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# Ethanol Distribution Ratios Between Urine and Capillary Blood in Controlled Experiments and in Apprehended Drinking Drivers

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**ABSTRACT:** Healthy men drank 0.51, 0.68, and 0.85 g of ethanol per kilogram of body weight as neat whisky in the morning after an overnight fast. During 6 to 8 h after the whisky was consumed, nearly simultaneous specimens of fingertip blood and pooled bladder urine were obtained for analysis of ethanol using an enzymatic method. The mean ratios of ethanol concentration [urine alcohol concentration (UAC)/blood alcohol concentration (BAC)] were mostly less than unity during the absorption phase. The UAC exceeded the BAC in the postpeak phase. The mean UAC/BAC ratios varied between 1.4 and 1.7 when the BAC exceeded 0.50 mg/mL. When the BAC decreased below 0.40 mg/mL, the UAC/BAC ratios increased appreciably. The mean UAC/BAC ratios of ethanol were not dependent on the person's age between the ages of 20 and 60 years old, but there were large variations within the age groups. In apprehended drinking drivers ($N$ = 654) with a mean BAC of 1.55 mg/mL, the UAC/BAC ratio of ethanol varied widely, with a mean value of 1.49. In 12 subjects (3.2%), the ratio was less than or equal to unity. In a second specimen of urine obtained approximately 60 min after an initial void ($N$ = 135), the mean UAC/BAC ratio was 1.35 (standard deviation = 0.17). The magnitude of the UAC/BAC ratio of ethanol can help to establish whether the BAC curve was rising or falling at or near the time of voiding. The status of alcohol absorption needs to be documented if drinking drivers claim ingestion of alcohol after the offence or when back-estimation of the BAC from the time of sampling to the time of driving is required by statute.

**KEYWORDS:** criminalistics, blood-alcohol concentrations, alcohol, blood, urine, body fluids, ethanol, urine/blood ratio, drunk drivers, kinetics, forensic and clinical practice, back-estimation

After its absorption into the blood, ethanol is distributed throughout all body fluids and tissues in proportion to the water content of those fluids or tissues. The concentration of ethanol in newly formed urine should therefore be about 20% higher than that in an equal volume of whole blood [*1,2*]. Because urine is normally stored in the bladder for various periods of time before voiding, the ratios between the urine alcohol concentration (UAC) and the blood alcohol concentration (BAC) observed in forensic science practice are highly variable and not always easy to interpret [*3*]. During the formation of urine

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in the kidneys and its subsequent storage in the bladder, a person's BAC is likely to change depending on the status of absorption, distribution, and elimination of ethanol [*4*].

Accordingly, the UAC does not necessarily reflect the BAC existing at the time of voiding. Instead, the UAC reflects the BAC prevailing during the urine collection period since the bladder was last emptied [*5,6*]. The concentration-time profiles of ethanol in the blood and in the bladder urine are therefore not in phase. The magnitude of the UAC/BAC ratio of ethanol and the change in the UAC between two successive voids within 30 to 60 min can help to establish if the BAC profile is rising or falling [*4*]. This information is important for three principal reasons. First, the status of alcohol absorption is of interest if the BAC at the time of the offence becomes an issue in drinking and driving litigation. Second, if drinking drivers claim they consumed alcohol after driving, the UAC/BAC ratio, together with other information, can help to support or challenge this defense tactic. Third, if back-estimation of the BAC is required, a conservative estimate can be obtained by dividing the UAC by 1.35, and the result reflects the BAC during the time urine was accumulating in the bladder [*7*].

This paper deals with various medicolegal aspects of ethanol determination in blood and urine. The UAC/BAC ratio was studied as a function of the dose of alcohol consumed, the age of the subjects between 20 and 60 years old, and the time after intake. For comparison, the relationship between the UAC and BAC was investigated in drinking drivers apprehended in Sweden.

## Materials and Methods

### *Subjects and Conditions*

Healthy male volunteers ($N$ = 80) took part in the laboratory studies. Table 1 gives details of their ages, body weights, and heights. Alcohol was administered as neat whisky in the morning (9.00 a.m.) after an overnight (10-h) fast. The doses of alcohol were 0.51 g/kg of body weight ($N$ = 16 subjects), 0.68 g/kg ($N$ = 48 subjects), or 0.85 g/kg ($N$ = 16 subjects), and the times allowed for drinking were 15, 20, or 25 min, respectively. Specimens of capillary (fingertip) blood were taken in triplicate at 30-min intervals for 2 h and then at 60-min intervals for a total time of 6 to 8 h, depending on the dose of alcohol.

