BREATHING-RELATED LIMITATIONS TO THE ALCOHOL BREATH TEST

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ALCOHOL EXCHANGE BY THE LUNGS

The conventional paradigm for the analysis of pulmonary alcohol exchange assumes that the airways serve as a dead space and do not participate in gas exchange. The airways were thought to act simply as a conduit for the passage of air between the outside environment and the alveoli. In reality, however, inspired air undergoes soluble gas and heat exchange during its trans-airway (between the mouth and the alveoli) passage (the new paradigm). During inspiration, the relatively cool and dry air is heated and humidified. During expiration, the opposite exchange occurs as exhaled air is cooled and dehumidified as it passes along the airways. Airway exchange is an important part of pulmonary gas exchange for other highly soluble gases, such as alcohol (George, S., J. Souders and M. Hlastala. Complexity in Structure and Function of the Lung. Hlastala and Robertson ed. New York; Marcel Dekker, Inc.; 1998, 205-242; Morris, J. Invited editorial on "Comparison between the uptake of nitrous oxide and nitric oxide in the human nose. J Appl Physiol. 1201-1202, 1998.Hlastala, M. and E. Swenson. In: The Bronchial Circulation. Ed.: J.Butler. Exec Ed: C Lenfant. Marcel Dekker, Inc. 1992, pp. 417-441. During expiration, ethyl alcohol is deposited onto the airway mucosa. During inspiration, ethyl alcohol is resorbed from the mucosa to the inspired air. Alcohol measured in the exhaled breath originates entirely from the airway mucous and tissue (which is perfused by the systemic bronchial circulation).

There are corollaries to this new paradigm with impact on the Alcohol Breath Test: 1) the alcohol in the exhaled breath comes from the airways and not from the alveolar regions; 2) during exhalation, breath alcohol concentration (BrAC) continues to rise, never reaching alveolar air alcohol concentration; 3) BrAC depends on exhaled breath volume. A common misunderstanding in the forensic community is that the flat plateau reached at the end of exhalation when the breath instrument samples breath indicates that the exhalation has reached alveolar air. This assumption has been shown to be false. The flat alcohol profile at the end of the breath occurs simply because the subject stops exhaling. The details of these anomalies to the old paradigm can be found in a prior review (Hlastala MP. The alcohol breath test - A brief review. J Appl Physiol 84:401-408, 1998. A copy of this review can be found at "www.mphlastala.com"). It is important to understand that BrAC depends on the volume of air exhaled. Because it is now recognized that alveolar air cannot be sampled with an alcohol breath test, the basic assumptions of the breath test must be discarded.

MINIMUM EXHALATION REQUIREMENTS

Most modern alcohol breath testing instruments (BTI) have minimal exhalation requirements before obtaining a breath sample. Typically, a subject must exhale for a minimum time (usually 4 to 5 seconds) at a minimum flow rate (often not specified, but may be on the order of 1.5 liters/minute). In addition, a minimum volume (somewhere between 1.1 and 1.5 liters) of exhaled air is required before sampling. Once those criteria are fulfilled, the sample is taken after a minimum slope (BrAC vs. time) is achieved. This minimal slope is obtained when the subject stops exhaling and is not an indication of alveolar air. The importance of this issue cannot be overstated because the alveolar air assumption is central to the validity of the breath test.

An important assumption of the forensic scientist in defining ABT is that a flat alveolar plateau and the end of exhalation provides a sample of alveolar air. This statement makes it easy to argue that the ABT is accurate because it "always" measures alveolar air. In fact, by changing the exhalation plateau, values for alcohol are found to increase as exhalation times increase. Thus a flat plateau does not indicate alveolar air but rather the flat plateau is simply an indication of stopping exhalation.

Alveolar alcohol is actually greater than had been thought. In fact, if it were possible to exhale all the way to the alveolar alcohol core, the BBR for blood to alveolar air would theoretically be 1756 (Jones, A. W. Determination of liquid/air partition coefficients for dilute solutions of ethanol in water, whole blood, and plasma. J. Anal. Toxicol. 7: 193-197, 1983), not the commonly assumed 2100.

