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# GASTRIC REFLUX, REGURGITATION, AND THE POTENTIAL IMPACT OF MOUTH-ALCOHOL ON THE RESULTS OF BREATH-ALCOHOL TESTING

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## Background

It must be a very old observation that some of the alcohol a person consumes is eliminated unchanged via the lungs along with the expired air. Indeed, the smell of alcohol on the breath, together with the person's appearance and behaviour, often constitute the first indications, albeit primitive, of over-indulgence in alcohol. The first scientific studies attempting to measure accurately the concentration of alcohol in a person's breath were published over 100 years ago in the LANCET medical journal (1). The article, which was authored by Dr. Francis Anstie, included the following warning about his attempts to analyze alcohol in the breath.

> *"Much caution is necessary, however, in applying this test. It must not be tried during at least the first quarter of an hour after a dose has been taken, for the mouth retains the characteristic smell, even of the mast moderate dose, of any of the stronger smelling drinks, for fully this time."*

Accordingly, the problem of mouth alcohol in connection with breath-alcohol testing has a long history and precautions are necessary to ensure that the results of such a test are valid and constitute a reliable measure of alcohol exposure and whether the parson might have exceeded the legal breath-alcohol limit for driving.

The first American studies dealing with the potential problem caused by alcohol in the mouth during breath-testing for alcohol as indication of drunkenness were published in the Journal of the American Medical Association (JAMA) in 1927 by Dr. Emil Bogen. His article contained the following statement (2).

> *"As soon as the disturbing factor of alcoholic liquor still in the mouth is removed, which occurs usually within fifteen minutes after imbibition, in the absence of hiccupping or belching, the alcohol content of 2 liters of expired air is a little greater than I cc of urine. "*

The importance of a 15-min deprivation period has since been well documented and is part of the rules and regulations for evidential breath-alcohol testing (3-5). It is interesting to note that Bogen considered it necessary to warn about the potential influence of hiccupping or belching on the results of breath testing. This suggests that besides alcohol in the mouth from a recent drink one also needs to consider alcohol originating from the stomach, via back-flux into the oral cavity. To my knowledge there are no experiments or articles published in the peer reviewed literature that document the effects, if any, of belching or hiccupping on the response of breath-alcohol analyzers.

Experiment designed to answer this question are urgently needed if gastric reflux or belching represent examples of a medical complaints that might artificially increase the result of a breath-alcohol test for law enforcement purposes.

**Evidential breath-alcohol testing.**
During the lecture I gave in San Francisco in May 2006 for the California Association of DUI Defence Lawyers, I pointed out that the current generation of evidential breath alcohol analyzers might not be able to detect mouth alcohol under some circumstances. For example, there is no published evidence that the more **dangerous form of mouth alcohol,** namely that which might erupt from the stomach in connection with a burp, belch or regurgitation can be successfully detected and distinguished from alcohol originating from the lungs.

Most modern evidential breath-alcohol instruments make use of infrared technology to determine the concentration of alcohol (ethanol) in expired air. These devices are also fitted with so-called slope detectors, the function of which are to monitor the rate of change in expired alcohol concentration as a function of time after the start of exhalation. Depending on the shape (slope) of the breath-alcohol profile, the instrument software is programmed to flag for mouth alcohol. If mouth alcohol is detected on the basis of abnormal alcohol profile the sample delivered for analysis should be invalidated. However, experience has shown that many slope detectors malfunction and fail their intended purpose, especially when fairly weak solutions of alcohol (-5% v/v) have been placed in the mouth before testing.

Importantly, fuel-cell based instruments, which are widely used in California for roadside testing, capture a snap sample of breath at the end of a prolonged exhalation. Such instruments are not fitted with slope detectors for mouth alcohol. **Widespread** use of fuel cell instruments for roadside evidential breath-testing means that more and more suspects are likely to be tested closer in time to finishing their last drink (e.g. shortly after leaving a restaurant). This implies that there might be significant quantities of alcohol still in the stomach at the time the test was made. A careful observation and documentation of the suspect immediately before the test is imperative to ensure reliable results.

