Breath/Blood Alcohol Concentration as an Indicator of Alcohol Use Problems

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INTRODUCTION: The Federal Aviation Administration Office of Aerospace Medicine (AAM) is required by law to identify pilots who have driving under the influence (DUI) convictions. It is the responsibility of AAM to determine, based on the DUI, if the pilot has a drinking problem and needs follow-up treatment. Pilots with alcohol problems are at risk to themselves and the public and need to have treatment to reduce the extent of the risk. It has been suggested by some that a blood alcohol concentration (BAC) of 0.15 $g \cdot dL^{-1}$ is evidence of tolerance and the pilot should be placed in an alcohol treatment program.

METHOD: The National Institute on Alcohol Abuse and Alcoholism (NIAAA) Clinician's Guide considers a person at risk for a drinking problem when a man drinks 5 or more drinks or a woman drinks 4 or more drinks in a day and reaches a 0.08 $g \cdot dL^{-1}$ of ethanol in the blood. It is possible to estimate from a BAC or breath alcohol concentration (BrAC) the number of drinks consumed using the volume of distribution for ethanol and the weight of the individual. A spread sheet tool was developed to estimate the number of drinks consumed.

RESULTS: It was determined that DUI/DWI concentrations could be used to determine the minimum number of drinks consumed. Overweight people reach binge drinking levels and higher Hingson levels at lower DUI/DWI concentrations than people with an average weight or lower.

DISCUSSION: Using this tool there is a high probability (99.7%) of identifying a true binge drinker.

KEYWORDS: blood alcohol concentration, breath alcohol concentration, binge drinking.

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The Federal Aviation Administration (FAA) is required by Title 14 of the Code of Federal Regulations (CFR), Chapter I, Part 61.15,[17] to search the National Driver Register[1,18] to identify pilots with driving under the influence (DUI) or driving while intoxicated (DWI) convictions on their driving record.[17] If a DUI/DWI conviction is found, the Office of Aerospace Medicine (AAM) must determine if the pilot has an alcohol problem that might lead to the death or injury of the pilot or the public.[10] FAA regulations also require pilots to report their history of arrests, convictions, or other administrative action on their medical exam application and provide details regarding their history of substance abuse, including alcohol, on the application.[19]

For a blood alcohol concentration (BAC) in the pilot's records of 0.15 $g \cdot dL^{-1}$ or higher, the "AME [aviation medical examiner] MUST DEFER the [medical certification decision-making] action to the Manager, AMCD [Aerospace Medical Certification Division of the FAA], AAM-300, or the appropriate RFS [Regional Flight Surgeon]."[10] The ability to operate and willingness to drive a motor vehicle at alcohol concentrations of or above 0.15 $g \cdot dL^{-1}$ are considered evidence of a person with alcohol tolerance resulting from the abuse of alcohol.

Binge drinking is defined as "5 or more drinks for males on an occasion and 4 or more drinks for females, marks risky alcohol use."[12] Binge drinking has been associated with many severe health issues affecting the brain, heart, liver, and pancreas. It is also associated with an increased risk of cancer and a lowering of the immune system. These health issues are described in detail in "Beyond Hangovers, understanding alcohol's impact

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on your health."[4] Hingson recommends binge drinking be broken out into different levels: Women: I = 4–7, II = 8–11, and III ≥ 12; Men: I = 5–9, II = 10–14, III ≥ 15.[12] Hingson correlates binge drinking levels and the odds ratio of the person having an alcohol use disorder (AUD).[12] The odds of having an AUD increases with the Hingson level. Alcohol use disorders were evaluated based on driving while drinking, driving after drinking too much, had a motor vehicle accident after drinking, physical fight after drinking, had a nonmotor vehicle injury to themselves or others (cut, fall, etc.), or where arrested or had other legal problems from drinking.

Individuals on the descending side of the alcohol elimination curve are less likely to realize they are impaired and be more willing to drive than the ascending side of the curve, "both of which are more affected at a stated ethanol concentration when BAC is rising than at the same concentration when BAC is falling, the 'Mellanby effect.'"[6,13,22] "By contrast, objective measures of skills necessary for safe driving, such as response to inhibitory cues and skills measured on driving simulators, were generally worse on the descending part of the BAC-time curve for the same BAC."[13] Aviation pilots are forbidden to drink alcohol within 8 h of reporting for flight and would be on the descending side of the curve, and therefore far less likely to recognize their impairment.