The subjects emptied their bladders before the start of drinking and provided specimens of urine at 60-min intervals for 6 to 8 hours thereafter. If necessary, the men were encouraged to empty the bladder completely each time the samples were collected. The volumes of urine produced were measured to the nearest millilitre, and the quantity of alcohol excreted in each void was calculated as the product of UAC and the volume

TABLE 1—*Demographic details of the healthy male volunteers and the doses of ethanol administered in the laboratory study.*[a]

| Ethanol, g/kg body weight | $N$ | Age, years | Body Weight, kg | Height, cm |
|---|---|---|---|---|
| 0.51 | 16 | 37.7 (11.1) | 83.9 (13.1) | 182 (4.1) |
| 0.68 | 12 | 24.6 (3.2) | 73.5 (7.7) | 183 (3.4) |
| 0.68 | 12 | 34.8 (2.8) | 80.9 (6.5) | 179 (5.1) |
| 0.68 | 12 | 44.4 (2.7) | 84.6 (7.2) | 184 (4.8) |
| 0.68 | 12 | 53.6 (2.4) | 84.2 (9.9) | 183 (4.8) |
| 0.85 | 16 | 37.8 (11.2) | 79.9 (8.0) | 181 (3.9) |

[a]Mean values are given, with the standard deviations in parentheses. $N$ = the number of subjects receiving each dose of alcohol.

collected. Quantitative data about ethanol-induced diuresis after drinking neat whisky has been reported elsewhere [*8*].

*Determination of Ethanol in Blood and Urine*

The concentration of ethanol in blood and urine was determined using an automated enzymatic [alcohol dehydrogenase (ADH)] method described in detail by Buijten [*9*]. Triplicate 10-μL aliquots of blood were taken into glass capillary microcaps after pricking the subject's fingertip. The specimens were diluted with 1 mL of sodium fluoride (NaF) (0.05% v/v) in Autoanalyzer cups and stored at 4°C until analyzed. Aliquots of urine (10 μL) were removed in duplicate from each specimen and diluted with 1 mL of NaF solution (0.05% v/v). The standard deviation (SD) of a single determination of ethanol in capillary blood was 0.0172 mg/mL at a mean concentration of 0.53 mg/mL. This gives a standard error of the mean for a triplicate determination of 0.01 mg/mL. The SD of alcohol analysis in urine was 0.0077 mg/mL at a mean concentration of 0.656 mg/mL. The standard error of the mean of a duplicate determination was 0.0054 mg/mL [*9*].

*Collection of Blood and Urine Specimens from Drunk Drivers*

At the start of this study, apprehended drunk drivers in Sweden were required to provide fingertip blood for determination of ethanol, and for this purpose, six Widmark capillaries (0.1-mL each) were filled within about 5 min. Whenever possible, two specimens of urine were also obtained for alcohol analysis. The first specimen was collected about 30 min before the blood was drawn and the second specimen about 60 min after the initial void. For practical reasons, the exact times of obtaining the body fluids from drunk drivers could not be standardized because it depends on cooperation from the suspect and the activity of the police. No attempts were made to correct the results for metabolism of ethanol between the times of sampling blood and urine. Ethanol was determined in blood and urine by enzymatic oxidation with yeast alcohol dehydrogenase, according to a manual method after precipitation of blood proteins with perchloric acid [*10*]. The SD of analysis was greater at higher concentrations of ethanol in the specimens. At a mean BAC of 1.5 mg/mL, the SD of a single determination was 0.05 mg/mL for blood and 0.01 mg/mL for urine. Note that, because the aliquots of urine were obtained from the same specimen pool, the preanalytical error is small or negligible.

*Evaluation of Results*

Concentration-time profiles for ethanol were plotted for each subject. The times required to reach the peak concentrations were noted, and the UAC/BAC ratios of ethanol were calculated at each sampling time. In the drinking drivers, UAC/BAC ratios were calculated separately for both the first and the second void. The mean, SD, and coefficient of variation (CV), and the range of values were calculated. The relationship between the UAC and BAC was determined by correlation-regression analysis, according to the method of least squares. Differences between groups were tested by analysis of variance and Student's *t*-test.

## Results

*Time Course of Ethanol Concentration in Blood and Urine*

Figures 1 through 3 give examples of the concentration-time course of ethanol in blood and urine for 12 different subjects after they drank either 0.51, 0.68, or 0.85 g of ethanol per kilogram of body weight. Note that early after the drinking ended, when the BAC was still rising, the UAC was less than the BAC. Thereafter, the BAC and UAC curves crossed and, in the postabsorptive phase of the concentration-time profiles, the UAC always exceeded the BAC. Between 60 and 120 min after the start of drinking, the UAC continued to increase in all except 5 of the 80 subjects, for whom a small decrease or no change in concentration was observed. The peak UAC was reached about 60 min later than the peak BAC (range, 30 to 120 min). A more or less rectilinear declining phase was evident for both the BAC and UAC profiles. The mean rate of disappearance of ethanol from these body fluids ranged from about 0.10 to 0.20 mg/mL/h.

