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Alcohol in Decomposed Bodies: Postmortem Synthesis and Distribution

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ABSTRACT: Blood alcohol (ethanol) concentrations in decomposed bodies can mean drinking during life and/or endogenous production after death. The correct interpretation is important in medicolegal cases. This retrospective study of 286 autopsied medical examiner cases was undertaken to evaluate alcohol concentrations and distribution in various fluids and tissues in decomposed bodies. Cases with alcohol present were classified as endogenous production, ingestion, or unable to determine based upon one or more of the following criteria: the presence of ethanol in only one of more than one body fluids, an atypical distribution of ethanol in body fluids, reliable scene or historical information, the presence of C3 alcohols in body fluids.

Alcohol was classified as endogenously produced in 55 cases. The presence of alcohol was attributed to ingestion in 130 cases. No alcohol was detected in 39 cases. We were unable to determine the source of the remaining 62 alcohol concentrations.

The highest blood alcohol concentration derived from endogenous production was 0.07% in the cases with other fluids negative. The mean blood alcohol concentration was 0.06% and ranged as high as 0.16% in cases having atypical ratios. Alcohol was found in blood and bile while urine and vitreous fluid were negative or had lower concentrations in cases with endogenous production.

We conclude that for the majority of cases in which endogenous blood production of alcohol occurs the concentration in blood may be as high as 0.15%.

KEYWORDS: toxicology, alcohol, ethanol, decomposition, putrefaction, endogenous alcohol, postmortem alcohol synthesis, postmortem alcohol distribution

Studies have shown that alcohol can be generated by bacterial synthesis in vitro [*1–6*] as well as in putrefying bodies [*1–9*]. Many authors have addressed the concern that such endogenous production not be attributed to premortem ingestion [*2,4,5,10–13*]. Several different concentrations of alcohol in body fluids have been attributed to endogenous production [*4,7,12*]. Alcohol concentrations have been attributed to postmortem production when multiple samples have been analyzed but alcohol is found only in one body fluid [*11,13*] or when the distribution of alcohol in body fluids is atypical [*10,13,14*].

Although atypical distribution of various drugs has been observed and attributed to postmortem redistribution, studies of postmortem alcohol distribution by Plueckhahn [*1*]

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and by Prouty and Anderson [*15*] did not show significant differences in concentrations of alcohol between heart and femoral vessels. More recently, statistical analysis by Briglia, Bidanset, and Dal Cortivo did not find any significant differences among various postmortem blood sites tested for alcohol [*16*].

Atypical distribution of alcohol also occurs at the extremes of the phases of absorption of alcohol. Alcohol will be present in blood before it is distributed to other fluids and will be present in other fluids, including urine, when it is no longer found in the blood.

A study by Zumwalt, Bost, and Sunshine in 1982 [*11*] examined the fluids of 130 putrefied bodies for the presence of alcohol. The degree of putrefaction was specified in the study and characterized by an objectively defined putrefaction score, SMELLBAD. The authors concluded that alcohol was endogenously produced when alcohol concentrations of equal to or greater than 0.01% were detected in blood or chest fluid but not in other fluid samples (vitreous humor or urine). Twenty-three such cases (18.7% of the total group) were identified. Four cases had blood alcohols greater than 100 mg/dL. The highest alcohol concentration they detected and attributed to endogenous production was 0.22% [*11*].

Corry [*4*] and Mayes [*7*] have stated that the upper limit of endogenous production is 0.15%. On the other hand, Plueckhahn indicated that "levels up to 0.200% do not necessarily indicate that alcohol was imbibed before death [*1*]." The recent article of Kuhlman, et al. included five cases with alcohol concentrations of >0.10% listed as probable putrefaction based upon the presence of C3 and C4 alcohols [*12*].

Other studies have suggested that even low concentrations of alcohol are probably ingestion. Levine, et al. reported an increasing likelihood that another specimen would be positive for alcohol as the concentration of blood alcohol increased through the range of 0.01–0.04 g/dL. These authors stated "in the absence of additional information, a BAC of 0.04 g/dL or higher probably resulted from ethanol consumption." This study did not mention the degree of decomposition, if any, and indicted that historical or scene information was not available [*17*]. A previous study of intact fresh bodies which were refrigerated within four hours of death found no postmortem alcohol production [*18*].

Materials and Methods

Cases for this retrospective study were selected by review of autopsy reports which included mention of postmortem decomposition or putrefaction. Postmortem alcohol concentrations had been determined as part of the death investigation. Additional information was gathered about the scene and history, and as was information about conditions of the specimens after the samples were obtained.

The determination of endogenous production of ethanol was based on one or more of the following four criteria: a) the presence of alcohol in blood or chest fluid but not in the other fluid tested; b) the presence of an atypical distribution of ethanol among the several body fluids; c) availability of reliable scene or historical information; and d) the presence of a higher alcohol (C3 alcohol/ 2-propanol/ isopropyl alcohol) in the analytical result. The determination of ingestion was based upon one or both of the following criteria: a) the presence of alcohol in a typical distribution among the several body fluids; and, b) availability of reliable scene or historical information. Cases were determined to be negative for alcohol if ethanol was not detected in any specimen. If the results and/or information available for a case were insufficient to reach a determination based on the above criteria, then that case was categorized as "Unable to Determine."

