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Differences Between Multisite Postmortem Ethanol Concentrations as Related to Agonal Events

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ABSTRACT: In a study of postmortem ethanol concentrations, blood was withdrawn from the right atrium, ascending aorta, and inferior vena cava. These samples, vitreous humor, and gastric fluid were analyzed in 307 autopsies, where a minimum blood ethanol concentration of 0.05% weight/volume (w/v) was present.

Premortem, agonal, and postmortem events were reviewed in an attempt to account for differences in blood ethanol concentrations between sites. The agonal aspiration of vomitus having at least 0.80% w/v ethanol appears to be associated with an increase in aortic ethanol concentrations. We conclude that valid interpretation of postmortem ethanol concentrations must take into consideration the possible entry of ethanol into the pulmonary venous circulation via the respiratory system.

KEYWORDS: toxicology, ethanol, postmortem chemistry, multisite sampling, aspiration of vomitus, fresh-water drowning, intravenous fluid therapy, hanging

In living persons, variation between arterial and venous ethanol concentrations in the absorption-distribution phase is well established [*1*]. Until recently, the postmortem blood alcohol was assumed to be uniform, irrespective of the sites of sampling, because of ethanol's capacity to diffuse freely through total body water.

Studies by others have documented variation in blood ethanol concentrations when sampled from the heart as opposed to other vascular sites [*1,2*]. Attempts have been made to relate these differences to massive trauma, cardiovascular disruption, gastric disruption, diffusion of ethanol from the stomach lumen into the heart blood, and other factors [*2–4*].

The medicolegal implications of postmortem blood ethanol concentrations are profound, especially when they are found to be above the legal level for intoxication at one site and below that level at another.

We speculate that certain events occurring during times of agonal circulatory collapse

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could alter the blood ethanol concentration to above or below that present prior to collapse. The events of interest include the following:

(*a*) aspiration of ethanol-laden vomitus,
(*b*) intravenous fluid therapy,
(*c*) fresh-water drowning, and
(*d*) the effect of hanging in a vertical posture.

Methods

In 1895 autopsies conducted by the Office of the Medical Examiner for Palm Beach County, blood samples were retrieved during autopsy from the right atrium (RA), ascending aorta (AA), and inferior vena cava (IVC). Each sample was separately stored in a 10-mL Vacutainer tube (Becton-Dickenson, Rutherford, New Jersey) containing 20 mg of potassium oxalate and 25 mg of sodium fluoride. The volume of blood in each tube was noted. Vitreous humor (VH), which typically measured less than 5 mL in volume, was similarly stored. The gastric content was secured in 50-cc screw-top vials without preservative; the gastric fluid phase (GF) was analyzed.

All specimens were stored at 4°C until analyzed at the Palm Beach County Sheriff's Office Toxicology Laboratory, where the analysis was performed under the direction of one of the authors (F.T.C.) within five days of collection.

Analysis of alcohols was performed by direct injection, utilizing the method of Baselt [5]. The column utilized was GP 60/80 Carbopack B/5% Carbowax 20 m (Supelco No. 1-1766). A Hewlett-Packard 5830 flame ionization gas chromatograph utilizing electronic integration was employed. The injection port and detector were maintained at 200°C and the oven was set at 85°C isothermal. Helium flow was maintained at 30 mL/min. Each 0.2-mL sample, whether of whole blood, vitreous humor, or a 1:10 dilution of gastric fluid, was diluted with 0.2 mL of an aqueous solution of 0.15% *n*-propanol. Then 0.5 mL of the diluted sample was injected directly after standardization of the system. The method was linear from 0.01 to 0.60% weight/volume (w/v) for ethanol. The precision of the method was within 0.01% w/v for replicate analyses.

The following exclusions were made before further cases were selected for analysis:

(*a*) any 10-cc Vacutainer filled with less than 5 cc of blood,
(*b*) significant decomposition with gas formation in blood vessels, and
(*c*) the presence of less than 0.05% w/v ethanol concentration at any vascular sampling site.

The selected 307 cases were then evaluated using fire rescue, medical, and police records. We grouped cases by the presence of the following agonal events:

Group 1-N: No agonal events as specified in other groups.
Group1-M: Intravenous fluid therapy via catheterization of jugular, subclavian, or arm veins.
Group 1-F: Fresh-water drowning.
Group 1-H: Hanging in a fully vertical posture for a prolonged period.
Group2: Aspiration of ethanol-laden vomitus, as identified by the observation of food particles in the distal bronchial tree or the presence of suspicious fluid resembling the gastric content in both color and texture.

Groups 1-N and 2 were also each subdivided on the basis of low (less than 0.80% w/v) and high (greater than or equal to 0.80% w/v) gastric fluid ethanol concentrations.