LUNG VOLUME BIAS

The inherent sampling criteria of BTI may lead to a bias against individuals with smaller lung volume. The problem follows from the minimum volume required by each BTI. As an example, the minimum volume required by the Datamaster (used in the State of Washington) is 1.5 liters. Any subject can stop exhalation at any point between 1.5 liters and the maximum available vital capacity (VC, maximum volume that can be exhaled from the lungs). The VC can vary over a relatively large range (2.48 liters for a 60 year old, 4’ 11” female to 6.32 liters for a 20 year old, 6’ 3” male). These values do not represent the extremes. In order to fulfill the minimum 1.5 liter volume requirement of the Datamaster in Washington, the sixty year old woman must exhale at least 60% of her vital capacity. Whereas the twenty year old man would only have to exhale about 25

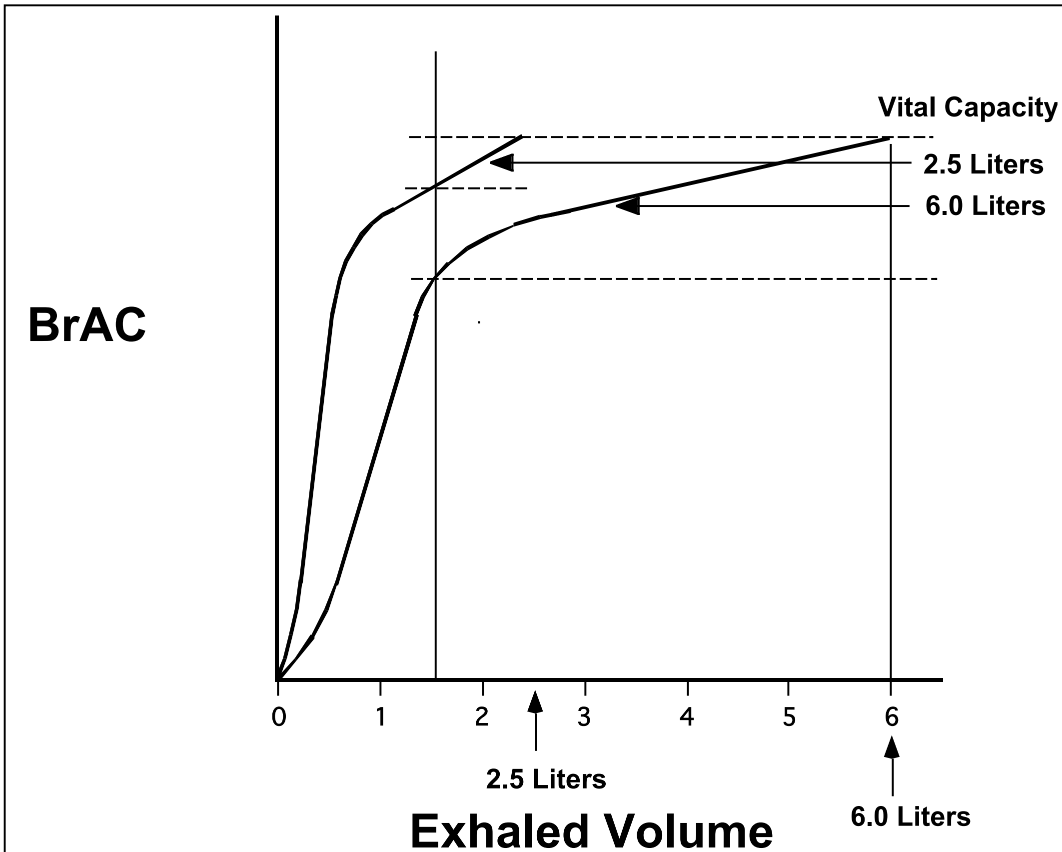

Figure 1. Exhaled alcohol profiles for two individuals with different lung volumes.

% of his vital capacity. At the same blood alcohol concentration (BAC), the smaller lung volume would yield a greater breath alcohol reading. Preliminary data to this effect has been published by Skåle et al (Skåle AG, L Slordal, G Wethe and J Mørland. Blood/breath ratio at low alcohol levels, a controlled study. Abstract. 40th meeting of the International Association of Forensic Toxicologists, 2002) who compared blood/breath ratio against body weight (VC was not measured in this study). Some BTIs require a 1.1 liter minimum exhalation volume. The same argument applies to these as well.

Examples of two hypothetical BrAC curves for a large (6.0 liters) and small (2.5 liters) lung volume individual are shown in Figure 1. Breath alcohol concentration is plotted against exhaled lung volume. The same alveolar alcohol concentration is assumed for both. The possible range of BrAC values is shown between the minimum of 1.5 liters and the maximum at the full vital capacity exhalation. The average BrAC for all possible exhaled volumes is greater for the subject with small lung volume compared to the subject with large lung volume thus indicating a bias. A further discussion of this small lung volume bias issue can be found in (Hlastala, M. Invited editorial on "The alcohol breath test". J Appl Physiol 93: 405-406, 2002. A copy of this article can be found at "www.mphlastala.com"). A client with a smaller lung volume (female, older, smaller stature) may have been unfairly treated by the BTI.