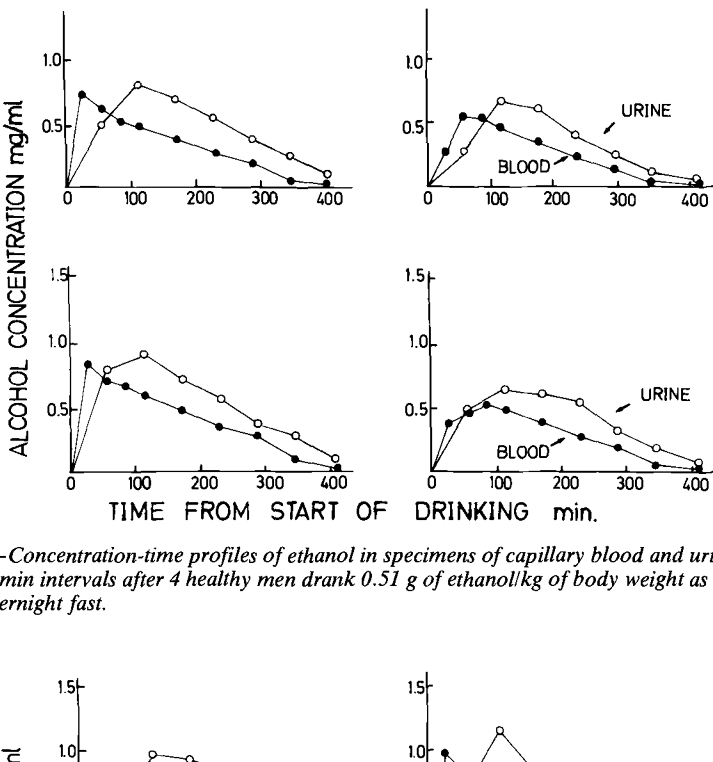


FIG. 1—*Concentration-time profiles of ethanol in specimens of capillary blood and urine obtained at 30 to 60-min intervals after 4 healthy men drank 0.51 g of ethanol/kg of body weight as neat whisky after an overnight fast.*

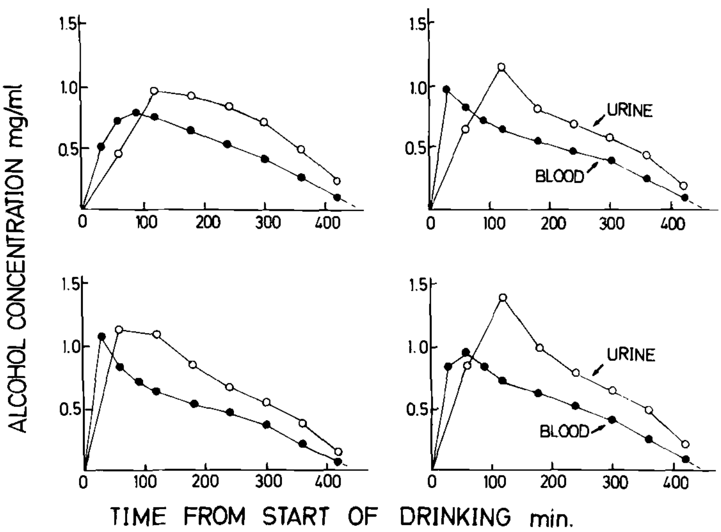


FIG. 2—*Concentration-time profiles of ethanol in specimens of capillary blood and urine obtained at 30 to 60-min intervals after 4 healthy men drank 0.68 g of ethanol/kg of body weight as neat whisky after an overnight fast.*

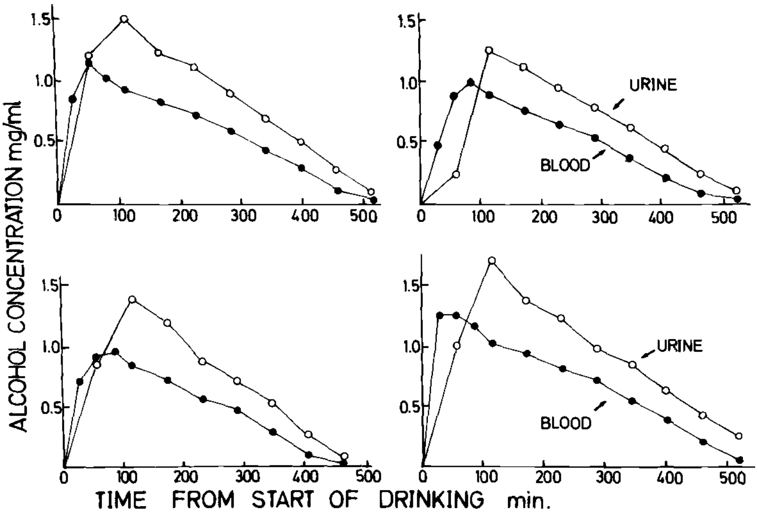


FIG. 3—*Concentration-time profiles of ethanol in specimens of capillary blood and urine obtained at 30 to 60-min intervals after 4 healthy men drank 0.85 g of ethanol/kg of body weight as neat whisky after an overnight fast.*

*Urine/Blood Ratios of Ethanol in Relation to the Dose and the Time After Drinking*

Figure 4 (*lower part*) shows the average BAC and UAC concentration time profiles after 0.51, 0.68, and 0.85 g of ethanol/kg of body weight. The upper part of this figure shows the corresponding UAC/BAC ratios for each dose of ethanol, and the arrows mark the mean BAC when the ratios start to increase appreciably.