Our precision is defined by the measurement accuracy of 0.01% w/v. We considered a between-site difference of at least 0.02% w/v sufficient to warrant a statistical analysis.

Results

Of the 1895 cases studied, 637 (33.6%) had some detectable ethanol.

In isolated cases, incomplete filling of one of the 10-cc blood tubes was found to be associated with profound differences between the "short-draw" and "full-draw" sites, as shown below:

Site	Volume, mL	Ethanol, g%
RA	10	0.20
AA	1	0.12
IVC	10	0.21
VH	4	0.23
GF	NA	0.21

Evaporation of ethanol into the headspace was the cause.

The mean ethanol concentrations, differences of means, and aortic blood/vitreous humor ratios are presented in Table 1 for all 307 selected cases.

One hundred and four (33.9%) individuals had one blood value 20% lower than the highest blood value. To put the problem in perspective, 26 cases (8.5%) had at least one blood ethanol concentration greater than 0.100% w/v at one site and, simultaneously, one level less than 0.100% w/v at another site.

We suspected that intravenous fluid therapy would dilute the venous return and cause lower RA and AA blood ethanol concentrations when compared with the inferior vena cava site, as illustrated by the following case:

> A 22-year-old driver received over 1 L of Ringer's lactate and normal saline through right subclavian and forearm intravenous catheters before he was pronounced dead 37 min after the injury. Intoxication appeared to have caused the accident, and the analysis revealed the following concentrations:
>
> RA 0.10% w/v
> AA 0.09% w/v
> IVC 0.13% w/v
> VH 0.22% w/v
> GF 0.17% w/v
>
> The vitreous fluid ethanol at equilibrium would be equal to a blood-ethanol level of 0.19 g% w/v.

We observed the most striking difference in mean ethanol concentration to be associated with agonal aspiration of vomitus containing GF ethanol greater than or equal to 0.80% w/v. These cases typically involved accident victims pronounced dead within minutes of injury. These individuals did not have disruption of the esophagus or stomach. The resulting ethanol concentrations are listed in Table 2.

When bloody fluid with the texture of vomitus but without the solid food particles or characteristic color was found within the distal airway, the case was classified as Group 1, recognizing that some aspirations of vomitus might be missed when using our study criterion. These "problem cases" are presented in Table 3 and will be discussed later.

When the difference between two mean concentrations of blood ethanol was found to be greater than 0.020% w/v, the Student's *t*-test [*6*] was applied to ascertain the probability of this difference occurring by chance. Comparison of RA and AA mean concentrations yielded a *P* value of less than 0.025 when aspiration of vomitus having more than 0.80% w/v ethanol occurred.

TABLE 1—*Mean ethanol concentration, difference of means, and blood/vitreous ratio for all cases.*

Group	No. of Cases	Mean Ethanol Concentration, % w/v								
		RA[a]	AA[b]	IVC[c]	AA − RA[d]	AA − IVC[e]	RA − IVC[f]	GF[g]	VH[h]	Ratio, AA/VH[i]
Group 1 (284)										
No Aspiration		0.176	0.177	0.177	+0.001	0.000	−0.001	0.730	0.206	0.903
1-N, no events	194	0.184	0.185	0.180	+0.001	+0.005	+0.004	0.827	0.211	0.948
1-M, IV fluid given	63	0.155	0.153	0.168	−0.002	−0.015	−0.013	0.559	0.198	0.773
1-F, fresh-water drowning	21	0.186	0.178	0.181	−0.008	−0.003	+0.005	0.369	0.211	0.844
1-H, hangings	6	0.120	0.130	0.120	+0.010	+0.010	0.000	0.400	0.110	0.945
1-N, GF < 0.80% w/v	124	0.172	0.172	0.170	0.000	+0.002	+0.002	0.304	0.205	0.890
1-N, GF ≥ 0.80% w/v	70	0.205	0.210	0.198	+0.005	+0.012	+0.007	1.755	0.221	1.052
Group 2 (23)										
With aspiration		0.166	0.186	0.162	+0.020	+0.024	+0.014	0.888	0.174	1.255
2, GF < 0.80% w/v	13	0.146	0.145	0.146	−0.001	−0.001	0.000	0.380	0.169	0.864
2, GF ≥ 0.80% w/v	10	0.191	0.238	0.182	+0.047	+0.056	+0.009	1.548	0.181	1.763
All cases (307)		0.173	0.175	0.173	+0.002	+0.002	0.000	0.675	0.201	0.870

[a]RA = right atrium.
[b]AA = ascending aorta.
[c]IVC = inferior vena cava.
[d]AA − RA = AA mean minus RA mean.
[e]AA − IVC = AA mean minus IVC mean.
[f]RA − IVC = RA mean minus IVC mean.
[g]GF = gastric fluid.
[h]VH = vitreous humor.
[i]AA/VH = ratio of aortic to vitreous ethanol concentrations, individual case ratios averaged per group.

