The metabolism of alcohol and its effect on estimating blood alcohol concentration

This article has been collated in response to a series of dialogues between members of AIM Social Scientific and Medical Council and The International Scientific Forum on Alcohol Research. Gordon Troup of Monash University, invited his mathematician colleague, Mike Deakin to look at the maths and statistics in the literature regarding the rate of metabolism of alcohol and blood alcohol concentration, much of which dates mainly from the 1950's and indeed back to the 19th century.

The mechanisms of how alcohol is broken down

We know that alcohol (ethanol), a small water soluble molecule, can be absorbed unchanged along the whole length of the digestive tract and that absorption takes place rapidly from the stomach (about 20%), and most rapidly from the small gut (about 80%).

We know too, that the rate of absorption after drinking is affected by several factors, such as the concentration and volume of liquid taken with the alcohol, whether drinking with or without food, the rate of gastric emptying and individual variations, such as ethnicity, height, weight and sex.

After absorption into the blood-stream, alcohol is distributed quickly throughout the total body water. Approximately 90% is broken down into carbon dioxide and water at a steady rate, the remainder is excreted unchanged in the urine, expired air and sweat.

The main site of metabolism of ethanol is the liver, although some other tissues, for example kidney, muscle, lung, intestine and possibly even the brain, may break down smaller quantities. It is thought that the rate-limiting step in the breakdown of alcohol is its conversion to acetaldehyde (toxic), a reaction catalysed by the zinc-containing enzyme, alcohol dehydrogenase (ADH).

The acetaldehyde formed in the first oxidative step in the metabolism of ethanol, is then converted to acetate (harmless) – and then into CO_2, H_2O and energy (this is known as the Krebs cycle) and excreted via the normal routes!

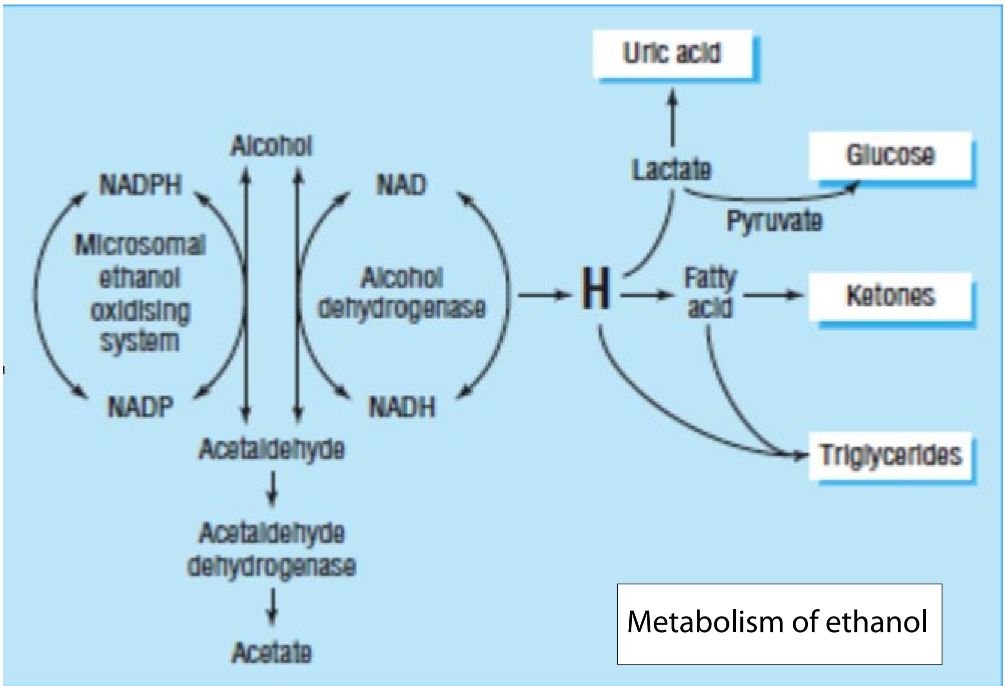
Myths and realities – can you speed up the rate of metabolising alcohol?

An interesting study in 1972 by G PAWAN (Metabolism of alcohol (ethanol) in man Proc. Nutr. Sac. (197z), 31, 83) investigated claims that taking vitamins and sugars can increase the rate of 'sobering up' in man and laboratory animals. He analysed the effects of caffeine and strong black coffee, dietary factors, physical exercise, environmental temperature changes, thyroid hormones, oxygen therapy and various drugs on the rate of metabolising alcohol in humans.

Physical exercise - Despite the increased pulmonary ventilation, sweat loss and general rise in metabolic rate, physical exercise did not significantly affect the rate of alcohol metabolism.

Vitamin supplements - It was concluded that in these normal, well-nourished individuals, vitamin supplementation did not affect the rate of alcohol metabolism.

Caffeine and strong black coffee - Caffeine (50mg) and two cups of strong, unsweetened black coffee were given one hour after the dose of alcohol; no effect on the rate of alcohol metabolism was seen.



Metabolism of ethanol

Significantly, Pawan found that both a long term high fat diet and a starvation diet slowed the bodies ability to break down alcohol by 20%. This was believed to be due to a depletion of enzymes (being inhibited by free fatty acids) and an enhancement of the reduced redox state of liver cells. However, eating a balanced meal before, during or even after drinking does help the metabolism of alcohol. Food, and particularly carbohydrate, retards absorption and blood concentrations may not reach a quarter of those achieved on an empty stomach.

