TOXICOLOGY REPORTER

ALCOHOL

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Alcohol: Fate-Testing-Effects

The Fate of Alcohol

The consumption, absorption, distribution, and elimination of alcohol

Alcohol use

Alcohol use can be described by terms that include the following:

Acute (recent) use
Chronic (longer-term) use
Experimental use
Social-recreational use
Situational use
Compulsive use
Binge drinking

Absorption of ethanol

The absorption of alcohol is a passive process: Ethanol moves from a location of higher concentration to a location of lower concentration. For example: While alcohol is being consumed and for a period of time following last consumption, the concentration of ethanol in the stomach or small intestine is greater than the BAC. The absorption of alcohol occurs under these conditions.

Because alcohol is slowly absorbed from the stomach compared to the small intestine, factors that slow the emptying of the stomach also slow the rate and extent and time-course of alcohol absorption. This results in a longer time between the person's last swallow of alcohol and the peak or highest blood alcohol concentration (BAC) as well as lower BACs at specific times including the time of the person's peak or highest BAC.

The speed with which the stomach is emptied into the small intestine (i.e. the gastric emptying time) affects the overall rate of absorption, the time available for the metabolism and excretion of alcohol while the BAC is rising, and the timing and level of the person's peak BAC. Food slows (delays) gastric emptying, increases the time to peak or highest BAC, and results in a lower peak BAC. Under some circumstances, it can take more than two hours after last alcohol consumption to reach the peak or highest BAC.

Distribution of ethanol

Distribution refers to the processes involved in the movement of alcohol within and between body tissues and fluids and the relative concentration of alcohol in different body tissues and fluids. Processes that are involved in the movement and equilibration of ethanol in and between body fluids and tissues include blood flow, water content of tissues and fluids, and diffusion or concentration-controlled rates of movement between tissues and fluids.

The diffusion of ethanol across blood:tissue barriers controls the amount (concentration) of ethanol at a specific site of action and in all other body tissues and fluids. For example: The concentration of ethanol in cerebrospinal fluid or vitreous fluid can be related to the equivalent BAC.

When considering the distribution of alcohol in the human body, one of the most important features is the distribution or equilibration of alcohol between body tissues and fluids that have different concentrations of water (e.g. urine > blood > muscle > brain > body fat). Alcohol is water-miscible and its distribution in all body tissues and fluids is determined by the amount of water in each tissue or fluid. One of the results is that, when urine is formed in the kidney, the urine alcohol concentration (UAC) is higher than the corresponding BAC. On the other hand, BAC is higher than the corresponding muscle alcohol concentration. These relationships allow a toxicologist to compare and interpret alcohol test results obtained from different specimens.

The total volume of alcohol in all body tissues and fluids is called the total body alcohol (TBA). The TBA is the minimum amount of alcohol the person must have consumed to account for his/her BAC; but TBA does not account for the alcohol eliminated (metabolized and excreted) between the time alcohol was first consumed and the time the test specimen was drawn or, if deceased, the time of death. This is discussed below.

Elimination of ethanol

Elimination of ethanol refers to the processes that result in a reduction of alcohol concentration. These processes include metabolism and excretion.

The metabolism of ethanol is largely controlled by an enzyme, alcohol dehydrogenase (ADH). ADH catalyzes the conversion of ethanol to acetaldehyde:

$$\mathbf{CH_3CH_2OH \rightarrow CH_3CHO}$$

The elimination of ethanol includes the physical excretion of ethanol in breath and urine.

Studies have shown that the rate of elimination (expressed as a fall in BAC or the elimination of an equivalent amount of alcohol over a defined period of time) can be affected by a number of biological and physiological variables.

For alcohol, the rate of elimination is usually mathematically characterized as zero ("0") order: The elimination rate does not depend on the concentration of ethanol. For example: The rate of elimination at BACs greater than about 0.025% is usually not affected by the actual BAC. A zero-order rate of elimination of alcohol during a post-absorptive period is illustrated below.

BAC Elimination Over Time

Hour	Event or BAC
1	Last consumption of alcohol
2	
3	0.165% (*post-absorptive*)
4	0.150
5	0.135
6	0.120

In this illustration, the apparent rate of elimination is constant over time and equal to 0.015% BAC per hour. For an average 180-pound adult male, an elimination rate of 0.015% BAC per hour is equivalent to the hourly elimination of the amount of alcohol in 3/5ths of a drink (e.g. roughly about 8 ounces of beer or 3 ounces of wine or one ounce of 80-proof liquor). For an average 125-pound adult female, an elimination rate of 0.015% BAC per hour is roughly equivalent to the hourly elimination of the amount of alcohol in about 4/10ths of a drink.

Elimination and the extrapolation of BAC

If the person's absorption of alcohol is complete and the BAC is falling (i.e. the person is in a post-absorptive state), the rate of elimination and the time between a specific event and the time the person's BAC was determined can be used to estimate the person's BAC at the time of the specific event. This is sometimes referred to as the retrograde extrapolation of BAC. An example retrograde extrapolation of BAC at the time of a MVA two hours after the last consumption of alcohol and three hours prior to a post-MVA BAC test follows.

Retrograde Extrapolation of BAC

Hour	Event or BAC
1	Last service of alcohol
2	Last swallow of alcohol
3	MVA (*post-absorptive*)
4	
5	
6	0.120%

BAC at MVA = 0.120% + 3(0.015%)

= 0.120% + 0.045%

= 0.165% BAC

Often times, case-specific circumstances and analyses indicate that other approaches to the estimation of BAC are more appropriate. These other approaches include forward extrapolation and range extrapolation.

Relating distribution-elimination-and-TAC

Given a person's sex and height and weight and BAC, the person's total alcohol consumption (TAC) must account for the total body alcohol (TBA, or the total body alcohol in all tissues and fluids) plus the total alcohol elimination (TAE) between the time alcohol was first consumed and the time the premortem BAC test specimen was collected or the time of death. Simply stated: Total alcohol consumption must account for the person's BAC and the person's elimination of alcohol.

TAC = TBA + TAE

When attempting to estimate a person's TAC, an experienced toxicologist should be consulted.

