the alcohol content of breath (10), it has been suggested that the presence of alcohol-laden blood in the oral cavity could cause a large increase in the alcohol concentration of the breath sample. It has been further argued that since the blood is continually bleeding into the oral cavity, the safeguards such as deprivation times and duplicate testing would not be sufficient as the blood alcohol in the mouth is continually being renewed by bleeding. The other safeguard, the mouth alcohol detector that is found in newer evidential instruments, such as the **Intoxilyzer® 5000C**, is not completely reliable at detecting mouth alcohol (11). Due to these potential concerns, the present study was conducted to simulate the effect of blood in the mouth on the breath alcohol concentration of drinking subjects.

METHOD

Twenty-six male volunteers who participated in **Breathalyzer** technician training courses conducted at the Centre of Forensic Sciences in Toronto were tested. After eating lunch the subjects consumed various volumes and types of alcoholic beverages over approximately one hour. The subjects' initial BrAC's were then tested on a **Breathalyzer® Model 900 or 900A** (National Draeger Inc, Pittsburgh, Pa., USA), which determines the breath alcohol concentration by potassium dichromate oxidation (12), and is an approved evidential instrument in Canada.

Negative control tests were conducted to ensure that the **Breathalyzer** and room air were alcohol free (i.e. $< 0.010\text{g}/210\text{L}$). The accuracy of the **Breathalyzer** was then checked

using Alcohol Standard in an equilibrator (13). The Alcohol Standard solution was manufactured at the Centre of Forensic Sciences and tested by the modified Widmark method (14) to ensure that the concentration was 3.38 ± 0.07 milligrams of alcohol in one millilitre of solution (mg/mL) as recommended by the Alcohol Test Committee (15). The results of the Breathalyzer tests were always within ± 0.005 grams of alcohol in 210 L of breath (g/210L) of the target value. The Breathalyzer results, or breath alcohol concentrations, are reported in this study as g/210 L of breath. This unit, which is widely used in the United States, is equivalent (when multiplied by 1000) to a blood alcohol concentration (BAC) measured in milligrams of alcohol in 100 millilitres of blood when using the forensically acceptable blood breath ratio of 2100:1. The Criminal Code of Canada and the Recommended Standards and Procedures of the Canadian Society of Forensic Science Alcohol Test Committee use these units (mg/100mL) to define BACs whether it is obtained from blood or breath samples (15).

At least 1.5 hours after drinking ceased, subjects provided breath samples into the Breathalyzer. While the breath result was being analysed and a flush test conducted, a blood sample was collected from the cubital vein by a qualified medical technician using a sterile disposable plastic syringe. Approximately one-half of the blood sample (3-10 mL) was transferred into a tube containing 1% sodium fluoride and 0.5% potassium citrate as a preservative and anticoagulant respectively. The remaining blood (3-10 mL) was injected into the mouth from the syringe, where it was held for up to 30 seconds and either swallowed or expectorated. Another Breathalyzer test was conducted on the subject within ten minutes of the first, but within 1 minute of expectorating or swallowing the blood. The spit trap mouthpiece used with the instrument was changed prior to each subject test.

The preserved blood sample was refrigerated, for no more than 7 days, until it was analysed for alcohol by headspace gas chromatography using the modified method of Machata (16). The mean of the duplicate blood test results is reported here.

Data are presented as the mean (+ 1 standard error of the mean). Statistically significant differences between measured breath alcohol concentrations before and after the addition of blood to the mouth were assessed using a paired Student's t-test, while an unpaired test was used to compare the actual measured blood alcohol concentration to the initial breath alcohol measurement. Differences between the measured blood alcohol concentration and the breath alcohol concentrations before and after blood was added to the mouth, were considered statistically significant when the calculated P value was less than 0.05 ($P < 0.05$ level).