When evidential breath-alcohol instruments are certified prior to their introduction into the field for use by traffic police, one element in the testing procedure involves gargling or swirling around in the mouth a strong solution of alcohol (40% v/v) or spraying the back of the tongue and back of the throat with an alcohol-rich spray. Immediately afterwards the operator blows into the breath analyzer and records the result, which is anticipated to respond with the message "invalid sample." With high concentrations of residual alcohol in the mouth, most if not all infrared instruments will successfully flag for mouth alcohol and abort the test (3-6). However, after waiting e.g. 5-10 minutes after rinsing the mouth with whisky it is by no means certain that the slope detector will identify an abnormally shaped curve (8).
Under these circumstances, the instrument software will not necessarily be able to flag for mouth alcohol.

An example is illustrated in figure 1, which shows three successive breath-alcohol profiles from a person who consumed a moderate amount of alcohol and –40 min later rinsed the mouth with whisky. Breath-alcohol tests were made after elapsed times of 8.5 min, 10 min and 17.5 min. The correct curve is that obtained after 17.5 min, because there is no mouth alcohol such a long after washing the mouth with whisky (3-8). The tests made at both 8.5 min and 10 min after the mouth wash look perfectly smooth but it is obvious they are contaminated with mouth alcohol owing to the fact they are run on a higher level compared with the 17.5 min curve. Yet all three curves were accepted as valid samples by the breath analyzer. Note that breath alcohol (BrAC) is reported as mg/L and not g/210 L as in USA.

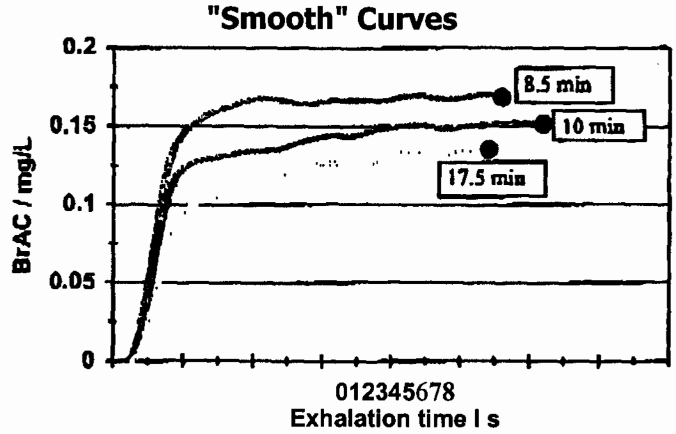


**Figure 1.** *Three successive exhalation profiles made at 8.5 min. 10 min and 17.5 min after washing the mouth with whisky in ǫperson with a* ***pre-existing blood*** *alcohol concentration of 0.03 g%. The test at 17.5 min was free of mouth alcohol whereas the others were not. The evidential breath analyzer (Alcorest 71 10) accepted the three* ***curves although those at 8.5 min and*** *10 min were still contaminated by traces of alcohol in the mouth. Graph provided by my colleague Lars Andersson, Uppsala, Sweden.*

**Time between drinking and testing and the need for better slope detectors**

The time elapsed after the last drink before conducting an evidential breath-alcohol test will almost certainly be longer than 15 min. In most US states standardized field sobriety tests must be performed **to provide evidence of impairment before** a chemical test for alcohol influence is motivated. Thereafter, the suspect is arrested and transported to a location where an evidential breath-alcohol instrument is available. Obviously a considerably longer time than 15 min will have passed after the last drink so evaluating the functioning of slope detectors, as described above, by swirling whisky in the mouth is rather pointless.

The most dangerous form of mouth-alcohol is that which might erupt from the stomach immediately before exhalation perhaps because of nervousness and various gastrointestinal ailments. To my knowledge this problem has not been investigated during type-approval and certification of evidential breath-alcohol instruments. Alcohol originating from the stomach will obviously be a lot weaker than straight whisky, which suggests that the current generation of breath alcohol analyzers cannot readily distinguish gastric alcohol from that coming from the lungs.

What this means is that the experimental protocol used to test an instrument's ability to flag mouth alcohol before certification needs to be carefully reviewed and revised.