Total Alcohol Consumption (TAC)

Hour	Event or BAC
0	First consumption of alcohol
1	Last service of alcohol
2	Last swallow of alcohol
3	
4	
5	
6	0.120%

For a 6', 180-pound adult male with an average rate of elimination equivalent to 0.015% BAC or 3/5ths of a drink per hour, the estimation of TAC follows:

TBA	=	4+ drinks, given a 0.120%BAC
TAE	=	3+ drinks over 6 hours
TAC	=	TBA + TAE
	=	8 drinks

Premortem Alcohol Testing:

Whole blood, blood serum, urine, and breath alcohol testing including results comparison

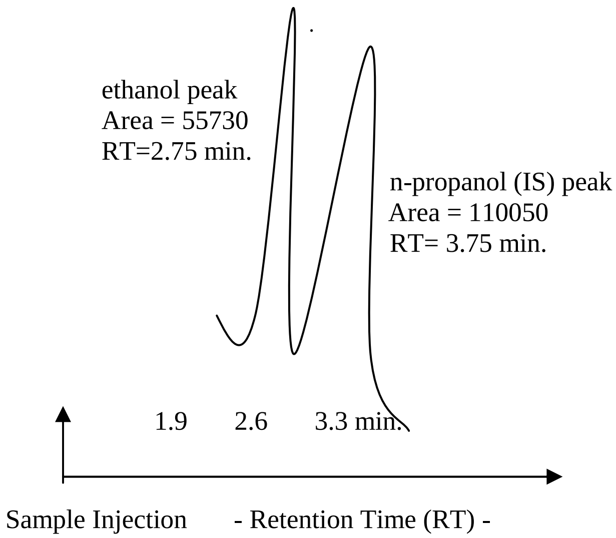
Over 90 percent of the hospitals in the United States routinely test for alcohol in blood serum using an enzyme-based method; and a blood serum alcohol concentration is about 15 percent greater than the equivalent BAC.

Whole Blood Alcohol Testing

The objective is to directly measure whole blood alcohol concentration (BAC). The most commonly used approach is to collect a specimen of whole blood and test for alcohol (i.e. ethanol) based on the separation and specific identification of ethanol by gas chromatography (GC) and quantitation by a method employing an internal standard (IS).

BAC Testing: When a BAC test is done by GC using an internal standard (IS) technique, the method usually involves the following:

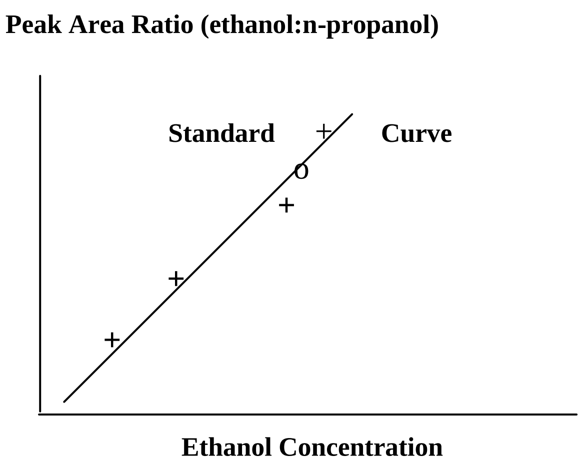
A known volume of the IS (e.g. n-propanol) is added to a fixed volume of ethanol standards, controls, and unknown (subject) specimen(s). GC is then used to separate-and-identify ethanol and the IS based on retention time (RT); and detector response to the ethanol and IS in each sample is measured as peak height or peak area;



The peak area ratio for ethanol versus the internal standard is then calculated;

$$\text{ethanol/IS ratio} = 55730/110050 = 0.50$$

The peak area ratio of the detector response for ethanol compared to n-propanol (i.e. the ethanol:IS ratio) in each standard (+) is then plotted on graph paper or analyzed by a micro-computer to prepare a standard curve; and …



The ethanol:IS ratio for each unknown (o) is compared with the standard curve to determine the concentration of ethanol in the unknown.

Because the ethanol:IS ratio for each sample is established when the internal standard is added to the sample, the procedure is "self correcting" for many of the potential errors that are sometimes associated with other types of tests including some types of GC tests.

Unknowns are often run in duplicate or triplicate to determine reproducibility; and unknowns are also often separated by ethanol-free check samples in order to establish the absence of cross-contamination.

Quality Assurance: Quality assurance, as one approach to assessing the reliability of reported test results, is often based on a combination of laboratory policies and procedures. These policies and procedures include the following:

Detailed written procedure including specimen collection and processing, standardization, instrument maintenance and function, analysis of specimens including alcohol-free and known check specimens, data collection-and-analysis, and results review and reporting

Determination of test reproducibility

External quality assurance surveys

One aspect of in-laboratory quality assurance is the determination of the reproducibility of a test procedure. Two statistical measures of reproducibility are the standard deviation (SD) and the coefficient of variation (CV) of test results for check or control specimens tested on different days. A chart of day-to-day quality assurance follows.

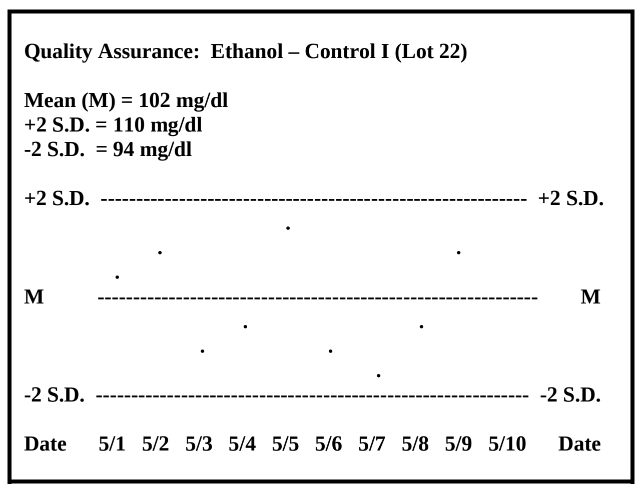


Chart: This Q.C. chart of 5/1 to 5/9 test results for an ethanol control allows a comparison with the previously determined mean of 102 mg/dl and SD of about 4 mg/dl. The 5/1 to 5/9 test results are within the acceptable limits for the control range (+/- 2 SD from the mean value).

