J Appl Physiol 93: 405–406, 2002;
10.1152/japplphysiol.00180.2002.

invited editorial

Invited editorial on "The alcohol breath test"

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RESPIRATORY GAS EXCHANGE PHYSIOLOGY began with the description of oxygen and carbon dioxide exchange in a one-compartment lung, followed decades later by investigation of the effects of heterogeneity. Those studies were followed by experiments utilizing multiple intravenously infused inert gases of varying blood solubility to further investigate ventilation-perfusion heterogeneity. More recently, researchers have focused on the exchange of heat, water, and highly soluble gases in the pulmonary airways and nasopharynx. These findings have proven relevant to the interpretation of the alcohol breath test (ABT).

The original ABT was developed (2, 4) on the basis of the hypothesis that initial dead space volume of air in exhaled breath contained little alcohol and that the remainder of the exhaled air was in equilibrium with blood alcohol concentration (BAC) as evidenced by the "flat" exhaled alveolar plateau. This assumption of a flat alveolar plateau was essential for the development of the ABT because fast-responding alcohol detectors were not available to experimental scientists at that time.

In an effort to validate the assumption that end-exhaled air had the same alcohol concentration as that in alveolar air, several studies have compared breath alcohol with blood alcohol in human subjects. More variability has been measured in the ratio of blood to breath alcohol than was expected. This range has been outlined in a previous review (5). The general finding is that breath alcohol concentration (BrAC), when compared with BAC, shows a variation among individuals of approximately ±20% (9), a variability that remains large, even with current-day detectors.

The conventional model for the analysis of pulmonary alcohol exchange tacitly assumes that the airways serve as a nonreactive conduit for the passage of air between the outside environment and the alveoli. In reality, however, respired air undergoes soluble gas and heat exchange during its transairway passage. 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 when passing along the airways. Airway exchange is an important part of pulmonary gas exchange for other highly soluble gases (3, 6, 10). During exhalation, ethyl alcohol is deposited onto the airway mucosa. During inspiration, the ethyl alcohol is resorbed from the mucosa to the inspired air. Calculations by Anderson (1) show that, whereas gases with blood-air partition coefficients (λ) of <1 exchange entirely in the alveoli, gases with higher solubility (λ of >10) also exchange within the airways. Gases with λ of >400 exchange entirely in the pulmonary airways, not within the alveoli. Exhaled BrAC originates entirely from the airway mucus and tissue (perfused by the systemic bronchial circulation).

The study of alcohol exchange has been hampered by the inability to directly measure alveolar alcohol concentration (AAC). In general, it has been assumed that BrAC is always lower than AAC, approaching AAC at the limit of a maximal exhalation. The ratio of BrAC to BAC has been assumed to be equal to or greater than 2,100. The magnitude of airway alcohol exchange has always been underestimated.

Jones (7) measured the equilibrium λ by using an in vitro equilibration chamber with controlled temperature. In that study, the partition between blood and air at 37°C was measured at 1,756 ± 8 (mean ± SE) at 37°C . Thus there is a 20% discrepancy between the directly measured partition ratio (1,756) and the blood-breath ratio (2,100) (2,100/1,756 ≈ 1.2). This difference can be explained by an average loss of alcohol to the airway mucosa in the average ABT of ~20%. This loss depends on the exhaled volume as well as other physiological factors (5). Further questions arise from studies with isothermal rebreathing to estimate AAC. With this method, respired air is rebreathed several times (into a heated bag), providing a relative equilibrium between AAC and BrAC. The studies have found blood-rebreathed air ratios of 1,947 (8) and 2,019 (11). On

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average, AAC is on the order of 15% greater than end-exhaled BrAC. During an average exhalation, each single breath alcohol test loses ~15% of the AAC to the airway mucosa during exhalation. During inspiration, air absorbs alcohol from the airway tissue in an amount equal to AAC. The net movement of alcohol is from the bronchial blood perfusing the airways to the exhaled breath.

Observations that are inconsistent with the old model (in which *1*) BrAC is increased with increasing exhaled volume, *2*) AAC is found to be 15–20% greater than end-exhaled BrAC, and *3*) BrAC begins to appear as anatomic dead space gas is exhaled) have continued to accumulate over the past few decades (5). A new model needs to be evaluated to continue the use of the ABT. Observations that are inconsistent with the old model must be experimentally evaluated before the ABT can be presumed to be accurate.

A consequence of continuing to use the old model is that subjects with larger lung volume may have a lower BrAC than a subject with a small lung volume because these subjects do not need to exhale as great a fraction of their vital capacity as subjects with smaller lung volume to fulfill the minimum volume exhalation required before stopping exhalation (usually ~1.5 liters). A person with smaller lung volume must breathe farther into the exhaled breath, resulting in a greater BrAC-to-BAC ratio. If experimental evidence is obtained to support this hypothesis, then a new model must be developed to accurately interpret breath tests (5). There is adequate justification to hypothesize a lung volume dependence of blood-breath ratio, and the observation has been made in preliminary unpublished data (lower blood-breath ratio with increasing lung volume); scientists must undertake appropriate experiments to correlate blood-breath ratio values with morphometric and physiological parameters. The ABT should be redesigned with modern respiratory physiological principles to be accurate and fair for all subjects.

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