RESULTS and DISCUSSION

Table 1 shows the BrAC before and after the blood was placed in the mouth and the blood alcohol concentration (BAC), with values arranged from lowest to highest BrAC. The first Breathalyzer test (initial BrAC = control) and the BAC were also used to determine the apparent blood:breath ratio of alcohol (BBR). The mean apparent BBR averaged 2319:1 (± 32) and ranged between 1947:1 to 2654:1, which is consistent with previous studies on the BBR (10, 17).

Since the blood contains approximately 2300 times as much alcohol as breath, it has been argued that blood in the mouth would falsely elevate breath alcohol concentrations. However, when one carefully considers alcohol's physico-chemical properties, it is evident that the presence of blood in the mouth should not elevate the measured breath alcohol concentration. The amount of alcohol in an air sample is based upon Henry's Law, which states that when a solution containing a volatile substance (such as alcohol) is in

TABLE 1

The BrAC (g/210L) before and after blood was placed in the oral cavity, the corresponding BAC (g/dL), and the apparent blood breath ratio for alcohol (BBR), in 26 male, drinking subjects.

Subject #	Initial BrAC Before Blood in the Mouth (g/210L)	BrAC After Blood in the Mouth (g/210L)	BAC (g/dL)	Apparent BBR
1	0.041	0.040	0.044	2254
2	0.059	0.055	0.069	2456
3	0.067	0.069	0.079	2476
4	0.068	0.067	0.072	2224
5	0.069	0.066	0.071	2161
6	0.069	0.068	0.078	2374
7	0.072	0.080	0.091	2654
8	0.072	0.065	0.082	2392
9	0.078	0.079	0.088	2369
10	0.078	0.074	0.082	2208
11	0.079	0.070	0.088	2339
12	0.079	0.077	0.088	2339
13	0.080	0.074	0.092	2415
14	0.080	0.079	0.093	2441
15	0.081	0.079	0.092	2385
16	0.085	0.089	0.095	2347
17	0.093	0.093	0.106	2394
18	0.094	0.094	0.089	1988
19	0.095	0.090	0.105	2321
20	0.095	0.098	0.099	2188
21	0.097	0.098	0.113	2446
22	0.099	0.100	0.115	2439
23	0.110	0.097	0.102	1947
24	0.115	0.110	0.120	2191
25	0.127	0.121	0.153	2530
26	0.175	0.163	0.168	2016
Mean	0.087	0.084*	0.095	2319
SD	0.025	0.023	0.025	164
SEM	0.0049	0.0048	0.025	32

Asterisks (*) indicates significant difference from initial BrAC ($P < 0.05$).

equilibrium with air, the ratio between the concentration of that substance in solution and its vapour pressure in air is fixed at a given temperature. Thus, when blood is in the mouth, the amount of alcohol vapour arising from the blood in lung air should be similar to that arising from the blood in the mouth air, after correcting for temperature differences between the two locations.

In the present study, the mean BrAC was 0.087 g/210 L before blood was placed in the mouth but significantly lower at 0.084 g/210 L, after blood was placed in the mouth (Figure 1; $P = 0.017$). In terms of evidential breath testing, these slight decreases in BrAC would not be considered forensically relevant. In Canada, qualified breath technicians truncate all breath alcohol readings to two decimal places when certificates of analysis are issued (15). When the data in this study were truncated in this manner, significant differences between the BrAC before and after blood was placed in the mouth were eliminated (Figure 2; $P = 0.20$).

