A Comparative Study on Blood and Urine Ethanol Levels

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Abstract

ADMINISTERED orally, alcohol is quickly absorbed by simple diffusion mostly from the small intestine. Peak concentration in blood is achieved ½ to 2 hours after ingestion. Alcohol level in urine, however, reaches its peak about 30 minutes later. Due to concentration, alcohol levels of urine are always higher than that of blood and maintain a more or less constant ratio of 1.3 : 1. This observation has its own importance in aircraft accident investigation. Ratio of blood and urine ethanol levels has been studied in 86 healthy adult males at various time intervals, after oral administration of known quantities of alcohol. It is emphasised that due to lingering traces of alcohol in urine, it may be possible to corroborate the evidence of a previous drinking bout even when the ethanol level in blood has declined to zero.

Introduction

When administered orally, ethyl alcohol is readily absorbed from stomach and small intestine. Alcohol laden blood reaches liver *via* portal vein, mixes with blood from hepatic artery and goes into the general circulation. After storage equilibrium in various organs is achieved, the resultant concentration in all the tissues is proportional to water content of the tissue.[7]

Most of the alcohol undergoes biochemical oxidation in the body to produce carbon-di-oxide and water. This is achieved by alcohol dehydrogenases which in the presence of co-enzyme DPN produce acetaldehyde from alcohol, subsequently feeding Krebs cycle with acetates. About 6% of alcohol is excreted from the body unchanged through skin, urine, breath and faeces.

After ingestion of alcohol, a peak concentration is reached in blood in half to two hours time. As a part of alcohol is excreted in urine unchanged, a peak concentration builds up in urine also. During absorptive phase, the blood levels are higher than those of urine but once the absorption is complete and peak levels of ethanol develop in urine, the urinary concentration is always higher than that of blood and maintains a constant ratio till the end.

As early as 1929, Evans and Jones had shown that the concentration of alcohol in urine is so precise that it gives an accurate indication of minimum quantity consumed. Wayne[11] showed that once peak levels in urine are achieved, there is a good correlation between the levels of alcohol in samples of blood and those of urine taken half an hour later. Ratio usually accepted between urine and blood was 1.33. Froentjes[6] in his study found this ratio to be 1.52. A special committee of British Medical Association was set up for the purpose of working out urine – blood concentration ratio and its report suggested the ratio of 1.32 : 1[2]. Payne et al[9] confirmed the observation that after absorptive phase of alcohol, urine : blood ratio of ethanol remains more or less constant at 1.32 : 1. with the advent of gas chromatographic techniques more accurate and specific determination of ethanol became possible[8] and Payne et al[8] used this technique in a subsequent study. They found the mean ratio to be 1.44 : 1.

Most of the above discussed work was undertaken with a view to dispensing blood examination of individuals charged with drunken driving and to use this ratio by which urine alcohol levels can be converted to those of blood. Payne et al[8] emphasised that this will lead to miscarriage of justice as the ratio is not always constant. Variability

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of the ratio was partly explained to be due to frequency of micturition in post absorptive phase.[10]

It is evident that most of the work on this subject was undertaken with higher alcohol levels, the basic aim being prosecution of intoxicated drivers. Not many studies have been undertaken to establish this ratio in the lower range of alcohol levels. Similarly, no studies have so far been undertaken on Indian population which may have different rate of ethanol metabolism due to racial differences.[1]

Authors during their study on "After Effects of Alcohol on Psycho-physiological Functions in relation to flying performance of aircrew[12]" noticed that nine hours after ingestion of alcohol, the blood ethanol levels declined to zero while some of the corresponding samples of urine continued to show traces. This observation was considered to be important due to its applied value in aircraft accident investigations. If urine ethanol values continue to show higher figures than those of blood, a situation is likely to arise during terminal phase of excretion, when blood will be free of alcohol with traces still present in urine.

We, therefore, present our own observations on the ratio of blood and urine ethanol levels in healthy Air Force personnel, determined at various time intervals after administration of a fixed quantity of alcohol. Interpretation of findings in the terminal phase and their importance in aircraft accident investigation are discussed.

Material and Method

86 healthy adult males volunteered for this study. All of them were either fighter pilots, doctors or other Air Force personnel. All of them were moderate social drinkers. Subjects were medically examined to exclude any physical disability and were asked not to consume any alcohol a day prior to the tests.

Subjects were administered 180 ml of 70 proof rum. Rate of drinking was roughly regulated at 60 ml in 20 minutes. After consumption of alcohol a time interval of 45 minutes was allowed for absorption. Urine was passed and discarded. Blood samples were collected ½ hour, 1 hour, 2 hours, 6 hours, 9 hours and 12 hours later in various subjects. Corresponding urine samples were obtained after 30 minutes lag. Samples were sealed in glass containers and preserved at 4°C.

Ethanol was estimated in the samples using an AIMIL dual column gas chromatograph fitted with Flame Ionisation Detector. Copper columns of 4 metres length and 0.6 cm diameter were filled with 10% poly ethylene glycol-400 coated on celite 100 – 120 mesh. Temperatures of injector, columns and detector were regulated at 130°C, 90°C and 110°C respectively. Nitrogen was used as carrier gas at a flow rate of 45 ml/mt. This technique was modified from that advocated by Curry et al.[3]

Results

Results showing the number of subjects studied, mean blood and urine ethanol levels and corresponding ratios at various time intervals are given in Table I. The mean of the urine – blood ratios given in Table I has been calculated as the mean of the individual ratios.