New algorithms should be developed with the aim of improving the capability of evidential breath-alcohol instrument to detect mouth alcohol. This might entail looking more closely at the degree of waviness in the curve, the BrAC rise in the first few seconds of exhalation compared with the last few seconds, or the closeness of agreement between duplicate test results made a sufficiently long time apart (e.g. 10 min). Introducing these more stringent safeguards and requirements might also have some negative consequences. Indeed, some

BrAC profiles without alcohol in the mouth might be mistakenly identified as containing residual alcohol. It seems that the manner of sample delivery, breathing pattern of the suspect, the temperature and humidity of the ambient air, the underlying true BrAC etc., might be such that the slope detector confuses a normal breath profile with residual alcohol in the mouth and flag an invalid sample (9).

**Absorption of alcohol from the stomach**

After drinking alcoholic beverages (beer, wine or liquor) the alcohol (ethanol) they contain first enters the stomach, mixes with its contents and remains there for a variable period of time depending on certain physiological factors (10,11). Alcohol is one drug that does get absorbed slowly through the stomach wall, but most is taken up into the portal venous from the small intestine. This means that the frequency of gastric emptying is a key variable for how long alcohol remains in the stomach after drinking. The absorption of alcohol from the stomach into the bloodstream obviously begins during the time of drinking and continues for some variable period of time after the end of drinking.

The duration of the absorption period is hard to define with certainty in any individual subject, although in my experience, a range of 5-120 min seems a good estimate for the vast majority of people who consume alcoholic beverages (10,11).

The absorption of alcohol occurs more rapidly when drinking occurs on an empty stomach, such as after an overnight fast (10,11). Absorption is generally faster after drinks with a high alcohol content, such as neat spirits (40 % v/v), are ingested compared with beer (5% v/v) or wine (12% v/v) (12-14). The alcohol in sweet drinks, those with a high content of sugar, seems to be absorbed more slowly because carbohydrates delay gastric emptying (12). People who smoke cigarettes absorb alcohol more slowly than non-smokers according to the results of a controlled study published in the British Medical Journal (15). The nicotine entering the bloodstream and alters various physiological processes that regulate gastric motility and stomach emptying. The single most important factor influencing gastric emptying is whether there was food in the stomach before drinking started (16,17). The quantity of food has a bigger influence than its composition in terms of protein, fat or carbohydrate content (17).

The kinetics of alcohol absorption from the stomach follows an exponential time-course according to first-order kinetics, which means that the quantity of alcohol absorbed is proportional to the prevailing concentration in the stomach. Very few controlled studies have been done to analyse alcohol in stomach contents at various times after drinking - the Cortot et al study (18) was a rare exception. Instead, most studies into the absorption rate of alcohol have looked at changes in blood- or breath-alcohol concentration as. a function of time after end of drinking and the time of occurrence of the peak BAC (16,17). The longer the time elapsed after the end of drinking the lower will be the concentration of alcohol remaining in the stomach contents.

If more than 2 hours have elapsed after the end of drinking, it is not very likely that there will be a sufficiently high concentrations of alcohol in the stomach contents (e.g. mixed with food) to skew the results of a breath-alcohol test. But more studies are needed involving direct sampling of stomach contents after 2-hours to verify this statement.

**Gastric reflux and breath-alcohol testing**

Gastric reflux, a condition often referred to as GERD, is widespread in today's society and statistics show that about 7-10% of the population in US suffer from GERD to some extent often medication and surgical treatment (19-21). GERD is often worse at night while in bed and is provoked by, among other things, drinking alcoholic beverages, eating spicy food and smoking cigarettes (22,23). Very little attention has been given by forensic scientists to the reliability of breath-alcohol analysis in people suffering from gastrointestinal problem such as GERD (24). One such study was conducted at the University Hospital in Linkoping, Sweden and the results were published in a peer-reviewed journal (25).

In brief, ten well-documented suffers of GERD (5 men and 5 women) drank small quantities of alcohol corresponding to two bottles of beer, two glasses of white wine or the equivalent amount of alcohol mixed with orange juice. The drinks were consumed in the morning on an empty stomach. The breath-alcohol concentration and the corresponding venous blood alcohol concentration were measured continuously at approximately 5 min intervals for about 4 h. We found that surprisingly few of the volunteers experienced an active episode of GERD after drinking these quantities of alcohol on an empty stomach. Those that did experience a GERD attack found it hard to comply with the demands of breath testing procedure, that is, to make a continuous forced exhalation for as long as possible (at least 6 seconds) into the breath-inlet tube of the BAC Datamaster, which was used for the study.