TABLE 2—*Group 2 aspiration cases with gastric ethanol concentrations greater than or equal to 0.80% w/v.*[a]

	Ethanol Concentrations, % w/v				
Case No.	RA	AA	IVC	GF	VH
87-048	0.26	0.39	0.26	3.10	0.20
87-165	0.26	0.25	0.27	1.87	0.30
87-1025	0.22	0.38	0.10	3.10	0.06
87-1164	0.13	0.20	0.12	0.94	0.13
88-464	0.17	0.12	0.14	1.01	0.20
88-605	0.11	0.16	0.10	0.87	0.07
88-756	0.16	0.15	0.15	0.83	0.14
89-386	0.14	0.17	0.18	1.12	0.20
89-694	0.23	0.27	0.24	1.60	0.24
89-796	0.23	0.29	0.26	1.04	0.27
All cases, average	0.191	0.238	0.182	1.548	0.181

[a]See footnotes for Table 1.

Discussion

Differences in blood ethanol concentrations between multiple cardiovascular sites were found to occur under certain unique conditions. This study retrospectively reviewed selected cases to provide a rationale for interpreting these differences.

Our suspicion that upper body administration of intravenous (IV) fluid would dilute the venous return is not borne out by a statistically significant difference between the mean ethanol levels, but anecdotal cases continue to suggest that this dilution event occurred. Further research should be directed towards quantifying the IV fluids and the survival interval for further correlation.

We also speculated that the hematocrit changes found in a sustained vertical hanging might lead to water content differences and ethanol concentration changes. Only six cases were selected and no significant differences were observed.

We speculated that water absorption during fresh-water drowning might lead to unequilibriated changes of hemodilution, but found no significant differences in ethanol concentration.

The investigation of aspiration of vomitus did yield statistically significant ($p < 0.025$) differences between the right atrial and ascending aorta blood sampling sites, but only when the GF ethanol concentration was greater than or equal to 0.80% w/v.

Based on this finding, we propose that ethanol in high concentration can be aspirated into and absorbed from the pulmonary tissues when agonal circulation occurs. The ethanol subsequently passes by means of the pulmonary veins through the left side of the heart and into the ascending aorta. In rare cases, equilibration will not occur, and the isolated measurement of ethanol concentration in the proximal left-sided circulation will overestimate the degree of impairment at the time of injury.

We retrospectively have speculated that the above mechanism caused elevations in aortic ethanol concentrations in 7 of 307 selected cases (2.3%). All 7 cases are included among the 10 cases cited in Table 2, and all had blood ethanol concentrations above 0.100% w/v at all sites.

Blood contaminating the airway may change the color of the bronchial lumen content and eliminate one of the clues used to identify liquid aspirated vomitus, as problem cases in Table 3 illustrate. A multisite analysis of blood ethanol is recommended in all cases where intoxication is a consideration because of the possibility of occult aspiration.

TABLE 3—*Problem cases where aspiration of vomitus was suspected but did not meet research criteria for Group 2.*[a]

	Ethanol Concentrations, % w/v								
Case No.	RA	AA	IVC	AA − RA	AA − IVC	RA − IVC	GF	VH	Ratio, AA/VH
88-1045	0.08	0.13	0.11	+0.05	+0.02	−0.03	0.25	0.26	0.500
87-1022	0.21	0.28	0.26	+0.07	+0.02	−0.05	0.50	0.29	0.966
87-699	0.26	0.31	0.23	+0.05	+0.08	+0.03	1.29	0.28	1.107
88-635	0.13	0.20	0.14	+0.07	+0.06	−0.01	2.80	0.19	1.053
Problem cases (4)	0.170	0.230	0.185	+0.060	+0.045	−0.015	1.21	0.255	0.907

[a]See footnotes for Table 1.

Conclusion

Postmortem blood ethanol concentrations differ between cardiovascular sampling sites. A single blood ethanol measurement is not adequate in certain circumstances to support an opinion of victim impairment. The use of pooled "heart blood" from the pericardial sac may obscure important differences between the right and left heart ethanol levels. Aspiration of ethanol-laden vomitus may potentially increase the ethanol content of the ascending aorta, and the bronchial passages should be carefully examined at autopsy for the presence of vomitus.

We recommend that multiple cardiovascular site samples, ocular fluid, and gastric content be analyzed in any case where an interpretation of ethanol impairment is warranted. The blood containers used for collection and storage should be filled as completely as possible to prevent ethanol evaporation into the headspace. These procedures will enhance the interpretation of postmortem ethanol values and help ensure the validity of medicolegal opinion.

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