TABLE I

Mean alcohol levels in blood and urine at various time Intervals and their mean ratios

Parameter		Time after ingestion of alcohol ½ hr	1 hr	2 hrs	4 hrs	6 hrs	9 hrs	12 hrs
No of subjects		22	6	4	5	6	25	18
Blood ethanol (mg/100 ml)	Mean	97.4	102.8	90.5	79.6	57.5	...	...
	Sd	18.8	46.3	15.3	23.7	33.9	...	...
Urine ethanol (mg/100 ml)	Mean	118.0	133.0	103.0	108.8	82.7	4.6	0.7
	Sd	25.5	49.0	19.3	16.9	46.8	5.5	1.1
Urine–Blood Ethanol ratio	Mean	1.21	1.34	1.16	1.43	1.52	I	I
	Sd	0.13	0.24	0.24	0.30	0.30		

Overall mean ratio = 1.29 (Sd = 0.23) I = Interminate

It is seen that blood ethanol levels remained hovering between 102.8 mg% and 79.6 mg% upto a period of 4 hours. Subsequently, the fall has been steep in that the average blood ethanol level has declined to 57.5 mg% at the 6 hours stage and has become unestimable in 9 hours and 12 hours samples. Similarly, urine levels dropped significantly in 6 hours, 9 hours and 12 hours samples. Overall mean ratio is worked out by pooling all the ethanol values of blood and urine samples.

Urine: blood ratio, however, continued to maintain a general trend between 1.16 and 1.52 with a mean of 1.29 (Sd = 0.23).

At the 9 hours stage, 25 samples of blood and corresponding urine were examined. Ethanol could not be detected in any of the blood samples while 17 out of 25 (68%) urine samples showed average concentration of 4.6 mg%. Similarly at 12 hours stage 18 paired samples of blood and urine were examined. While ethanol was absent in all blood samples, 7 urine samples (39%) showed an average concentration of 0.7 mg%.

Discussion

Overall urine : blood ethanol ratio in this study is found to be 1.29 (Sd = 0.23). This is in agreement with many workers, though lower than the ratio of 1.32 recommended by the special committee of British Medical Association.

Frequency of passing urine after the drinks can significantly modify this ratio. It was observed that most of the subjects did not pass urine for the preceding few hours before collection of 9 hours samples. This could account for significant concentration of alcohol in urine (positive in 68% cases), while being absent in blood. To eliminate this factor, we made 7 such subjects, pass urine at 4 hours interval and examined their urine 3 hours later. Even then, it was observed that urine samples yielded alcohol in average concentration of 0.7 mg/100 ml while it was absent in corresponding blood samples. This established beyond doubt that traces of ethanol may be found in urine upto 12 hours after ingestion of alcohol though corresponding blood samples may not yield positive results. Whether the presence of traces in urine are as a result of mixing in bladder with residual urine excreted earlier or due to delayed metabolism in some individuals, is difficult to decide.

Recognition of urine : blood ratio was objected to because of its variability rendering it unsuitable as a legal tool. Its importance in the terminal stages of metabolism has also been under-emphasised. While investigating an aircraft accident or incident in the Indian Air Force, we are not confronted with the problem of acute alcoholic intoxication. Our object more often is to assess whether alcohol has acted as a factor or not, by causing its delayed effects.

It is commonly observed that once blood samples are detected to be free of alcohol, the possibility of having consumed alcohol within 12 hours of flying is ruled out. This may not be so in view of the results obtained in this study. In such cases, examination of urine for alcohol is very necessary and if even traces are detected, the evidence of alcohol ingestion is fully corroborated.

Authors during their studies on delayed effects of alcohol on psychophysiological performance[12] *have observed that even 12 hours after ingestion of alcohol, when the blood samples are free of ethanol,* significant deterioration occurs in tolerance to + Gz, vestibular functions and psychomotor performance. In view of such observations, the detection of ethanol in urine assumes greater importance.

Tests for presence of alcohol in the blood and tissues are conducted as a routine in all cases of fatal aircraft accidents. Putrefaction due to bacterial and mycotic fermentation of glucose in such samples produces ethanol and other volatiles like acetaldehyde and acetone.[6] Under such circumstances, urine provides a better sample for ethanol estimation if removed from an intact bladder, as it is unlikely to putrefy, is easier to collect and yield more constant levels.[4]

Conclusions

Ethanol levels have been studied in blood and urine at various time intervals after administration of a fixed quantity of alcohol. Mean urine : blood ethanol ratio on 86 subjects thus studied was found to be 1.29 (Sd = 0.23). After a period of 9 hours no ethanol was detected in blood while it was present in many 9 hours and 12 hours samples of urine.

Importance of ethanol detection in traces in

urine has been emphasised in relation to investigation of aircraft accidents/incidents. Such observations corroborate the evidence of a previous drinking bout. Urine, at the same time, is considered a better sample due to stable ethanol levels and is less prone to contamination and decomposition.

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