For a highly reproducible alcohol test, the day-to-day SD might be 4 mg/dl for an ethanol control with a mean of 102 mg/dl based on test results over a period of one month. Given a mean of 102 mg/dl, a SD of 4 mg/dl would be equivalent to a CV of four percent; and one would expect that about 95 percent of the day-to-day test results for the ethanol control would fall in the range of 94 to 110 mg/dl (a range equal to plus or minus two SDs from the mean value for the control results).

One generally accepted laboratory practice is to review aspects of the test procedures such as standardization if the control result falls outside of two standard deviations (SDs) from the control's mean value.

But … remember that a reproducible test is not necessarily an accurate test… it only means that the test gives similar results when the specimen is tested more than once … it does not mean that the test results are correct. On the other hand, an accurate test should produce a reliable result that is reproducible.

Most whole blood and blood serum alcohol test methods are accurate.

Blood Serum Alcohol Testing

Over 90 percent of the hospitals in the United States routinely test for alcohol in blood serum using an enzyme-based spectrophotometric method.

Drawing blood: After topical disinfection with a non-alcoholic preparation such a betadine, a venous blood sample is usually drawn from the anticubital area (opposite the elbow) using a sterile needle and glass evacuated blood tube. This tube is sealed with a red-rubber stopper . . . hence the name: red-top tube. The tube does not contain anticoagulants, and the blood sample clots on standing.

Processing the blood specimen: The clot tube is allowed to sit for a period of time and then processed by centrifugation to separate the blood clot from the straw colored fluid called blood serum. Serum is tested.

BSAC testing: Most hospitals use a test procedure based on the enzyme-catalyzed conversion of ethanol to acetaldehyde and the biochemical reduction of NAD, an enzyme-cofactor:

Ethanol + NAD → Acetaldehyde + NADH

These tests are normally run on an automated spectrophotometer that determines the rate or extent of formation of NADH (based on the absorbance of 340 nm ultraviolet light) as a measure of the alcohol concentration.

Standards are used to calibrate the instrument; and controls are usually tested at least once a day to verify test performance. An example set of instrumental responses for a set of ethanol standards follows:

An Example Standard Curve

Ethanol Standard	Abs. at 340 nm
0.00 %	0.015
0.05	0.170
0.10	0.350
0.20	0.705
0.30	1.100

For BSACs greater than 40 mg/dl, test error is usually less than 10 percent of the reported alcohol concentration. For example, a reported BSAC of 50 mg/dl would be consistent with a true BSAC between 45 and 55 mg/dl.

Results-reporting: Printed test results usually include the date and time of specimen collection, the test result, and the normal range. For alcohol, the normal range is none-detected or less than 10 mg/dl (< 0.01% BSAC).

Never assume that a "blood ethanol" result actually represents the patient's BAC. If it is a hospital-based alcohol test result, the test was probably done on blood serum; and BSAC is about 15 percent greater than the equivalent BAC.

The most common unit of measure is mg/dl (milligrams of ethanol per deciliter of blood serum). To convert XXX mg/dl to percent BSAC, divide by 1000 (e.g. 100 mg/dl = 0.10%). To convert XXX mg/L (milligrams per liter) to percent BSAC, divide by 10,000 (e.g. 1000 mg/L = 0.10%). Remember … to convert the BSAC to a BAC, divide the BSAC by 1.15.

100 mg/dl BSAC is 0.100% BSAC
0.100% BSAC equals about 0.087% BAC

1500 mg/L BSAC is 0.150% BSAC
0.150% BSAC equals about 0.130% BAC

29 mg/dl BSAC is 0.029% BSAC
0.029% BSAC equals about 0.025% BAC

In these examples, percentage BAC is expressed as a percentage weight-by-volume: 0.10% w/v (weight-by-volume) is the same a 0.10 grams of ethanol per 100 milliliters (or 100 cubic centimeters) of blood or 0.10 grams of ethanol per deciliter of blood or 100 milligrams of ethanol per deciliter of blood (or 100 mg/dl blood).

To express percentage weight-by-volume as a percentage by weight (% w or % w/w), you have to divide the % w/v BAC by 1.055 to correct for the fact that the specific gravity of whole blood is about 1.055 (i.e. 1.0 milliliter of blood weighs about 1.055 grams).

% w/v BAC / 1.055 = % w/w BAC

Note: Connecticut defines alcohol concentration as percentage by weight in its administrative and criminal statutes.

Urine Alcohol Testing

When urine is formed in the kidney, the urine alcohol concentration (UAC) is about 1.35 times the BAC; and the use of this BAC:UAC ratio of 1.35 as a correction factor would seem to provide for a reasonably accurate indirect measure of BAC.

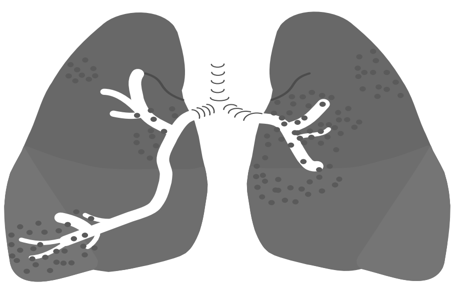
BAC = UAC/1.35

However, the problem with the use of a correction factor is that UACs are routinely determined using a spot urine sample (bladder urine) that does not reflect the person's BAC at the time of specimen collection. Urine is formed in the kidney; but it is collected and stored in the bladder for an undetermined period of time prior to voiding a specimen. When a subject provides two urine specimens, the subject is usually not instructed to void his/her bladder at the time of the first test … therefore, a second, timed UAC test does not always allow for a reliable correction-based estimate of the subject's BAC.