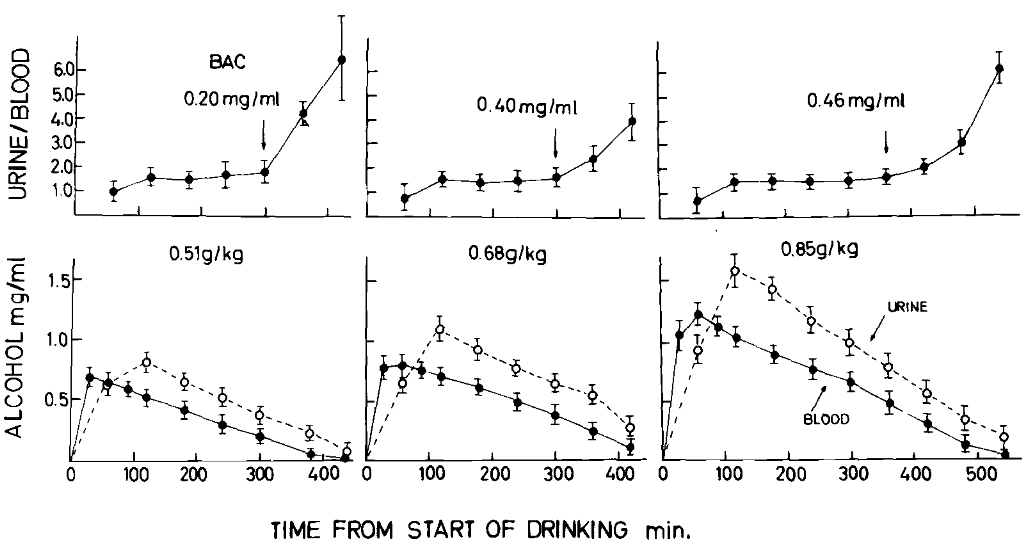


FIG. 4—*Mean concentration-time profiles of ethanol in capillary blood and urine* (lower trace) *when healthy men drank 0.51* (left), *0.68 g* (middle), *or 0.85 g* (right) *of ethanol/kg of body weight as neat whisky after an overnight fast. The* upper trace *shows the UAC/BAC ratios of ethanol, and the* arrows *indicate the mean BAC when the ratios started to increase in the post-absorptive phase.*

Figure 5 gives an indication of the magnitude of between-subject variation in the UAC/BAC ratios over time for the three doses of alcohol. The UAC/BAC ratios increased throughout the time course of ethanol metabolism, being mainly less than or equal to unity during the absorption phase, between 1.4 and 1.7 during the elimination phase, and increasing further as the BAC continued to decrease. After intake of small doses of alcohol on an empty stomach, a rapid absorption occurs, and the peak BAC is sometimes reached immediately after the end of drinking. Under these conditions, the UAC/BAC ratio exceeds unity at the time of the first void 60 min after drinking began or 35 to 45 min after the end of drinking. Table 2 gives the mean UAC/BAC ratios and the range of values at various times after the start of drinking ethanol. The mean and range of BAC at the time of voiding are also shown. The ratios were less than unity at 60 min after drinking and varied between 1.4 and 1.7 in the postabsorption phase. The ratios then increased again as the BAC decreased, becoming abnormally high in some subjects as the BAC approached zero.

### *Relationship Between the Urine/Blood Ratio of Ethanol and Diuresis*

Figure 6 (*upper part*) shows that the quantity of ethanol excreted in urine increases with increasing flow rate, as is reflected in the ethanol-induced diuresis between 60 and 120 min after drinking. In contrast, the urine/blood ratios of ethanol were not influenced by the dose of ethanol and the associated diuresis at 120 min after drinking.

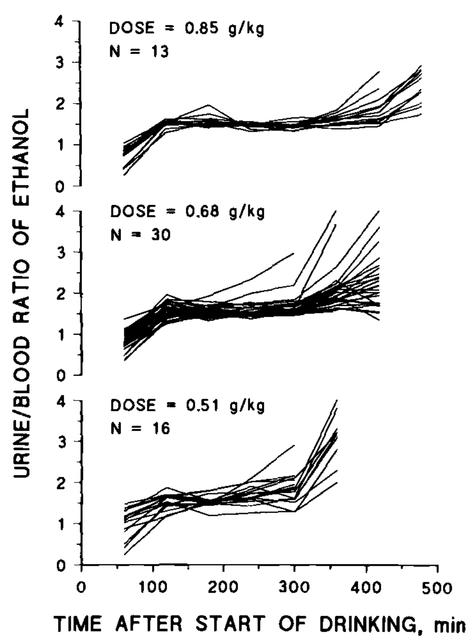


FIG. 5—*Between-subject variations in the UAC/BAC ratios during the time course of ethanol metabolism. Healthy men consumed 0.54, 0.68, or 0.85 g of ethanol/kg of body weight in the form of neat whisky during 15 to 25 min after fasting overnight. Some subjects failed to void at certain times and these curves were incomplete and have not been plotted.*

