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# Detection of mouth alcohol during breath alcohol analysis

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ABSTRACT

The presence of mouth alcohol (MA) during alcohol breath test for law enforcement is the most common cause of falsely high breath alcohol concentrations (BrAC). A fast and reliable test for detection of MA roadside at the scene of the act would facilitate the police efforts for proper prosecution. A tentative technique to use orally exhaled water vapour as a reference gas to position the origin of alcohol was validated. BrAC and water vapour concentration (WVC) were simultaneously measured as a known MA component was added to subjects with existing blood alcohol. In the absence of MA, water always precedes alcohol in a volumetric expirogram. In the presence of MA this relationship reversed. A scatterplot of WVC versus BrAC from similar fractional exhaled volumes illustrates how their relative positions change by MA. A deviation area (DA) between the scatterplot curve and a fictitious linear relationship was defined as a measurement of MA. The accuracy and cut-off level of the DA to detect MA were determined with receiver operating characteristic (ROC) curve analysis. The area under the ROC curve (AUC) was 0.95 (95% CI 0.90–1.0), indicating excellent discriminatory ability. The optimal cut-off for DA to discriminate between MA $\geq$0.010 mg/L (1 μg/100 ml, 0.002 g/210 L) or lack of MA was −0.35, with a sensitivity of 0.91 and specificity of 0.95.

Analysis of BrAC in relation to WVC is a practical method to detect and confirm MA contamination with high reliability.



## 1. Introduction

Determination of the breath alcohol concentration (BrAC) is a widely used quantitative method to test whether a subject is below or above the statutory alcohol limit. The alcohol in pulmonary capillary blood equilibrates instantaneously with the air in the alveoli following partial pressure gradients and solubility properties [1]. As the air is exhaled the alcohol vapor is reabsorbed onto the airway mucosa by diffusion during its passage through the deep airways before it is exhaled into ambient air [2]. Breath alcohol measurements incorporating standardization to alveolar water vapour predicts the alcohol concentration in the pulmonary capillary blood [3] and is as precise as determination of the arterial blood alcohol concentration (ABAC) [4]. The ABAC/BrAC is constant without fixed or proportional bias in the post-absorptive phase [3]. The arterial blood is ejected and transferred to all body compartments and governs thereby drunkenness [3–5]. However, an accurate BrAC always assumes that the measurement occurs on breath alcohol coming from the deep lung. The presence of residual alcohol in the oral mucosa, mouth alcohol (MA), has the potential to distort this condition by contaminating the passing deep lung air, when it arrives to the mouth, potentially causing a falsely high BrAC reading [6–8].

Mouth alcohol appears after recent ingestion of alcohol, regurgitation of gastric content containing alcohol or use of other alcohol containing products, such as mouth washes, medicines and certain foods [9–11]. This fact has been used as a defense tactic in court to free subjects, who have offended the statutory BrAC limit. It has led to the introduction of a 15–20 min deprivation period before an evidential breath-alcohol test is performed. This routine delays the analysis, during which the alcohol is metabolized and in particular cases can be eliminated below the statutory limit. However, more importantly, every victim occupies the police 15–20 min, since the waiting period demands strict surveillance of the subject to prevent late drinking and to guarantee that regurgitation of gastric content has not occurred. It has also become a judicial problem to rule out, without any doubts, the presence of MA in subjects with breath alcohol above the statutory alcohol limit [12–14].

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Different strategies have, therefore, been developed to detect MA and some breath alcohol analyzers have incorporated MA detecting algorithms to certify the validity of the breath sample. One algorithm is based on the detection of an initial peak concentration in the alcohol exhalation profile caused by the presence of MA. However, in the presence of blood alcohol the distinctive peak features of the profile disappears a few minutes after ingestion of alcohol despite that the breath samples contain significant amount of MA making this technique unreliable. The peak concentration in the alcohol profile actually disappears when the mouth alcohol concentration has decreased to a concentration approximately similar to that coming from the deep lungs [8].

Another algorithm is based on a two-measurement cycle within a delay not less than 2 min coupled to the known difference in the elimination kinetic of MA and of blood alcohol. This technique has also been shown to be unreliable, when e.g. fuel cells are used [12,15].

It is a common knowledge that the mouth mucosa contains and releases water vapour during an exhalation. Is it possible to use the position of orally vaporized water as a reference to position the source of the exhaled alcohol? A valid mouth alcohol detection system, that could without doubts reject the presence of significant amounts of MA at the scene of the crime would secure the measurement without delay, prohibit further alcohol elimination, avoid the need for surveillance of the victim during an observation period and minimize the problem of using MA as a defense tactic in court.

The aim of the present study was to illustrate, where in an exhaled volume MA is positioned and to determine if the position of water vapour and alcohol in the first part of the exhaled breath volume can be used by a new described method to exclude and detect MA.