Absent a near complete voiding of the subject's bladder and the subsequent production of a substantial volume of urine prior to time of the collection of the second specimen, the second UAC test result is often an unreliable indirect indicator of the subject's BAC at the time of specimen collection. ***However, case analysis including a UAC test result can sometimes provide useful information regarding the subject's prior total alcohol consumption and/or a likely range for the subject's premortem BAC.***

You should always consult a toxicologist regarding the interpretation of UAC test results.

Breath Alcohol Testing



The objective of breath alcohol testing is to indirectly estimate BAC. A breath test machine captures a sample of deep lung air; it measures the alcohol concentration in that breath sample; it multiplies the test result by 2100; and it then reports the breath alcohol concentration (BrAC) test result as an equivalent percentage weight-by-volume BAC.

INTOXILYZER - ALCOHOL ANALYZER
MODEL 5000

SUB = JOHN DOE

TEST	% BAC	TIME
AIR BLANK	.000	01:55 EST
CAL. CHECK	.102	01:55 EST
AIR BLANK	.000	01:56 EST
INTERNAL STD	OK	01:56 EST
AIR BLANK	.000	01:56 EST
SUBJECT TEST	.114	01:56 EST
AIR BLANK	.000	01:57 EST
CAL. CHECK	.103	01:57 EST
AIR BLANK	.000	01:57 EST

AIR BLANK refers to a test of room air. It should read .000, indicating no environmental contamination.

CAL CHECK refers to the reading obtained when testing a simulator solution. It can be compared with the acceptable range (e.g. 0.090-0.110).

INTERNAL STD refers to a reading obtained using an internal optical filter. It can be compared with the expected value (e.g. 0.100).

SUBJECT TEST refers to the subject's test result, which is an indirect estimate of the subject's BAC at the time of the breath test.

While BrAC testing has been subject to criticism as an indirect measure of BAC, most test result between 0.10 and 0.20% are within about 10 percent of the subject's true BAC at the time of breath testing. However, example criticisms of BrAC tests are summarized below.

Breath test variables: Because breath test machines are not completely selective and they do not measure an individual's physiological parameters (e.g. an individual's blood:breath alcohol ratio), breath testing has been criticized for being subject to a variety of errors:

Machine error (1) . . . referring to the accuracy of the breath machine's measurement of the alcohol concentration in the captured breath sample. Some experts consider the permissible level of error for a breath test simulator (e.g. plus or minus 0.005% to 0.010%) as representative of machine error.

Biological error (2) . . . referring to the error associated with the machine's use of a fixed breath-to-blood (i.e. BrAC:BAC) multiplication factor of 1:2100 when indirectly estimating the BAC at the time of the breath test. This is the error due to the use of an arbitrary multiplication factor of 2100 when the breath machine *converts* the measured breath alcohol level as an *equivalent* BAC.

Physiological error (3) . . . referring to the over-estimation of BAC when the subject's alcohol level is rising or at a peak (i.e. when the person is still absorbing some amount of alcohol and the BAC in the blood going to the subject's lungs is higher than the BAC in the rest of the body).

Chemical interference (4) . . . referring to error due to the measurement of other chemicals similar to alcohol.

Unit-of-measure: Percent by weight (w/w) BAC. As mentioned earlier, Connecticut alcohol-related laws are based on percentage by weight BAC. To express a percent weight-by volume (% w/v) BrAC as a percentage by weight (% w/w), you have to divide the breath alcohol level by the specific gravity of whole blood (SpGr = 1.055).

It is then argued that the total potential breath test error (e.g. for 1-4) can be estimated based on case-specific assumptions.

For example, the lower limit for a person's true % w/v BAC at the time of breath testing can be calculated by subtracting appropriate values for each of the potential breath test errors:

BAC = (BrAC - (Test Errors))

BAC = (BrAC - (1) - (2) - (3) – (4))

BAC = % (w/v)

For example: Given a BrAC result of 0.120% and considering only a biological error of five percent, the BrAC test result would over-estimate the true BAC by 0.006%.

BAC = (BrAC - (Test Errors))

= 0.120 – 0.006

= 0.114% w/v or 0.108% w/w

A more reliable but generally impractical approach would be to experimentally determine potential errors. For example:

Determination of the breath:blood alcohol ratio

Determination of the machine error

The Effects of Alcohol

Effects of ethanol

Acute (shorter-term) v. residual (longer-term) effects

For example: Are residual neurological deficits attributable to chronic alcohol abuse? What effects? What is the degree of certainty?

Dose:effect and concentration:effect relationships

For example: What is the relationship between BAC and the likelihood that a person will exhibit visible signs of intoxication? How is BAC related to the risk of accident?

Physical and behavioral effects and associated risks

For example: Did the person's consumption of alcohol substantially contribute to his decision to commit suicide?

Causation v. contribution v. coincidental factors

For example: Was the pedestrian-MVA related to alcohol? How? To what extent?

Degree of certainty or predictability or likelihood

For example: What percentage of a group of adult social drinkers will exhibit one or more visible or obvious signs of intoxication at a specific BAC?

Other questions relating to the effects of alcohol include the following:

What it known about the first reported (threshold) effects of alcohol at relatively low BACs?

What are the relationships between increasing BACs and the number-nature-severity of physical and behavioral effects and the risk of alcohol-related accident?

What is the relationship between a person's history of alcohol use and the person's sensitivity or tolerance to alcohol and his/her appearance-behavior-demeanor?

What is the potential relationship between learned experience or behavioral modification and a person's ability to mask the effects of alcohol?

Illustrations of the relationship between BAC and the risk of accident are presented below.

Motor vehicle accidents:

There is scientific consensus that alcohol causes deterioration of driving skills beginning at 0.05% BAC or even lower and progressively serious impairment at higher BACs. *JAMA 255:522-7 (1986)*

Research indicates that each 0.02% increase in BAC doubles a driver's risk of being in a fatal crash; the risks increase even more rapidly for drivers under age 21; and the risks also increase more rapidly for women. *Reference to Zador in Alcohol and Health Res World 17(1):28-34*

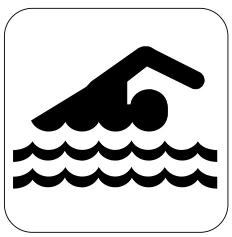
Accidental falls:

A large percentage of falls are related to alcohol. Compared to the population, studies of fatal falls among alcoholics report odds ratios of 2.9 to 16. Determination of the odds ratios at significant BACs for fall-related patients compared to disease-related patients yielded odds ratios from 2.5 to 10.