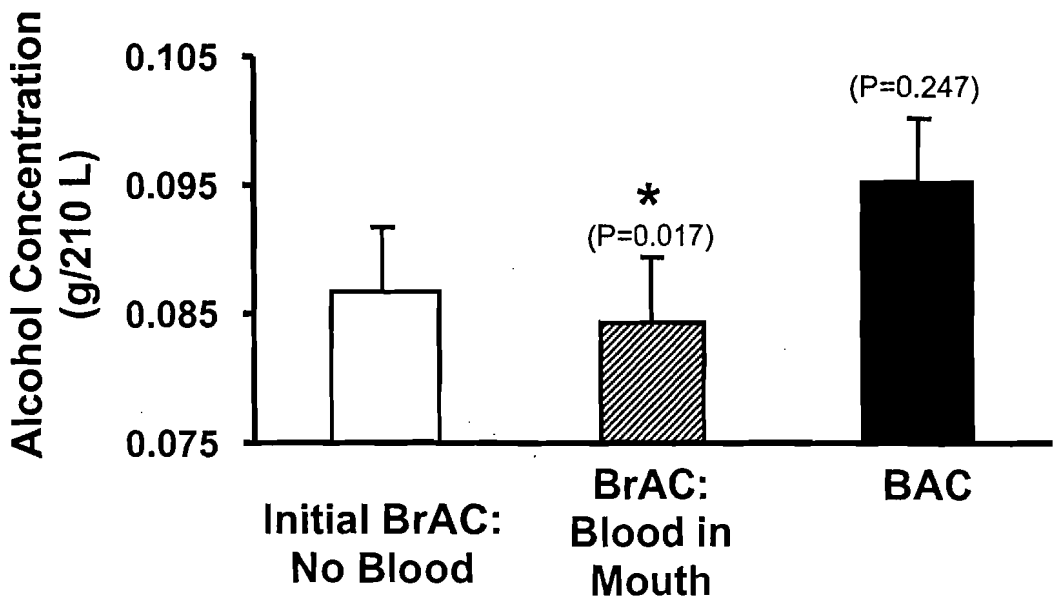


Figure 1. Mean breath alcohol concentrations (BrAC) measured in male subjects following alcohol consumption. BrAC was measured before (open bar) and after the addition of blood to the mouth (hatched bar) of each subject following alcohol consumption. For reference, data are compared to the blood alcohol concentrations (solid bar) measured in blood samples obtained within 10 minutes of the initial BrAC measurement. The data are expressed as the mean (+ 1 standard error of the mean; $n = 26$ subjects). Asterisk indicates that the mean BrAC is significantly different from initial BrAC measurements (No Blood; $P = 0.017$).

The slightly lower second BrAC detected may be explained in part by the up to ten minute time interval between the two tests. Under these conditions a subject is in the elimination phase, and with the generally accepted rates of elimination of 0.01 to 0.02 g/100 mL per hour (18), could undergo a decrease in BrAC of approximately 0.002 to 0.003 g/210L.

Another possible reason for the lower BrAC result is that the end-expiratory BrAC is based in part on the saliva/mucous alcohol concentration in the oral cavity. Saliva contains 1.08 times as much alcohol than whole blood (19). Thus, the addition of blood to the mouth could tend to slightly decrease the overall alcohol concentration in the oral cavity. As the breath measurements were made within one minute following the removal of blood from the mouth cavity, it is unlikely that there would have been sufficient time for any potential mouth alcohol effect to dissipate.

Another aspect to consider is that the quantity of alcohol in the blood is much less than that in the usual mouth alcohol experiment using alcohol solutions of up to 40% v/v (Table 2). For example, 5 mL of blood at a concentration of 0.080 g/dL will contain 0.004g of alcohol, whereas 5 mL of beer (5% v/v) will contain approximately 50 times more alcohol (Table 2). A mouthful of beer swallowed by alcohol-free subjects has been shown to elevate the BrAC by up to 0.016 g/210L after five minutes (20), so proportionally the amount of alcohol in the blood sample may be expected to elevate the BrAC by only 1/50th of the beer result (Table 2).