LUNG DISEASE

Because lung disease alters the pattern of breathing and/or the ability to blow into a BTI, there can be a significant change in the accuracy of a breath test for alcohol subjects with lung disease. Two studies (Haas, H and JF Morris. Breath-alcohol analysis in chronic bronchopulmonary disease. Arch Environ Health 25:114-118, 1972 and Russell , JC and RL Jones. Breath ethyl alcohol concentration and analysis in the presence of chronic obstructive pulmonary disease. Clin Biochem 16:182-187, 1983) have been performed on individuals with lung disease showing greater variability than with normal subjects. But no study has critically analyzed the influence of lung disease on breath test accuracy. By relating the changes which occur with disease to the physiological factors affecting breath tests, it will be possible to pursue questions regarding the role of any particular defendant's lung disease on his/her breath test accuracy.

Diseases can develop in the lungs in many forms. Some lung diseases affect the airways; some affect the lung tissue (parenchyma); and some affect the blood vessels. In reality, most lung diseases have an influence on more than one of these areas at a time. Because the distributions of lung ventilation (air flow) and of perfusion (blood flow) are complex and not always matched, the effects of a disease process are often complicated and unpredictable.

Diseases of the lungs are usually classified into four major categories:

1) Obstructive lung disease
2) Restrictive lung disease
3) Pulmonary vascular disease
4) Diseases of respiratory control

Each of these disease types may have an effect on the accuracy of a breath alcohol test. Further detail regarding the various types of diseases can be found in a prior article (Hlastala, MP. Effect of respiratory diseases on alcohol breath tests. Drinking/Driving

Law Letter 7(24):1-5, 1988. A copy of this article can be found at "www.mphlastala.com").

Obstructive diseases are the most likely to influence the breath test. This category includes Chronic Bronchitis, Asthma and Emphysema. The nature of obstructive diseases is to limit the exhaled flow rate due to a narrowing of the airways (air tubes). Chronic Bronchitis results in an increase in mucus production which narrows the diameter of airways. Asthma causes the muscle around airways to constrict with an increase in mucus production leading to a narrowing of the airways. Emphysema is a break-down of lung tissue decreasing the tethering of airways again causing airway narrowing. This makes it difficult to exhale rapidly. The increase in mucus production enhances airway interaction of alcohol (see above) causing increased variability of the breath test. The increased airway resistance leads to a sense of "shortness of breath" or "dyspnea". Breathing into a restricted tube, as is present in all alcohol BTIs, causes the subject to have a need to inhale again such that they may not be able to complete the minimum exhalation requirements of the BTI. Because of the difficulty in exhaling, there is often a reduction in vital capacity (amount of air that can be exhaled). A study by Robinson et al (Robinson, RW, DP White and CW Zwillich. Moderate alcohol ingestion increases upper airway resistance in normal subjects. Amer Rev Resp Dis 132:1238-1241, 1985) found that consumption of alcohol increases the resistance of upper (smaller) airways in the lung.

Restrictive diseases lead to a reduced vital capacity. The smaller lung volume results in the subject exhaling a greater fraction of their lung volume leading to higher BrAC (see above). Some of the diseases that fall into this category include: fibrosis, scoliosis, kyphosis, lobectomy, lung reduction surgery and other congenital chest abnormalities. Your client may have been unfairly treated because of the presence of lung disease.

ANXIETY AND STRESS

A situation often misdiagnosed as a refusal can be caused by the stress of an arrest situation. In some individuals, stress leads to hyperventilation (increased breathing) which can, but may not cause dizziness and/or faintness. This also may result in the inability to exhale the minimum volume required for a BTI. Even though a subject may attemp to blow into the BTI, he/she may be unable to complete the requirements of the BTI leading the officer to conclude that the test is a refusal, even though the subject is making an earnest attempt to blow.

Another potential problem for the individuals with lung disease is the cough reflex. During exhalation into the narrowed tubing of a BTI, the back pressure causes a cough reflex in some individuals. Coughing results in periodic reduction in air flow which means that the subject cannot fulfill the minimum requirements of the BTI, leading the inappropriate assumption of a refusal by the officer. Your client's refusal may not truly have been a true refusal, but rather simply a pulmonary limitation.

In summary, evaluation of a DUI case should always include consideration of the presence of lung disease and how that may influence your client's BTI results. In the event of a refusal, careful examination of the statements of the client may uncover a stress-related inability to fulfill the minimum requirements of the BTI.

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