53% of patients injured in accidental falls in the evening in Helsinki [Finland] and 15% of the time-, site-, and sex-matched control pedestrians were alcohol-involved. Relative risk of injury (if 1.0 at zero BAC), was 3 at BACs of 0.060-0.100%, 10 at 0.101-0.150%, and about 60 at BACs greater than 0.151%. The authors concluded that 1) alcohol increases a pedestrian's risk of accidental fall somewhat more than it does a driver's risk of traffic accident; 2) the relative risk of a fall increases with an increase in the pedestrian's BAC; and 3) the risk at BACs greater than 0.100% is so high that practically all cases with such BACs can be considered to have been caused by alcohol. *J Stud Alcohol 44(2):231-245 (1983)*

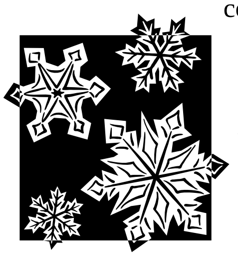
Aquatic accidents:

Alcohol is associated with an increased risk of neck fracture and spinal cord injury.

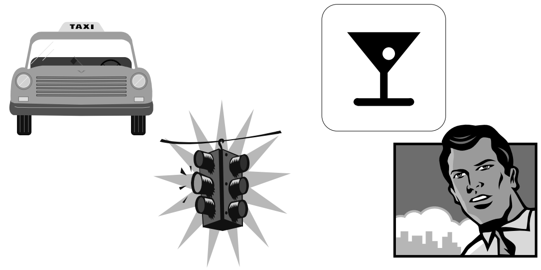


One study found that 44 percent of the 220 hospital admissions for neck fracture from diving accident showed evidence of alcohol use; and more than 22 percent had BACs greater than 0.10%. Another study reported that subjects who sustained spinal cord injury from diving were four times more likely than controls to have consumed alcohol. Perrine et al. reported that diving performance is impaired at a BAC of 0.04%. *J Stud Alcohol 55:517-524 (1994)*

Snowmobile accidents:



Studies have found a strong association between the consumption of alcohol and snowmobile accidents. Sixty-four percent of the drivers were OUI and fatalities had a ratio of 4.3 for the use of alcohol; 86% of the fatally injured drivers were OUI and had a mean BAC of 0.17%; alcohol was implicated in 69% of the fatally injured and 59% had a BAC over the legal limit; and 80% (24 of 30) of the fatally injured drivers were found to have been DWI. A review of these studies leads to a general overall impression that fatal snowmobile accidents are most frequently associated with the use of alcohol and sub optimal lighting conditions and young male driver. *Ann Emer Med 24(5):842-8 (1994); Artic Med Res 51(Suppl 7):56-8 (1992); J Can Med Assoc 146(2):147-52 (1992); and, J Trauma 22(12):977-82 (1982)*

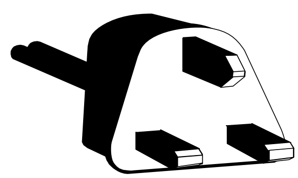


Pedestrian-MVA:

Of the 10,000+ pedestrians killed and 100,000+ pedestrians injured each year as a result of pedestrian-motor vehicle accident (Ped-MVA), the consumption of alcohol plays a contributing factor in a large percentage of these accidents.

Case studies have reported that at least 50 percent of the pedestrians having a BAC greater than 0.10% were responsible for the accident. Risk analysis studies have reported that as the pedestrian's BAC increased, the apparent risk of accident increased more rapidly than the increase in the pedestrian's BAC. *This finding regarding risk assessment is similar to that reported for a driver's risk of MVA.*

Alcohol and electrical deaths:



References:

RK Wright and JH Davis, The Investigation of Electrical Deaths: A Report of 200 Fatalities, J For Sci, 25 (3), 514-21 (1980), and PF Mellen et al., Electrocution: A Review of 155 Cases with Emphasis on Human Factors, J For Sci, 37 (4), 1016-22 (1992)

Other types of accidents or injuries that are sometimes related to alcohol include the following:

Motorcycle accident	**Bicycle accident**
Aquatic deaths	**Firearm accident**
Boating accident	**Fire**

Other alcohol-related adverse effects or events include the following:

Seizure	**Suicide**
Cancer	**Cognitive deficits**
Malnutrition	**Liver disease**
Kidney disease	

Like all other types of potential alcohol-related cases, review and analysis should include the following:

- Review to establish the reliability of post-accident toxicology test results including alcohol and drugs and the history of the use of prescription medications
- Calculation of the total amount of alcohol consumed in order to account for the subject's elimination of alcohol and the alcohol test results
- Estimation of the subject's BAC at the time of the accident
- The expected effects of alcohol or alcohol-and-drugs and foundation relating to an opinion regarding the risk of accident and/or the factors relating to the occurrence of accident
- Review of relevant medical and other records

Alcohol and assault:

Abstract: Data from a prospective, longitudinal study of males and females age 12, 15 and 18 years were used to study the relationship between alcohol use and aggression. Prevalence rates for alcohol use are similar for males and females. *A Longitudinal Investigation of Alcohol and Aggression in Adolescence, HR White, J Brick, S Hansell, J. Studies on Alcohol (Supplement), 11, pp 62-77 (1993, Sep).*

However, prevalence rates for aggressive behavior and alcohol-related aggression among females are lower than those for males and too low to permit meaningful analysis. Two series of nested structural equation models examine the inter-relationships between alcohol consumption and aggressive behavior over time for all males in the sample and for male alcohol users only.