In another arm of the study, GERD was provoked by applying a pressure cushion around the abdomen and under these conditions, as expected, more volunteers suffered from GERD. One lady suffered so badly that the testing was discontinued. Even when GERD was provoked there was no compelling evidence that the breath-alcohol concentration (BrAC) was abnormally higher when compared with values expected. This was verified by comparing BrAC with the concentrations of alcohol in near simultaneous specimens of venous blood.

What was evident from this controlled study was that BrAC (g/210L) was higher than the concentration in venous blood BAC (g%) during the first 90 min or so after the end of drinking. The BAC and BrAC were about equal at about 90 min post-dosing and thereafter the venous BAC was always higher than BrAC. These findings as well as the temporal variation between BAC and BrAC can be accounted for by distribution of alcohol in the vascular system and the differences that exist between the arterial and the venous blood circulation, rather than on GERD (26).

In this small study (25), no attempt was made to measure the concentration of alcohol in the stomach during the absorption phase just before testing. However, the absorption portions of the curves were well documented by frequent blood and breath-alcohol testing. The dose of alcohol *was* adequate for the legal limit in Sweden (0.02 g%) but more alcohol should be administered to compare with the legal limit in USA (0.08 g%). It would also have been of interest to allow people to drink alcohol after eating various foods known to provoke GERD. But not all variables can be covered in a single experiment.

In summing up the results of these experiments on GERD patients, a plea was made for other scientists to embark on more studies into the problem, but to my knowledge nothing has been published so far. A single case report of a DUI suspect, who apparently suffered from GERD, was reported by Gullberg although the results were inconclusive (27).

**Conclusions**

The presence of alcohol in the mouth after drinking an alcoholic beverage, or the use of alcohol-containing hygiene products (mouthwash, breath-sprays), or alcohol-containing medication (cough syrups or vitamin tonics), or regurgitation of stomach contents enriched with alcohol, may elevate results of breath-alcohol analysis (28-30). This problem can be avoided or minimized in several ways, the simplest of which would be to document the behaviour of the suspect before testing starts. It is essential to include a proper observation and deprivation period before starting the evidential breath testing sequence.

The key research question that needs answering is how rapidly stomach alcohol concentrations dissipate after drinking ends and what minimum dilutions are necessary to be identified as mouth-alcohol by the slope detectors on present day instruments. If the concentration in the stomach is similar to that in blood, which also matches that in the saliva and oral mucosa, then regurgitation or a belch containing a similar content of alcohol would not be expected to negate the breath test result. Evidence for this comes from placing in the mouth an aliquot of blood containing alcohol and sampling a portion of breath immediately afterwards (31). The subsequent breath-alcohol test was not elevated compared with a control test without blood in the mouth.

Whether there a sufficient quantity of alcohol exists in a burp or belch to contaminate a large area of the oral mucosa is an open question. The alcohol emerging from the lungs and reflecting the alcohol exhaled during a prolonged end-exhalation must get contaminated with alcohol from the stomach to increase the breath-test result. All these things need to be investigated
1.

Great care is needed when evidential breath tests are performed for legal purposes. Any alcohol residing in the mouth after a recent drinking is much less of a problem than alcohol that enters the mouth because of gastric reflux, for the reasons explained above. Whether a burp or a belch can falsify the result of an evidential breath-alcohol test can only be evaluated by means of carefully designed experiments. This might entail in-vitro studies, tests with healthy volunteers and of course with people who are prone to suffer from belching, dyspepsia or gastroesophageal reflux (32).

Another solution to the problem of mouth alcohol originating from GERD is to allow suspects the option of providing a blood or urine sample for laboratory analysis of alcohol concentration. If this is not possible for some reason the suspect should be questioned about the medical condition, what kind of medication was being used and the breath-alcohol test made only after a careful 15 min observation period. The entire operation from arrest to conducting the breath test could be videoed.

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