TABLE 2—*UAC/BAC ratios as a function of time after healthy men drank 0.51, 0.68, or 0.85 g of ethanol/kg of body weight.*[a]

| | 0.51 g/kg | | 0.68 g/kg | | 0.85 g/kg | |
|---|---|---|---|---|---|---|
| Time, min | Mean BAC, mg/mL | UAC/BAC Ratio[b] | Mean BAC, mg/mL | UAC/BAC Ratio[c] | Mean BAC, mg/mL | UAC/BAC Ratio[d] |
| 60 | 0.65 (0.48–0.75) | 0.96 (0.24–1.47) | 0.85 (0.50–1.09) | 0.84 (0.22–1.35) | 1.22 (0.89–1.54) | 0.69 (0.25–1.03) |
| 120 | 0.53 (0.45–0.68) | 1.53 (1.16–1.80) | 0.71 (0.65–0.87) | 1.58 (1.26–1.96) | 1.02 (0.87–1.13) | 1.51 (1.29–1.62) |
| 180 | 0.42 (0.34–0.58) | 1.53 (1.19–1.79) | 0.61 (0.53–0.73) | 1.55 (1.33–1.93) | 0.89 (0.74–1.01) | 1.55 (1.41–1.96) |
| 240 | 0.30 (0.22–0.44) | 1.70 (1.25–2.00) | 0.50 (0.38–0.62) | 1.56 (1.36–2.32) | 0.77 (0.57–0.89) | 1.45 (1.31–1.54) |
| 300 | 0.20 (0.12–0.34) | 1.84 (1.29–2.90) | 0.39 (0.23–0.56) | 1.64 (1.43–2.96) | 0.65 (0.48–0.75) | 1.45 (1.32–1.65) |
| 360 | 0.06 (0.02–0.17) | 4.20 (2.0–7.8) | 0.23 (0.06–0.41) | 2.14 (1.56–4.64) | 0.48 (0.29–0.59) | 1.58 (1.36–1.82) |
| 420 | ...[e] | ... | 0.06 (0.01–0.30) | 2.42 (1.00–7.67) | 0.31 (0.09–0.43) | 1.85 (1.43–2.77) |
| 480 | ... | ... | ... | ... | 0.15 (0.04–0.24) | 2.60 (1.72–5.00) |

[a]Results are given only for those subjects who managed to provide a specimen of urine at each sampling time.
[b]Mean and range of values for $N$ = 16 subjects.
[c]Mean and range of values for $N$ = 30 subjects.
[d]Mean and range of values for $N$ = 13 subjects.
[e]... indicates that no samples were taken.

### *Urine/Blood Ratios of Ethanol as a Function of a Subject's Age*

Figure 7 compares the mean UAC/BAC ratios of ethanol for four age groups of healthy men at various time points after they had consumed 0.68 g of ethanol/kg of body weight. No significant differences were noted in men between 20 and 60 years old, but variations within the age group studied were especially large 6 to 8 h after the start of drinking, when the BAC was low and approaching zero for some subjects.

### *Urine/Blood Ratios of Alcohol in Drunk Drivers—First Void Specimens*

Figure 8 (*upper part*) is a scatter plot of urine/blood ratios of ethanol for the first void specimen as a function of BAC in apprehended drinking drivers. The average BAC was 1.55 mg/mL (SD 0.66). The UAC/BAC ratios were equal to or less than unity in 3.5% of all the specimens examined ($N$ = 654). The variability was higher at low BAC, as is indicated by a greater scatter of points around the regression line. The mean UAC/BAC ratio was 1.49, and the existence of outlying values precluded calculating confidence limits based on the assumption of a normal distribution. Figure 8 (*lower part*) shows a scattergram of urine ($y$) and blood ($x$) concentrations of ethanol for the first void specimen. A highly significant correlation ($r$ = 0.946) is evident. The UAC and BAC show a linear association, but when the BAC reaches zero, there is alcohol still present in the bladder urine. The average concentration of alcohol in urine at zero BAC, as reflected by the $y$-intercept in the regression equation, was 0.31 mg/mL.

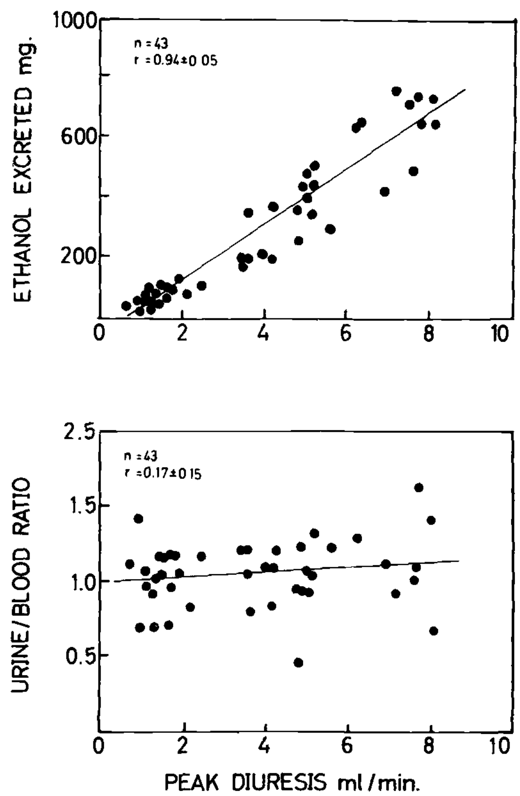


FIG. 6—*Relationship between the amount of alcohol excreted in urine* (upper part) *and diuresis in specimens collected between 60 and 120 min after drinking, when ethanol-induced diuresis was most pronounced. The lower plot shows the corresponding UAC/BAC ratios at 120 min.*