This paper provides another approach to identifying people with alcohol-related problems by identifying binge drinkers using the reported BAC or breath alcohol concentration (BrAC). "One of the most significant flaws in the current system of evaluating DUI offenders is its over-reliance on data self-reported by the offender."[21] This report provides an objective way of evaluating the reliability of self-reported drinking habits.

METHODS

Knowing the blood or breath alcohol concentration of an individual makes it possible to calculate the amount of alcohol in the body and subsequently the number of standard drinks consumed prior to the test. A Microsoft® EXCEL program was developed to allow the user to calculate the number of drinks based on the BAC and alerts the user when binge drinking is reached or exceeded.

Erik M. P. Widmark is well known for his fundamental work on blood alcohol analysis and pharmacokinetics. He developed an equation for estimating the amount of alcohol consumed based upon the BAC/BrAC.[22] For intake of moderate doses of alcohol, Widmark's method provides reasonable estimates of the actual amount of consumed ethanol with an uncertainty of about ± 20%.[11] Dominguez, in 1934, introduced the concept of the volume of distribution (Vd) and defined it as the hypothetical volume of body fluid dissolving the substance at the same concentration as that in plasma.[7,20] The Vd is currently used in pharmacokinetics to calculate the dose taken and was used in calculating the amount of alcohol consumed. The mean Vds used for this paper are 0.55 $L \cdot kg^{-1}$ for men and 0.48 $L \cdot kg^{-1}$ for women. The mean body mass index (BMI) for Americans has been rising over the years and is now reported to be 29.2 for women and 28.7 for men.[3] Using these BMIs to estimate the Vd results in a low Vd. Using a low Vd in the calculations increases the probability of a true positive to 99.7%, but also increases the number of false negatives.

Volume of distributions for this paper were derived using the equation: Vd (Men) = −0.0090 * BMI + 0.8202 and Vd (Women) = −0.0099 * BMI + 0.7772.[15] Mean and standard deviations for BMIs and weights used for men and women were obtained from U.S. anthropometric data.[3]

The first step in calculating the number of drinks consumed is to convert BAC/BrAC into the dose of alcohol in the body at the time of the test using the equation Dose = Concentration ($g \cdot L^{-1}$) * Volume distribution (Vd) * weight (kg). The dose is then converted into the number of standard drinks consumed based on a concentration of 5% (14 g) alcohol by volume (alc/vol) in a 12-oz can of beer.[2] Although the concentration of alcohol in different alcoholic drinks varies, the dose of alcohol per drink remains relatively the same.[2] Using a standard drink as the criteria for calculating the number of drinks is valid, because the danger of alcohol consumption is based on the grams of alcohol consumed and for this study a standard drink contains 14 g of alcohol per drink.[4]

RESULTS

It was determined that DUI/DWI concentrations could be used to determine the minimum number of drinks consumed by the driver prior to the arrest and the odds of a person having an AUD (**Table I** and **Table II**). Overweight people reach binge drinking levels and higher Hingson levels at lower DUI/DWI concentrations than people with an average weight or lower (**Table III** and **Table IV**).

DISCUSSION

Using 0.15 $g \cdot dL^{-1}$ or greater BAC/BrAC as a criteria for identifying individuals who have developed tolerance to alcohol and endanger themselves and/or the public is valid because most people would be significantly impaired at this concentration.[5]

Table I. Calculation of the Number of Drinks Consumed for the Average Male Weight of 195.7 lb at Different BAC/BrAC.

BAC ($g \cdot dL^{-1}$)	DOSE (g)	# OF DRINKS	HINGSON LEVEL
0.02	9.76	1	
0.04	19.53	1	
0.08	39.06	3	
0.10	48.82	3	
0.15	73.23	5	I
0.20	97.65	7	I
0.25	122.06	9	I
0.30	146.47	10	II
0.35	170.88	12	II
0.40	195.29	14	II

Table II. Calculation of the Number of Drinks Consumed for the Mean Female Weight of 168.5 lb at Different BAC/BrAC.