An interesting study by Dr Wayne Jones et al explored food-induced increase in the rate of disposal of ethanol. Ten healthy subjects ate a meal 5 hours after drinking when the post-absorbtive phase of ethanol metabolism was well established. The mean rate of disappearance of alcohol from the blood was increased by between 36 and 50%. The results demonstrate that eating a meal boosts the rate of disappearance of ethanol from the blood, and the increase was seen after 3 different doses of alcohol. (Jones AW, Jönsson KÅ. Food-induced lowering of blood-ethanol profiles and increased rate of elimination immediately after a meal. Journal of Forensic Sciences 1994;39:1084-93).

No sugars, with the exception of fructose, affected the rate of metabolism of alcohol.

Women

Responsible drinking guidelines are lower for women for good biological reasons.Very little alcohol enters fat because of fat's poor solubility. Blood and tissue concentrations are therefore higher in women, who have more subcutaneous fat and a smaller blood volume, than men, even when the amount of alcohol consumed is adjusted for body weight. Women also may have lower levels of the enzymes alcohol dehydrogenases (ADH) in the stomach than men, so that less alcohol is metabolised before absorption.

Populations lacking gene to metabolise alcohol

As explained, alcohol metabolism, is catalysed by an enzyme, acetaldehyde dehydrogenase (ADH). This enzyme converts acetaldehyde to acetate, which is a normal metabolite in humans and hence is non toxic.

Certain individuals, common in the Japanense and some other Asians, have a defective aldehyde dehydrogenase gene, ALDH2, which doesn't metabolise acetaldehyde as rapidly as normal. Thus, a person who drinks too much builds up acetaldehyde in their system and feels bad or is sick. This manifests in Asians with the defected ALDH gene as a facial flush as they drink. These responses make drinking any alcohol unpleasant, as well as toxic.

Comments of Mike Deakin School of Mathematics Monash University, Victoria 3800 Australia

One would think it a relatively simple matter to discover the rates of alcohol clearance from the human body, and in a sense this is the case. However, if one looks for reputable sources backed up by well-conducted experiments, then the search suddenly becomes more difficult!

However, the book Drink, Drugs and Driving by H. J. Walls and A. R. Brownlie, 2nd Ed. (London & Edinburgh: Sweet & Maxwell, 1985) is accessible and authoritative. The first author is a former director of the Metropolitan Police Forensic Science Laboratory (UK) and the second a solicitor of the Edinburgh Supreme Court.

Sensibly, these authors do not try elaborate mathematical modeling or fancy curve-fits. Rather they supply 2 straight-lines that summarise the data excellently well. The rule is this:

For a BAC of 0.15 or greater, the elimination rate is 0.02 per hour, for lower BACs, 0.015 per hour.

Although this source is authoritative and commands respect, it is not primary, but rather draws on two other sources,

The rule just given is based on data from a German study: Gerchow & Steigleder's Blutalkohol (1961); it is partially supported by an English study ("Effect of small doses on a skill resembling driving", Medical Research Council Memorandum No. 38, HMSO, London, 1959). (This source considers only lower levels of BAC, but agrees with the figure of 0.015. It should, of course, be borne in mind that the figures given are averages only.

The two editions of Walls and Brownlie's book differ in some places, and the first edition includes references not cited in the second. Regrettably, most of these are likewise difficult of access.

Blood Alcohol Content Metabolised at 0.01 per Hour?

Comments by Gordon Troup School of Physics, Monash University, Victoria 3800 Australia

The difficulties in finding satisfactory articles were great, and there were difficulties even in the articles.

An article by in 'Nature' by Jacobsen [1] in1952 refers to work by Mellanby (1919) and Widmark (1922-35), To quote from Jacobsen: "Both studies found in man an average of 15 mgm. percent alcohol disappears from the blood per hour, the range being 10-20 mgm. per cent."

So we now know when respectable work started! Again, to be brief as to respectable work and its interpretation, the best reference in English is by Walls and Brownlie (1985) [2].We give a reference in German, by Ebbel and Schleyer (1956).

Since the respectable works agree on the .015 rate of recovery, to work on a .01 rate seems a good margin of safety for people to to judge by. Remember, This is for MEN. If necessary, experts could re-examine the old references with regard to methods and conclusions in the light of modern techniques and analytical developments. In the meantime, it is suggested that we continue with the .01 rate.

Lynn Gretkowski MD comments

'Regardless of citations this "clearance number" is merely now only a number that is generalisable. The individual pharmacodynamics of alcohol elimination take into account liver weight, gender, ethnicity, type and density of alcohol dehydrogenase receptors, rate at which alcohol is consumed, associated consumption of food and activities among many other factors. The reason no new calculations exist from the mid-nineteenth century onward is likely largely a reflection of that. It seems as though this is about as specific as it can be to be clinically useful'.

Dr Erik Skovenborg finds that

'Very little has been added to the Widmark formula during the years. One aspect, however, investigated by a pupil of Widmark has found inter individual variations in the ethanol metabolism: (Jones AW. Interindividual variations in the disposition and metabolism of ethanol in healthy men. Alcohol 1984;1:385-91)'.

Dr David Van Velden cited:

'The ABC of alcohol was published in the BMJ Volume 330, 8 January 2005 (bmj.com). The 4th edition of the ABC of Alcohol, became available in February 2005. According to this article alcohol is removed from the blood at a rate of about 3.3 mmol/hour (15 mg/100ml/hour)'.

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