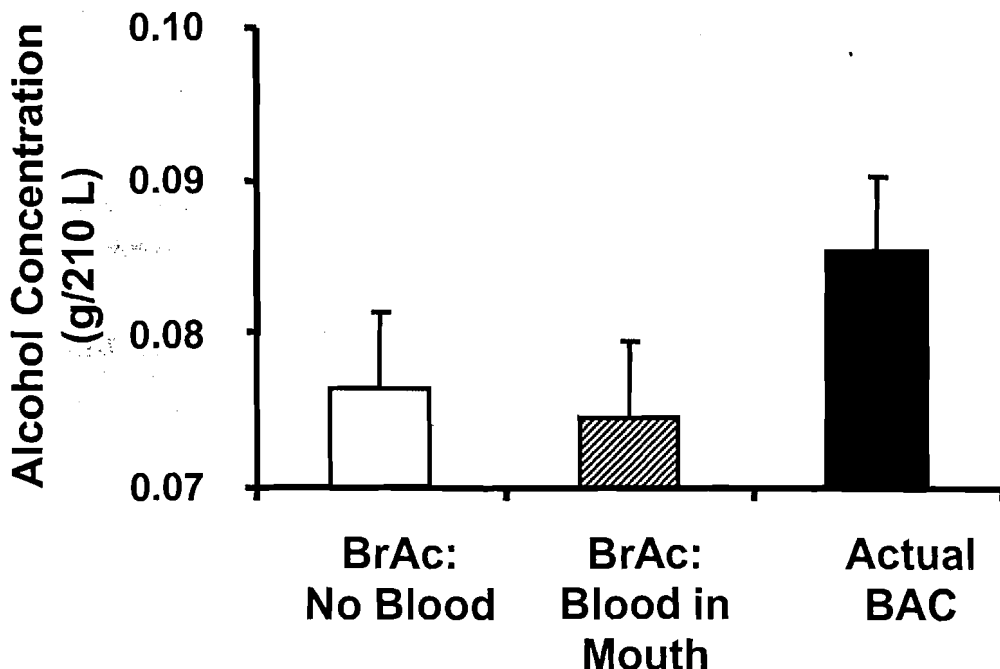


Figure 2. Mean truncated breath alcohol concentrations (BrAC) measured in male subjects following alcohol consumption. BrAC was measured before (open bar) and after the addition of blood to the mouth (hatched bar) of each subject following alcohol consumption. For reference, data are compared to the truncated blood alcohol concentrations (solid bar) measured in blood samples obtained within 10 minutes of the initial BrAC measurement. The data are expressed as the mean (+ 1 standard error of the mean; n = 26 subjects). No significant differences were observed.

TABLE 2

The weight of alcohol in grams (g) for alcohol solutions of different concentrations.

Alcohol Solution	Concentration of alcohol	Weight of alcohol in 5 mL of solution (g)
Blood	0.080 g/dL	0.004
Beer	5% v/v	0.198
Wine	12% v/v	0.474
Mouthwash	20% v/v	0.790
Liquor	40% v/v	1.580

Although the quality of the breath sample provided may also account for variability in breath sample analysis, it is unlikely it contributed significantly to the drop in BrAC after blood was placed in the mouth. Unlike in the field, the volunteer subjects used in this simulation study were trained breath technicians and very cooperative, and therefore more likely to provide uniform and consistent samples of deep lung air for analysis.

Whatever the reason(s), the present study has demonstrated that a slight decrease in BrAC occurs when there is blood in the oral cavity. Our findings are consistent with a recent Australian study in which 1 to 2 mL of alcohol solution, at concentrations of 0.050, 0.100 and 0.150 g/dL, were placed in the mouths of 40 drinking subjects (mean BrAC of

0.076 g/210L) to simulate blood in the mouth (9). These authors concluded that the presence of blood (containing alcohol) in the oral cavity is unlikely to substantially elevate the BrAC. Similarly in the case of Regina v. Campbell, Dr. Stirrat, an expert witness reported that placing a "tablespoon" of blood in the mouth of a drinking subject "did not particularly affect the breathalyzer result" (21). This anecdotal observation also supports our findings.

CONCLUSION

The presence of blood in the mouth of a drinking subject tends to slightly decrease the BrAC. However, this slight decrease has no practical significance in evidential breath alcohol testing of drinking drivers when the results are reported to two decimal places. We conclude that blood in the mouth has no forensically relevant effect upon the measured breath alcohol concentration.

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