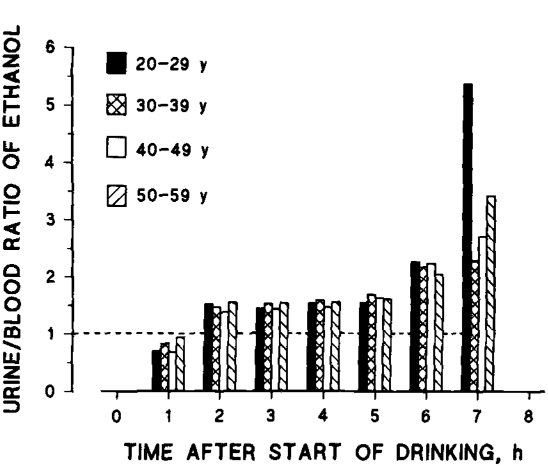


FIG. 7—*Comparison of mean urine/blood ratios of ethanol in four age groups of healthy men (20 to 29, 30 to 39, 40 to 49, and 50 to 59 years old) at various time points after they drank 0.68 g of ethanol/kg of body weight on an empty stomach. At 7 h after drinking, the BAC was abnormally low, particularly in the 20 to 29-year-old age group.*

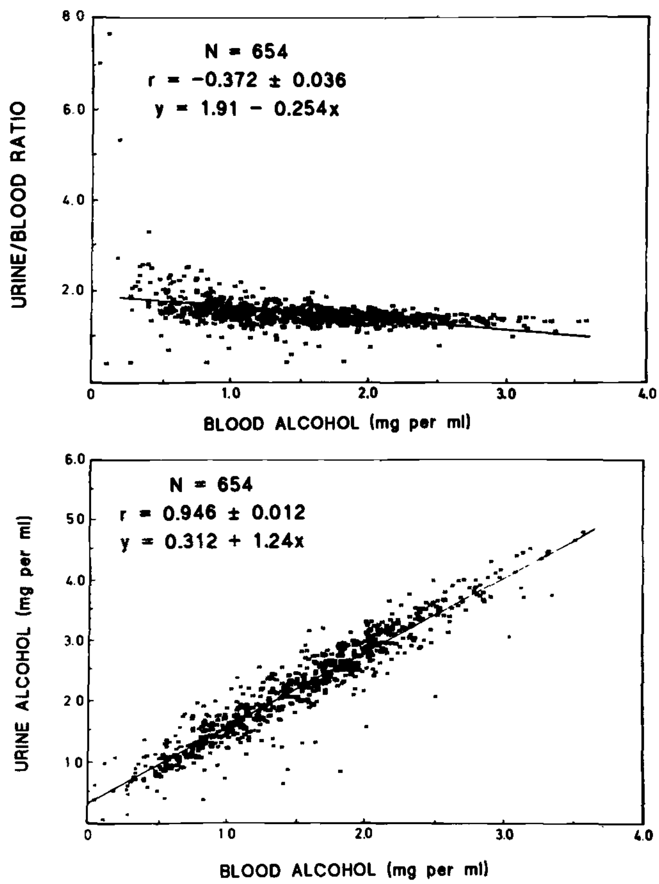


FIG. 8—*Relationship between the UAC/BAC ratio for ethanol and the BAC for the first-void specimen of urine obtained from drinking drivers* (upper plot) *and regression analysis of UAC* (y) *against BAC* (x) *for the same material* (lower plot).

*Urine/Blood Ratios of Ethanol in Drunk Drivers—Second Void Specimen*

Figure 9 (*upper part*) shows a plot of UAC/BAC ratios as a function of BAC for the second specimen of urine obtained about 60 min after the initial void. The data points now hug the regression line more closely and none of the UAC/BAC ratios are less than unity. The variability in the data was higher at low BAC, as is indicated by the greater scatter of points. The mean BAC was 1.66 mg/mL (SD 0.63), and there were fewer outlying UAC/BAC ratios in this material. The mean UAC/BAC ratio was 1.35 (SD 0.17), and 95% of the individual ratios were within the range 1.01 to 1.69, assuming a normal distribution of values. In the same individuals ($N$ = 136), the mean UAC/BAC ratio for the first void specimen was 1.49 (SD 0.24), in comparison with the second void mean of 1.35 (SD 0.17). The mean within-subject difference, 0.14 (SD 0.218), was statistically different from zero ($t$ = 7.6). The UAC and BAC were highly correlated ($r$ = 0.967), as is shown in the scatter plot in the lower part of Fig. 9, indicating a strong linear association between the BAC and UAC. When the BAC reached zero, the average concentration of ethanol in urine was 0.11 mg/mL.