## 2. Materials and methods

### 2.1. Subjects

Eight healthy volunteers, six men and two women, with ages ranging from 35 to 71 years and body weights ranging from 60 to 89 kg participated in the study. All were moderate drinkers of alcoholic beverages and all gave their informed consent. The study was approved by the Ethics Committee of Lund University, Sweden (DNR558).

### 2.2. Protocol

All experiments were carried out after a minimum of 2 h fasting following a light meal. After baseline alcohol breath tests to ensure that the subjects were free from alcohol, each subject ingested 0.4 g alcohol per kg body weight. The alcohol was prepared from gin (40% (v/v)), diluted to 20% by the same volume of tap water. The subjects then provided single-exhalations into a breath analyzer (Servotek AB, Sweden) at regular intervals until a linearly decreasing alcohol concentration was identified in every subject indicating that the elimination phase had been reached. To add a MA component on the pre-existing blood alcohol component, the subjects rinsed their mouths with 30 ml undiluted gin for 30 s without swallowing anything. The expelling of the gin was timed to occur 90 min after the start of the alcohol ingestion. The subjects then provided single-exhalations into the analyzer for up to 40 min after the expelling of the alcohol.

### 2.3. Detection of mouth alcohol

The elimination of BrAC, free from MA in the post-absorptive phase was described as a linear zero-order elimination function. The parameters of the linear function were determined by linear regression from 4 measurements of BrAC before the mouth was rinsed with alcohol and 4 BrACs measured ≥25 min after the MA component was added in every subjects. This yields estimated BrACs free from MA at any specific time ($t$) in the post-absorptive phase (Fig. 1). Each subject was used as its own control. MA adds alcohol to the alcohol coming from the deep lung. After the subject had made a measurement containing both alcohol origin from MA and deep lung ($BrAC_{tot}$), the alcohol component coming from the deep lung ($BrAC_{deep\ lung}$) was estimated by extrapolation of the linear curve in that particular subject to the time ($t$) of the measurement. The MA component was calculated with the equation

$$MA = (BrAC_{tot} - BrAC_{deep\ lung}) \quad (1)$$

and this MA concentration was regarded as the reference or "gold standard". The further analysis was performed on measurements obtained from 4 min before the mouth was rinsed with alcohol and up to 25 min after the rinse.

### 2.4. Measurement

The gas concentrations were measured mainstream by a breath analyzer (Servotek AB, Sweden), which utilizes absorption of infrared light. Three filters allow the passage of wavelengths of 3.32, 3.40 and 3.49 μm, respectively, to allow for discrimination and calculation of alcohol by means of infrared absorption. Three additional filters are also mounted on the disc, one reference filter (3.70 μm), one for determination of water vapour (2.58 μm) and one for determination of $CO_2$ (4.40 μm). The disc spins at a rate of 33 Hz. The concentrations of alcohol and water vapour are thus determined near-simultaneously 33 times per second. The walls of the measuring chamber are electrically heated and thermostatically controlled and in contact with the inflow air to regulate it to 55 °C and the outflow air, which is isolated from the cuvette, is 45 °C to avoid condensation within the analyzer.

The subjects blew a forced exhalation after a near-maximal inhalation through a mouthpiece with no flow restriction into the inlet of the cuvette of the analyzer, where the measurements take

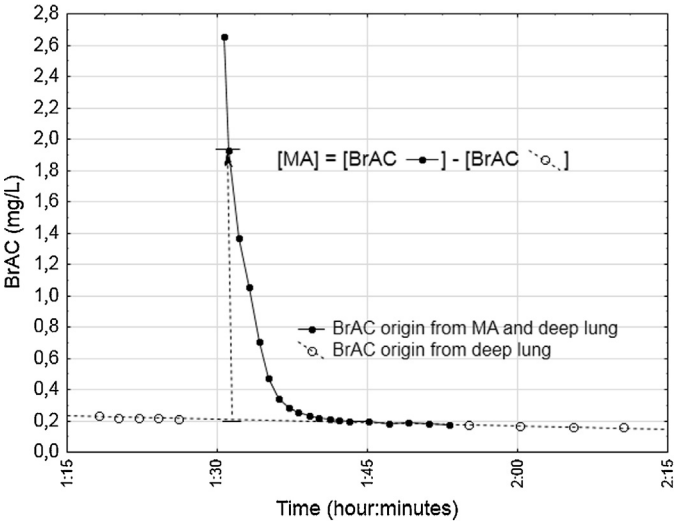


**Fig. 1.** How the mouth alcohol concentration (MA) was determined. BrAC origin from the deep lung was estimated from a linear zero-order function determined from 4 measurements of BrAC before the mouth was rinsed with alcohol and 4 BrACs measured ≥25 min after the MA component was added in every one of the subjects. The BrAC containing both alcohol origin from the deep lung and decreasing levels of MA was measured as single exhalations. The MA concentration was calculated as the difference between the measured $BrAC_{(measure\ at\ t)}$ and the estimated $BrAC_{(MA\ free\ at\ t)}$ coming from the deep lung.