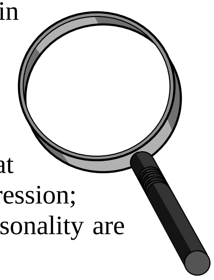
The findings indicate that early aggressive behavior leads to an increase in alcohol use and alcohol-related aggression, but that levels of alcohol use are not significantly related to later aggressive behavior. Thus, the study data suggest that alcohol-related aggression is engaged in by aggressive people who drink. These data lend support to other research indicating that early aggressive and antisocial behavior is predictive of later alcohol-related problems.

A toxicologist should be able to provide you with current information regarding competing medical/scientific theories and case-related opinions.

Question: Does the intoxication of young males cause or result in physical aggression?

Quotation: "Twenty subjects participated in an experiment testing the effects of a moderate dose of beer on physical aggression. Subjects were randomly assigned to a beer drinking group or a control group. Aggression was measured in terms of number of shocks given, shock intensity, and shock duration in a modified version of the Buss' aggression machine. **There were no differences among groups and there was no interaction of beer by frustration on aggression.** The results are explained in terms of expectancies held by subjects as to the effects of beer intoxication on behavior." *Unreferenced (B. Pape)*

Alcohol and Bars and Assault



Substance abuse is a common factor in aggression … [and] … habitual substance abuse has been reported for repeat murders; but alcohol abuse and aggression share antecedents that include childhood abuse. It appears that the use of alcohol contributes to aggression; but contextual clues and individual personality are important. *(Unreferenced, B. Pape)*

"Systematic observation of Vancouver barrooms showed that **aggression was highly predictable on the basis of situational variables** and [the results of these studies] identified a drinking environment highly associated with aggression." *K. Graham et al., J. Studies on Alcohol, 41(3), 277-92 (1980).*

Alcohol and Aggression: What do most people believe?

Over 75 percent of the respondents obtained in a survey of Canadian adults believed that alcohol is associated with aggression … 92% believed that an intoxicated person is responsible for any behavior and that alcohol is not an acceptable excuse. *From Paglia and Room; J Subst Abuse 10(2): 199-216 (1998).*

Alcohol and Aggressive Behavior: Explanations

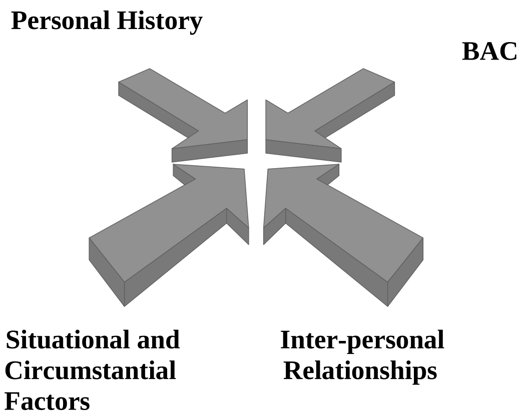
Physiological disinhibition theory: Alcohol increases aggression directly by depressing the brain center that normally inhibits aggressive behavior.

Expectancy theory: Alcohol increases aggressive behavior because people expect it to.

Indirect cause theory: Alcohol increases aggression by causing changes within the person that increase the probability of aggression (e.g. by reducing intellectual functioning).

A simple illustration of relevant factors follows.

Illustration: Alcohol and Behavior



Because of the uncertainties regarding the application of only one of these theories to a case-specific situation, it is prudent for case-analysis to consider all reasonable theories and relevant factors.

Alcohol-drugs-and-aggressive behavior:

The theories of drug use and aggressive behavior appear to be similar to those proposed for alcohol. Examples of drug-associated relationships follow.

Cocaine-ethanol-cocaethylene-and-assault

The consumption of cocaine and alcohol results in the formation of cocaethylene (CE or BEEE), and unique transesterification product associated with the presence of alcohol and cocaine.

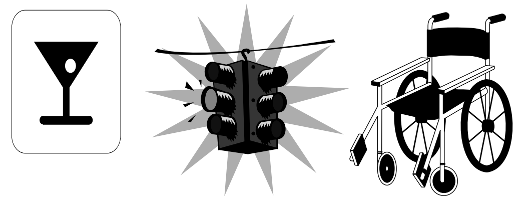
Cocaine + Ethanol → Cocaethylene

The individual and/or additive effects of cocaine, CE, and ethanol have been associated with adverse behavioral effects including deviant or violent behavior.

Other drugs that have been associated with aggressive behavior include benzodiazepines such as diazepam or Valium.

If you have questions regarding the relationship between alcohol-and-drugs and aggressive behavior, you should consult with a toxicologist.

Liquor Liability



Trial testimony by an alcohol expert usually focuses on five case-specific issues:

Alcohol Concentration Test Results

Total Alcohol Consumption

BAC at the Time of Last Service

Reported Appearance-Behavior-Demeanor

Expected Effects Based on BAC

Alcohol test results

In most liquor liability cases, the relevant post-accident alcohol concentration tests are done in hospitals using blood serum. The reliability of a blood serum alcohol concentration test result (BSAC) should be reviewed; and the BSAC should be expressed as an equivalent whole blood alcohol concentration (BAC).

As previously discussed, BSACs are about 15 percent higher than the equivalent BAC. To convert a BSAC test result to an equivalent BAC, divide the BSAC by 1.15. An example follows:

115 mg/dl BSAC = 0.115% BSAC
= 0.100% BAC

Alcohol consumption

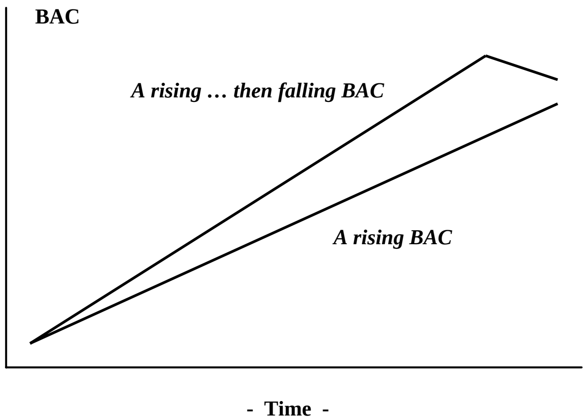
The estimation of a person's total alcohol consumption (TAC) should account for the total amount of alcohol eliminated (TAE) between the time alcohol was first consumed and the time the alcohol test specimen was drawn or the time of death plus the total body alcohol (TBA) in all tissues and fluids necessary to account for the BSAC or BAC.