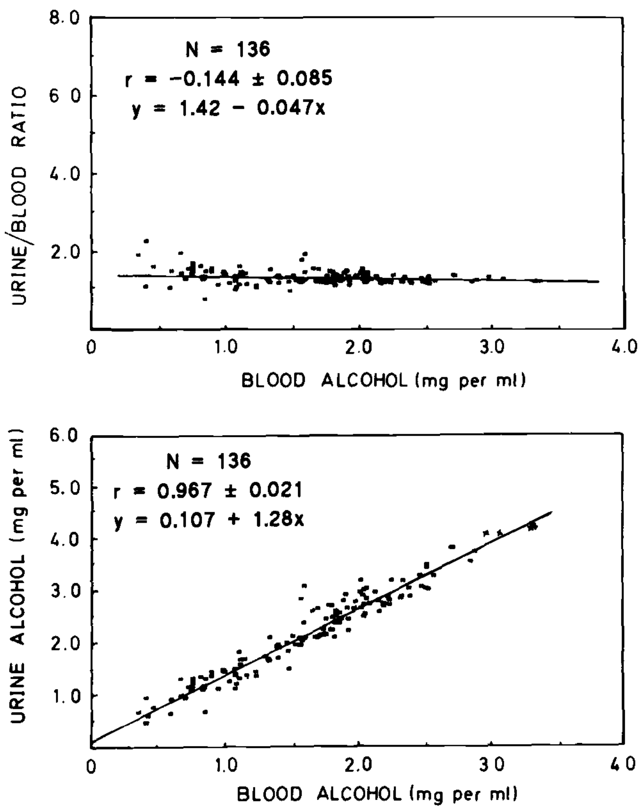


FIG. 9—*Relationship between the UAC/BAC ratio for ethanol and the BAC for a second-void specimen of urine obtained about 60 min after an initial void* (upper plot). *The* lower plot *shows the scattergram of UAC* (y) *against BAC* (x) *for the same material.*

## Discussion

The physiology of ethanol excretion in urine, ethanol-induced diuresis, and the magnitude of variation of UAC/BAC ratios were established during the first decades of this century [*11–13*]. Urine was the first biological fluid suggested for use in traffic law enforcement to provide evidence of intoxication based on the result of a chemical test [*14–16*]. Indeed, several countries and some of the states in the United States, have laws that prohibit driving a motor vehicle when the UAC exceeds a threshold concentration [*17–20*]. In Great Britain, a UAC of 107 mg/dL, a BAC of 80 mg/dL, or a breath-alcohol concentration of 35 μg/100 mL constitute evidence of impairment at the wheel [*2*]. This implies a urine/blood ethanol ratio of 1.33 for all subjects. Note that it is the concentration of alcohol in a specimen of urine collected 30 to 60 min after an initial void that is accepted as evidence for the prosecution of drunk drivers [*17*]. The initial void is meant to empty the bladder, and the UAC of the second specimen reflects the BAC during the time of accumulation of urine. The mean UAC/BAC ratio in drunk drivers in Sweden for the second void specimen was 1.35, and this agrees with the value of 1.33 currently used for legal purposes in Great Britain. This UAC/BAC ratio is an average figure accepted for legal purposes. In forensic science practice, individual ratios might vary widely, especially for the first void specimen. Little confidence can be attached to the BAC estimated from analyzing a randomly timed specimen of urine. The reason for this large variability in the UAC/BAC ratio is partly physiological and partly analytical. Errors and uncertainty with the methods used to measure alcohol will contribute to variations in the ratio.

The UAC/BAC ratios determined in laboratory studies varied less than those in the apprehended drinking drivers. The mean UAC/BAC ratio of 1.4 to 1.7 can be compared with 1.35 for the second void in drunk drivers. This discrepancy might be explained by the inability to ensure the same sampling times for blood and urine when specimens were collected in the field. Because of the higher average BAC in drunk drivers (mean, 1.55 mg/mL), this would also tend to give lower UAC/BAC ratios in comparison with the laboratory study results, in which the BAC was mostly less than 1.00 mg/mL. Indeed, it might be argued that the UAC should be compared with the BAC existing at the midpoint between two successive voids. Yet another factor to consider is the source of the blood specimen analyzed when calculating the UAC/BAC ratios [*21*]. In the postpeak phase of ethanol metabolism, the concentrations of ethanol in venous blood are slightly higher than those in capillary blood, and this should be kept in mind when UAC/BAC ratios reported in different investigations are compared [*22–25*].

There are differences of opinion about the validity and practical usefulness of urine as a biological specimen for alcohol analysis in traffic law enforcement, especially when "per se" statutes are enforced [*26–28*]. The large inter- and intra-subject variations in UAC/BAC ratios (Fig. 5) and the abundance of ratios higher than 1.35 make it obvious that the UAC should not be translated into a presumed BAC for legal purposes. This conclusion is particularly valid with the trend in some jurisdictions towards introducing lower legal limits for motorists. Nevertheless, the results of analyzing two specimens of urine voided within 30 to 60 min, together with other information, tell us whether the BAC was rising or falling at the time of sampling. If the UAC is divided by 1.35, one obtains a conservative estimate of the BAC existing during the time the urine was being produced and accumulated in the bladder [*7*]. Note that if the BAC profile was rising, which might be the case if specimens were taken early after the drinking ended, the ratio UAC/1.35 underestimates the coexisting BAC [*3*].

