Comparative analysis of breath and blood alcohol concentration after experimental alcohol loading

Varga T., Erzsébet Jeszenszky, I.Kovács
Albert Szent-Györgyi Medical University, Department of Forensic Medicine, Szeged, Hungary

INTRODUCTION

Drunk driving is a prominent subjective risk factor in traffic accidents and as such, it is sanctioned by law all over the world. Various methods have been traditionally used for the determination of ethanol concentration in venous blood (and also in urine). During the past decade a number of countries introduced the use of breath alcohol testing for evidential purposes. Most of the devices use infrared spectroscopy.

Parallel with this process, the quality assurance requirements of the analysis have also been formulated (Dubowski, 1994) and numerous experiments have taken place to explore more accurately the relationship between breath alcohol and blood alcohol concentration, the latter being accepted in legal practice (Bilzer at al. 1994; Mason et al. 1976), and define the impact of various factors upon alcohol concentration (Gibaldi et al. 1975; Jones et al. 1991).

The authors investigated the concentration of alcohol in breath and in venous blood as a function of time in various drinking situations (drinking on an empty/full stomach, repeated drinking). The pharmacokinetic parameters of the relevant curves were compared.

MATERIAL AND METHOD

In all three experiments, the same group of ten voluntary male subjects aged 23 to 26 were used. Following initial clinical, neurological and laboratory tests and examination, the alcohol dose was administered using analytically pure ethanol diluted to 20 percent in orange juice.
Experiment 1
Following 6 hours of fasting, the subjects consumed 0.8 gram alcohol per kg of body weight within a period of 2 minutes.

Experiment 2
Following eating to full stomach, the same dose of alcohol equivalent to experiment 1 was consumed.

Experiment 3
Two hours following an alcohol load as described in experiment 1, the subjects had to consume an additional 0.4 gram alcohol per kg of body weight within a period of 2 minutes.

Breath and blood samples (the latter from cubital vein) were taken in intervals not exceeding 5 minutes every half hour for two hours following the individual alcohol loads, then every hour until the concentration of alcohol on the breath dropped to 0.1 mg per litre.

Head space GC analysis was used to measure the ethanol concentration in the blood (HP 5890), while the content of alcohol on the breath was measured by infrared spectroscopy (Seres ethylometer 679 TH) as the average of two parallel measurements within 3 minutes.

The mg/l value of the breath alcohol concentration was converted into the equivalent blood alcohol value using the 2:100:1 distribution ratio. The concentration versus time curves were depicted on the basis of one compartment open pharmacokinetic model as primary absorption and elimination values (George et al. 1995; Martin et al. 1984).

RESULTS AND DISCUSSIONS

The result of the clinical, neurological and laboratory tests was negative in each case. There were no markers indicating preliminary or regular alcohol consumption or chronic alcoholism.

In the first experiment, when the alcohol load was taken on an empty stomach resulted in a breath alcohol concentration curve which peaked in a significantly shorter time compared to
the venous blood alcohol curve, although the maximum concentration value was not significantly higher than that of the blood. The Co values of the breath and blood curves did not differ. This indicated that the total amount of alcohol in the two phases was identical and the difference between the time peaks of the two curves is caused by a significantly higher C_max value in the case of the breath curve representing the speed at which alcohol reaches this phase. In the absorption phase, the difference between the curves can be explained by differing arterial-venous alcohol concentrations. This disappears around the point of intersection of the two curves (at about 120 minutes), which coincides with the accomplishment of absorption processes of alcohol in the experimental circumstances as described in the literature.

There is no difference in the speed of elimination processes, the breath alcohol curve runs parallel with, and somewhat below the blood curve (Fig.1.).

In the second experiment, the comparison of the parameters of the blood and breath curves after alcohol consumption on a full stomach showed a tendency similar to the first experiment. However, there was no obvious difference at any point (Fig.2.).

Comparing the findings of the first and second experiments, there are two significant differences.

There is a significantly higher alcohol concentration in the empty stomach situation both in the blood and in the breath. This can only be explained by the significantly lower C_0 values in both blood and breath in the second experiment, since there was no significant difference in the t_max values, nor in the absorption coefficients. This may mean that the higher alcohol concentration in the empty stomach situation does not result from a quicker absorption; rather it is the consequence of a significantly smaller absorption loss (Table 1.).

In the same sense, we can establish that after the same alcohol load in the full stomach situation, absorption is prolonged and the arterial-venous difference prevails continuously owing to the mechanical blocking effect of the gastric content, and the curves do not intersect. In the downward period, the breath curve is above and parallel with the blood curve and no significant difference was found in the elimination coefficients.
In the third experiment when repeated drinking took place as in the first experiment, the peaks for the two breath curves occurred significantly sooner. Also the values are much higher than those of the blood curve.