BAC (g · dL^{-1})	DOSE (g)	# OF DRINKS	HINGSON LEVEL
0.02	7.34	1	
0.04	14.67	1	
0.08	29.35	2	
0.10	36.69	3	
0.15	55.03	4	I
0.20	73.37	5	I
0.25	91.72	7	I
0.30	110.06	8	II
0.35	128.41	9	II
0.40	146.75	10	II

Table IV. Calculation of the Number of Drinks Consumed for a Woman in the 95th Percentile Weighing 256.8 lb at Different BAC/BrAC.

BAC (g · dL^{-1})	DOSE (g)	# OF DRINKS	HINGSON LEVEL
0.02	11.18	1	
0.04	22.37	2	
0.08	44.73	3	
0.10	55.91	4	I
0.15	83.87	6	I
0.20	111.83	8	II
0.25	139.78	10	II
0.30	167.74	12	III
0.35	195.69	14	III
0.40	223.65	16	III

However, some overweight binge drinkers would be missed, as illustrated in Table III and Table IV, where men and women reach the binge drinking criteria at 0.10 g · dL^{-1} or greater BAC/BrAC rather than 0.15 g · dL^{-1}. Using the equations developed in this paper for calculating dose would identify binge drinking at 0.10 g · dL^{-1} BAC/BrAC, much lower than the stated 0.15 g · dL^{-1} used to identifying pilots who have developed tolerance to alcohol.

"Studies of the impairing effects of alcohol on behavior often show greater tolerance in heavy drinkers compared with light drinkers, suggesting a causal link between heavy consumption and tolerance. Tolerance also develops during the time course of a single drinking episode, and this 'acute tolerance' might play an important role in the escalation to heavy drinking."[8] This is also evident in Tables I–IV, showing a relationship between binge drinking and BAC (tolerance). A BAC of 0.15 g · dL^{-1} in Table I and Table II for the average weight of women and men is indicative of binge drinking as well as tolerance.

The dose estimates calculations, based on BrAC analysis, have been shown to underestimate dose in most cases.[9] Most DUI/DWI convictions are based on BrAC and would, in most cases, underestimate the dose taken. BAC analysis has been demonstrated to show a ± 20% variability in calculated dose.[11] This difference can be easily explained by the fact that U.S. breath alcohol instruments are calibrated using 1/2100 breath to blood ratio when, in fact, the ratio is usually higher (1/2300). "Alcohol concentrations reported by breath-alcohol instruments in the United States typically are lower than those found in the blood."[5]

Table III. Calculation of the Number of Drinks Consumed for a Man in the 95th Percentile Weighing 275.4 lb at Different BAC/BrAC.

BAC (g · dL^{-1})	DOSE (g)	# OF DRINKS	HINGSON LEVEL
0.02	13.74	1	
0.04	27.48	2	
0.08	54.97	4	
0.10	68.71	5	I
0.15	103.06	7	I
0.20	137.41	10	II
0.25	171.77	12	II
0.30	206.12	15	III
0.35	240.47	17	III
0.40	274.83	20	III

It was decided to assume a relatively high BMI to calculate the Vd used in the calculations of dose. This made the probability of a false positive binge drinker highly unlikely (less than 1.0%) when using 3 SDs (0.51) above the mean BMI (29.2) reported in the literature.[3] The volume of distribution often used in legal proceedings is 0.60 for women and 0.70 for men.[14–16,20] If the BMI is known for an individual, the Vd can be calculated and used to estimate the number of drinks consumed.

Hingson Level I binge drinkers are at 6.9 times greater risk of having an AUD than none-binge drinkers, Level II binge drinkers are at 20.4 times greater risk, and Level III binge drinkers are at 52.5 times greater risk.[12] Tables I–IV illustrate the Hingson Levels at different BAC/BrAC, weight, and sex. Tolerance in an individual can be identified using a 0.15 g · dL^{-1} or greater BAC/BrAC as stated in the existing FAA Guide for Aviation Medical Examiners (AMEs).[10]

Using the Microsoft® EXCEL program developed here would allow AMEs to objectively identify binge drinkers who are at high risk for alcohol use disorders. The number of drinks calculated will most likely be less than the actual number of drinks consumed prior to the DUI/DWI considering alcohol is being eliminated from the body over time and the Vd used underestimates the number of drinks for the majority of the population, unless one considers the BMI in calculating the Vd.

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