Great care is needed when UAC/BAC ratios are interpreted for legal purposes. This is especially evident when the previous drinking pattern, the frequency of urination, and the functioning of the kidneys and bladder are unknown. The advantages and limitations of urine as a biological fluid for analysis of ethanol in law enforcement were elaborated upon in a comprehensive review by Biasotti and Valentine [*3*]. Among other issues, the following points deserve more attention:

- The UAC/BAC ratio of 1.35:1 is an average value and depends on, among other things, the water content of the blood and urine. Although the blood water concentration is fairly constant at 80% w/w [*29*], the specific gravity of urine is more variable and will depend on the person's diet, fluid-water balance, kidney function, and general state of health [*30*].
- If an alcohol-free pool of urine exists in the bladder before consumption of ethanol, the first specimen voided might have an abnormally low UAC/BAC ratio. This situation is not likely to last long because of ethanol's well-known diuretic effect, which is most pronounced during a rising BAC [*8*]. The heavy drinker will soon be inclined to urinate.
- If the individual's bladder is not completely emptied, batches of "old" urine might have higher concentrations of ethanol than those in the newly formed urine. The measured UAC might, accordingly, be higher than expected from the coexisting BAC at the time of voiding. The errors introduced by retention of urine will depend on the volumes retained and the collection time frame in relation to the time of drinking. Difficulty with complete emptying of the bladder appears to be more common in older men [*31*], although age-related differences in UAC/BAC ratios were not uncovered in the present study

(Fig. 7). However, retention of urine might explain, at least in part, the tendency of UAC/BAC ratios to increase as the BAC decreases during the postabsorptive phase. The problems associated with retention of urine might be small or negligible compared with other aspects of ethanol pharmacokinetics in any individual charged with driving under the influence (DUI).

- If a specimen of urine is voided in the morning after an evening's drinking, a high concentration of alcohol might exist even though the coexisting BAC is zero. The UAC of the morning void reflects the changes in BAC during the night. Urine does not easily diffuse through the bladder walls and cannot become reabsorbed into the blood and metabolized to any great extent [*13,25*].
- A tricky situation arises if there is a pool of "old" urine in the bladder that contains alcohol from a previous drinking spree when the BAC is zero. Both the BAC and the UAC will increase if the subject drinks more alcohol, and under these circumstances, the UAC/BAC ratio in the first void after starting to drink again might exceed 1.35, even though the BAC profile was rising and alcohol was being absorbed into the blood.

The UAC and BAC profiles shown in Figs. 1 through 3 are typical of those obtained after a bolus dose has been drunk, followed by sampling and analysis of a series of successive voids. However, the UAC/BAC ratios under real-world drinking conditions are not well established and the changes of alcohol in blood and urine over time are much more complicated. New studies are needed to elucidate the time course of ethanol in blood and urine under more realistic social drinking conditions, when mixed drinks are taken in divided doses [*32*].

Despite these limitations, UAC/BAC ratios provide useful evidence to pinpoint the phase of ethanol metabolism at the time of sampling. If the UAC/BAC ratio is less than unity or not more than 1.2, this suggests, but does not prove, the existence of a rising BAC. If the UAC/BAC ratio exceeds 1.3, this suggests that the subject was in the postabsorptive stage at the time of sampling. Moreover, if the concentration of alcohol in two successive voids 30 to 60 min apart shows a decreasing concentration by 0.10 mg/mL or more, then the bulk of the dose of alcohol was probably consumed at least 2 h earlier. The lowest BAC since the previous void can be estimated by dividing the UAC by 1.35, provided that the disappearance phase of ethanol kinetics has been reached. In this study, the UAC/BAC ratio was equal to or less than unity in 3.2% of drunk drivers, and these individuals might therefore have been absorbing alcohol at the time of sampling.

In sum, the determination of ethanol concentration in urine and the resulting UAC/BAC ratios have several useful applications in forensic toxicology. The allegation of drinking after the offence can be challenged if the UAC/BAC ratio exceeds 1.3 and the concentration in two successive voids within 30 to 60 min shows a decreasing trend. Obviously, it is important to obtain the first specimen as soon as possible after the postoffence drink. If more than 1 to 2 h has elapsed between the start of drinking and the time of first urination, then the UAC/BAC ratio has limited evidential value to challenge or support this line of defense. One should be aware, however, that abnormally low UAC/BAC ratios might reflect adulteration of the specimen by intentional dilution with water or some other liquid. Unusually high UAC/BAC ratios might reflect accumulation of urine over a long period of time. The measurement of creatinine, an endogenous component of urine, might be a useful biochemical marker to indicate a highly concentrated specimen [*30*]. The current emphasis on testing for alcohol abuse in the workplace has created a renewed interest in the use of urine as a biological specimen for alcohol analysis. This study underscores the need for care when interpreting the results obtained. The sampling and analysis of two successive voids within 30 to 60 min should be a minimum requirement.

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