TAC = TAE + TBA

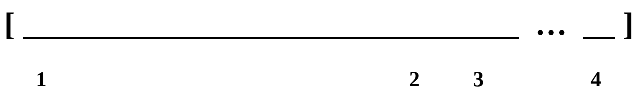
For example: If, after drinking for five hours, a 180-pound male has a BAC of 0.150%, the TAE would be equal to about three drinks and the TBA would be equal to about six drinks. Therefore, the TAC would be equal to about nine drinks or an amount of alcohol equivalent to about 13 ounces of 80-proof liquor.

Estimation of BAC at a specific time

The estimation of a drinker's BAC at the time of last service is usually based on a process of extrapolation that is applied to case-specific information.



A Case-Example Time-Line



When (1) is the time alcohol was first consumed, (2) is the time alcohol was last served, (3) is the time of last consumption, (1-4) is the time period during which alcohol was eliminated prior to the alcohol test, and (4) is the time the alcohol test specimen was collected or the time of death.

There are a variety of ways to estimate BAC at a specific time and, indirectly, the expected alcohol-related effects:

- Retrograde extrapolation from a BAC test
- Forward extrapolation based on consumption
- Range extrapolation based on all variables
- Evaluation of witness statements and testimony

In most liquor liability cases, the drinker's BAC is rising: The BAC is usually lower at the time of last service than it is at the time of a post-service accident; and the drinker's post-accident BAC is sometimes the peak or highest BAC experienced by the drinker.

… ***at the time of last service, there is usually alcohol in the drinker's stomach and there is alcohol in the last alcoholic beverage served to the drinker, … and the drinker usually experiences a rising BAC that does not reach a peak level or highest concentration until sometime after the last swallow of alcohol.***

Retrograde extrapolation is the calculation of BAC at a specific time based on one or more alcohol concentration test result(s) at some later time(s) and what are often unspecified or implicit assumptions. These assumptions usually include the following:

Assumptions that the subject was fully post-absorptive and experiencing a falling BAC between the time of interest and the time of the alcohol concentration test; that the assumed rate of elimination used to calculate the fall in the subject's BAC was reliable; that there were no special factors affecting the subject's post-accident BAC; and that the alcohol test result is reliable.

Example: Assuming that the subject was post-absorptive at the time of the MVA and his BAC was 0.09% 90 minutes after the MVA, what was the BAC at the time of the accident? **Solution:** During the 90 minute post-accident period, the subject's BAC fell about 0.023% (1-1/2 hours x an elimination rate of 0.015% per hour). Therefore, his BAC at the time of the accident was about 0.11%. *Note: The most frequently reported average rate of elimination for adult males is 0.015% BAC per hour.*

Example: Assuming the same facts and a second BAC test result of 0.04% four hours post-MVA, what is the highest reasonable estimate of the subject's BAC at the time of the accident? **Solution:** Assuming that the subject's apparent decline in BAC between the two post-MVA tests reflected the subject's true rate of elimination (0.05% over 2-1/2 hours) at prior times, the apparent rate of elimination would be 0.02% per hour. Therefore, the subject's true BAC at the time of the accident (90 minutes before the first BAC test) would be 0.12%.

Forward extrapolation: Forward extrapolation is based on the analysis of factors that include the time(s) of alcohol service and consumption as well as the time-course and extent of the absorption, distribution, and elimination of alcohol. An alcohol test result is not required; but, when available, the extrapolated BAC and actual BAC should be compared.

Range extrapolation: A process that explicitly considers all of the reasonable variables affecting the reliability of the factors involved in the extrapolation of the person's BAC.

Clinical indicia: Depending on the case-specific circumstances, clinical indicia (i.e. visible and/or obvious signs) of intoxication might include witness testimony regarding the subject's appearance-behavior-demeanor. Indicia of intoxication can sometimes be related to an estimate of the subject's BAC.

Effects of alcohol

Expert case-analysis regarding whether or not the subject would be expected to exhibit visible or obvious indicia of intoxication should include the consideration of all reasonable-and-relevant points of comparison. Some examples follow.

Impairment Estimation Procedure (IEP)

While a recent study suggests that a behavioral-based Impairment Estimation Procedure (IEP) can be used to estimate BAC as well as alcohol impairment, the results are not conclusive:

IEP cues for severe impairment seem extreme. Examples include A) social interaction that is uncontrolled (e.g. urinating), hostile (e.g. cursing), withdrawn (e.g. reclusive), or confused (e.g. loss of memory); B) physical appearance that is sloppy (e.g. slovenly); and, C) motor coordination that is stumbling (e.g. weaves or falls) or fumbling (e.g. shaky).

IEP cues seem to improve the likelihood that the moderately impaired person will be identified. However, the use of IEP cues (and, presumably, responsible beverage service practices) does not ensure the identification of the moderately impaired patron. Some patrons who are chemically impaired (based on BAC) may be difficult to detect ... presumably due to an acquired tolerance to alcohol or learned behavior intended to avoid detection as visibly or obviously intoxicated.

One study reports 32 cues that were observed while assessing the reliability of IEPs including speaking very loudly, unusual or expanded gestures, and flushed or red-faced. It may be helpful to compare a list of cues with case-specific facts or testimony.

Tolerance to alcohol

One of the few clinical studies regarding tolerance at high BAC was reported in the Journal of Forensic Science. A summary follows.

110 consecutive alcoholics who voluntarily entered a detoxification center were studied to determine their ability to perform certain designated functions (a) while under the influence of alcohol at admission and (b) four days later, after they had undergone detoxification. The findings indicate that alcoholics develop an increased tolerance to alcohol at extremely high BACs including levels generally considered potentially fatal.

Witness testimony

The deposition testimony of witnesses often seems to provide information favorable to the defense; and, at trial, deposition testimony is often the defendant's best "*home base*". For both plaintiff and defendant, the approach to taking the deposition of witnesses is very important!