Significantly faster absorption was found (about twice as quick) in the upward phase following repeated alcohol load compared to the upward phase after the first load. A possible explanation is that gastrointestinal hyperemia boosts the effect because of the irritation caused by the previously consumed alcohol.

The phases of the curve both prior to and following additional alcohol intake shows an opening of the curves due to the differing arterial-venous alcohol concentrations in the absorption phases, similarly to the findings of the first experiment. The curves then meet again when the absorption processes are practically completed. No difference was found in the coefficients describing the elimination speed of blood and breath alcohol curves (Fig.3.).

The elimination phases before and after repeated drinking could not be compared due to the shortness of the first elimination phase and also to the "diffusion drop" in this first phase. The $C_0$ values of the breath and blood curves did not show a significant difference, as expected on the basis of the findings of the first experiment (Table 2.).

In addition to the pharmacokinetic observations, it is to be noted that besides the relative difference between the curves in the absorption phase, individual blood breath differences were very large, reaching 86 percent of the blood alcohol concentration in some of the subjects during the first experiment. This suggests that simple ratio calculation does not allow for conclusion as to the alcohol concentration in the blood. Such conclusion can at the best be drawn only in the phase after absorption.

In routine traffic checks, in the half of the cases the authors found great differences between the concentration of alcohol in the blood and on the breath in samples taken in the elimination phase. This was described in a previous publication (10). Accordingly, attention was drawn to the possible influence of other factors (such as for example, the temperature of exhaled air (4)) as well as the pharmacokinetic aspects.
Table 1.

Pharmacokinetic parameters of Exp. 1. and 2.

<table>
<thead>
<tr>
<th></th>
<th>Cmax (%)</th>
<th>tmax (min)</th>
<th>k0 (1/min)</th>
<th>k1 (1/min)</th>
<th>k0 (%)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Blood</td>
<td>Breath</td>
<td>Significance</td>
<td>Blood</td>
<td>Breath</td>
</tr>
<tr>
<td>Exp. 1</td>
<td>0.73±0.082</td>
<td>0.58±0.064</td>
<td>0.074</td>
<td>78.60±7.03</td>
<td>60.65±7.68</td>
</tr>
<tr>
<td>Exp. 2</td>
<td>0.47±0.12</td>
<td>0.54±0.12</td>
<td>0.404</td>
<td>85.90±9.90</td>
<td>61.5±7.56</td>
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<tr>
<td>Significance</td>
<td>0.001</td>
<td>0.0006</td>
<td>0.119</td>
<td>0.786</td>
<td>0.134</td>
</tr>
</tbody>
</table>

Cmax: maximal ethanol concentration
\( t_{max} \): time interval up to Cmax
k0: absorption constant
k1: elimination constant
\( C_0 \): theoretical ethanol concentration at 0 min.

Table 2

Pharmacokinetic parameters of Exp. 3.

<table>
<thead>
<tr>
<th></th>
<th>Cmax (%)</th>
<th>tmax (min)</th>
<th>k0 (1/min)</th>
<th>k1 (1/min)</th>
<th>C0 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cmax1</td>
<td>Cmax2</td>
<td>tmax1</td>
<td>tmax2</td>
<td>k0</td>
</tr>
<tr>
<td>Blood</td>
<td>0.74±0.10</td>
<td>1.02±0.09</td>
<td>56.90±7.05</td>
<td>170.17±6.66</td>
<td>0.023±0.003</td>
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<td>Breath</td>
<td>0.93±0.11</td>
<td>1.11±0.09</td>
<td>45.34±5.51</td>
<td>157.20±7.29</td>
<td>0.042±0.012</td>
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<tr>
<td>Significance</td>
<td>0.006</td>
<td>0.08</td>
<td>0.004</td>
<td>0.013</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Cmax1: maximal ethanol concentration after the first loading
Cmax2: maximal ethanol concentration after repeated loading
tmax1: time interval up to Cmax1
tmax2: time interval up to Cmax2
k0: absorption constant after the first loading
k10: absorption constant after repeated loading
k1: elimination constant after the first loading
k11: elimination constant after repeated loading
\( C_0 \): theoretical ethanol concentration at 0 min.
Average blood and breath alcohol curves (Exp. 1.)

Fig. 1.

Average blood and breath alcohol curves (Exp. 2.)

Fig. 2.
Average blood and breath alcohol curves (Exp. 3.)

Fig. 3.
Literature


Gibaldi M., Perrier D.: Pharmacokinetics. III.First order absorption (New York, 1975)