Examination of an expert:

Case-decisions regarding deposition, voir dire, and cross-examination at trial

Case-evaluation and case-strategy are two important considerations when an attorney is deciding if-when-how to examine an adversarial expert. When considering these and other case-specific options, counsel will often benefit from a discussion with an experienced liquor liability expert.

Expert deposition: Should you depose the expert?

There are at least three good reasons to consider deposing an expert:

- You know little or nothing about the expert's approach to case-analysis and his/her ability to defend the approach taken, case-assumptions, case-calculations including BAC and TAC, and relevant scientific studies.
- You want to establish the nature, scope, and limits of the expert's case-analysis as presented in a written report and/or you want to "marry" the expert to a flaw in the case-analysis or written report.
- You want to settle the case and hope to indirectly affect the negotiations by diminishing the perceived impact of the expert's anticipated testimony.

When should the expert be deposed? As a general rule, as late as possible ... after you have obtained a detailed report or exhausted all related attempts to define the expert's opinions and/or anticipate the expert's testimony as well as the expert's reaction to cross-examination.

Voir dire

A voir dire is an under-utilized technique. While you might be hesitant to disclose your approach to cross-examination at a pre-trial deposition, you should be much less concerned when conducting a voir dire.

What's in his file?	*What's not there?*
What has he done?	*What has he charged?*
What does he know?	*How does he react?*

A well-devised voir dire can be much more than a discovery deposition. The expert is usually not able to effectively rehabilitate his/her approach to case-analysis: *"Isn't it true that when I questioned you about 20 minutes ago, you were not able to …?*

Cross-examination

The effectiveness of your examination is based in large part on your preparation, your anticipation of the content of expert's testimony, the expert's usual behavior, your confidence, the use of control techniques, and a goal of providing the members of the jury with both information and explanation.

Are you able to control the expert?

Are you familiar with the scientific literature, the expert's implicit or unspoken assumptions, and the expert's usual appearance-behavior-demeanor … such that you can confidently and effectively use techniques to control the expert? Are you able to effectively use different types of questions to control both the flow of the cross-examination and the expert's response to the particular question?

When you know the answer to the question, you can ask that question in a number of different ways:

Isn't it true that …
Are you able to …
Are you familiar with …
Why didn't you tell the members of the jury …
Have you ever published anything in …
Did you …

You must be able to follow-up!

Isn't that because …
Would you agree with a statement that …
Let's review …

Do you have a case strategy?
Does your cross-examination of the expert reflect a consistent case-strategy including ways to effectively present information about the witness's … ?

Qualifications
Knowledge of case-specific facts
Focus (i.e. what he did and did not do)
Implicit and explicit assumptions
Disregard for case-relevant factors
Gaps in testimony re relevant issues
Accuracy when describing the case analysis

Do you *think forward*?
Do you visualize a cross-examination that is organized, understandable, easy to follow, relevant, to the point, interesting-informative-and-illustrative, and persuasive?

Do you begin on a *solid footing*?

Do you close on a strong note?

Do you practice and test your trial skills?
Think through example outlines of case-specific questions-and-answers, your reaction to potential adverse answers, techniques you can use to maintain or regain control of the witness and/or focus on your strategic "home-base", follow-up questions and/or case-illustrations, and checklists used to ensure that you have provided the jury with necessary information.

Have you thought about *role playing*?
Have you ever asked an expert to assume the role of the *other* expert … agreeing to a summary of anticipated testimony and then conducting a telephonic cross-examination?

An example of a special liquor liability assignment follows.

Special Assignment: Case Consultation

Case Consultation: Even without testimony, an experienced liquor liability expert can assist legal counsel. Consider the following example case-assignments:

Evaluation of potential expert testimony and anticipation of cross-examination with special emphasis on at least six case-specific issues:

Alcohol Concentration Test Results

Total Alcohol Consumption

BAC at the Time of Last Service

Reported Appearance-Behavior-Demeanor

Expected Effects Based on BAC

Witness Testimony

Review of the experience and record of an *adversarial* expert and evaluation-discussion of options including deposition. voir dire, and cross- examination.

Initial telephonic consultation: An attorney should engage a potential expert in an initial telephonic consultation prior to hiring the expert. Some of the example topics might include the following:

Determination of an absence of conflict and agreement that the phone consultation is done without charge or obligation or restriction

Case-related features or hypotheticals

The alleged intoxicated person

The time-line for the consumption of alcohol and food, the time of last service, and the time of the post-service accident

Relevant clinical/medical treatments such as the administration of intravenous fluids

The alcohol test specimen(s) and test result(s)

Witness statements and/or testimony

A discussion based on relevant features such as those noted above

The reliability of the alcohol test result(s)
The total amount of alcohol consumed
BAC at the time of the last service of alcohol
The expected alcohol-related effects
A consideration of subject-specific features

A detailed discussion of the expert's prior experience and testimonial record in similar cases

BRIAN E. PAPE, Ph.D., BCFE, BCFM

Dr. Brian Pape is the principal consultant with Pape & Associates, specializing in toxicology and related sciences. His professional experience includes the following:

- Associate Professor of Pathology (*Clinical Appointment*), University of Massachusetts School of Medicine.
- Senior Associate Consultant for Mayo Clinic (Rochester, MN) and Director of Toxicology at New England Toxicology Services (Woburn, MA).
- Director of Toxicology and Associate Professor, Department of Pathology, University of Missouri School of Medicine.

Dr. Pape has published more than 50 research papers, abstracts, and professional articles relating to alcohol and drugs, pesticides and toxic chemicals, analytical chemistry, forensic science, and general toxicology. He authors the *Toxicology Reporter*.

He has served as a technical and expert consultant to business, labor, and governmental agencies. He has been qualified as an expert in toxicology and related sciences in State and Federal Courts.

Dr. Pape has been board-certified by the American College of Forensic Examiners (BCFE) and the American Board of Forensic Medicine (BCFM).

He has been qualified on more that 100 occasions in State and Federal Courts. His case testimony has included liquor liability, alcohol and drug related testing-effects-and-accidents, laboratory testing, toxic torts, and product liability.