Atypical distribution is used to describe those cases in which the concentration of alcohol in one body fluid is higher (or lower) than values expected from known fluid/ blood partition ratios. Backer, et al. [*19*], Budd [*20*], and Stone and Rooney [*21*] calculated ratios among fluids or tissues and blood. Budd also calculated ratios for vitreous

or bile and urine [*20*]. These studies undertook to correlate the concentrations of alcohol in other body fluids or tissues with blood alcohol concentrations. The ranges of the ratios included different phases of metabolism of alcohol.

Two-hundred-eighty six autopsied cases in varying stages of decomposition examined at the Dallas County Medical Examiner's Office between 1982 and 1989 were included in the study (most were obtained between 1984 and 1989). The Dallas County Medical Examiner's Office investigated Dallas County deaths and performed autopsies for a number of other counties in an area from Oklahoma to mid-central Texas and from Arkansas to New Mexico. The geographic areas served are hot and dry much of the year with periodic rains and flooding. Winters are relatively mild except in the Panhandle. During the period approximately 17 000 deaths were investigated, and approximately 8000 were autopsied. Scene and historical information were available in 240 of the 286 cases selected for the study. Specimens were routinely retained in a refrigerator in the autopsy room until the end of the working day when they were taken to the toxicology laboratory and refrigerated until they were examined.

SMELLBAD scores similar to those described by Zumwalt, Bost, and Sunshine [*11*] based on eight physical changes in putrefying bodies were determined in 128 of the cases. A modified SMELLBAD system of four degrees of putrefaction was defined by: the SMELLBAD score when it could be derived, or by the prosector's description when fewer than all of the eight physical changes used in the SMELLBAD grading were mentioned. The comparison of the degrees of decomposition by the two systems is shown in Table 1.

Fluid samples from multiple sites had been previously obtained as available and analyzed for alcohol. Alcohol testing was performed using a Perkin-Elmer Sigma 2000 gas chromatograph with a Perkin-Elmer HS-100 head space autosampler, and a flame ionization detector (FID). The column was 6 feet by one-quarter inches OD packed with 60/80 Carbopack B/5% Carbowax 20 M. The samples were tested for ethanol, methanol, 2-propanol, and acetone. The internal standard was 1-propanol.

In cases where no fluid samples were available, tissue samples were homogenized then analyzed for alcohol. The tissues included liver, spleen, and skeletal muscle.

Results

Of the 286 cases in the study, 64 were mildly decomposed (22.4%), 42 were mild to moderate in decomposition (14.7%), 90 were moderately decomposed (31.5%), and 90 were markedly decomposed (31.5%). Blood, vitreous, urine, bile, and chest fluid were available in one case (0.3%), four fluids were available in 71 cases (24.8%), three fluids were available in 74 cases (25.9%), two fluids were available in 83 cases (29.0%), one fluid was available in 23 cases (8.0%), and no fluids were available in 34 cases (11.9%).

Various tissues were analyzed in the 34 cases with no fluids available for toxicologic

TABLE 1—*Comparison of descriptions of degrees of decomposition.*

SMELLBAD score	Modified SMELLBAD score	Description of decomposition
0	0	none
1–4	1	mild
5–12	2	mild-moderate
13–20	3	moderate
>20	4	marked

analysis. Alcohol was detected in 23 cases. Twenty-one of the 23 cases had alcohol concentrations of 0.01% to 0.09%. In the other two, the concentrations were 0.14% and 0.15%. There was history of alcohol ingestion in these two and one other cases. We classified all three of these cases as ingested. The other 20 were classified as unable to determine. All but one of 14 liver samples had alcohol detected. Among spleen and muscle tissue samples, 12 of 28 samples were negative.

Distribution criteria could not be used to assess endogenous production unless there were at least two fluids. Twenty-three cases had only a single fluid available for testing. Of these, six were negative for alcohol, and 17 had alcohol detected in the single fluid. Historical information was available in only three cases and indicated that ingestion was more probable. The other 13 were classified as "unable to determine" and concentrations ranged from 0.01% to 0.16%.

Decomposing fluid recovered from the chest has been used as a substitute when blood is not obtainable from the vascular system because of decomposition. Table 2 shows the presence and concentration of alcohol in 23 cases in which chest fluid was tested. Six chest fluid cases were included in the single fluid group described above. The remaining 17 cases had more than one fluid available for testing. One case chest fluid case was classified as endogenous production with an alcohol concentration of 0.14% and vitreous negative. Two cases were classified as endogenous production, one with atypical distribution of ethanol in urine and bile, the other with isopropyl alcohol also present in the

TABLE 2—*Chest fluids, classification of alcohol as endogenous, ingested, or unable to determine.*

DCME	Modified SMELLBAD score	Alcohol Concentrations %					Classification
		Chest fluid	Blood	Vitreous	Bile	Urine	
0968-87	4	0.00	...	...	...	0.01	I hx
3710-87	3	0.00	...	...	0.02	0.01	I typ
1556-86	3	0.03	0.02	0.01	0.01	0.01	I typ
2160-87	4	0.03	...	...	...	...	U
1696-86	3	0.03	...	...	0.02	...	U
0928-87	4	0.05	...	...	0.04	...	U
2386-88	4	0.05	...	...	...	...	U
2553-88	4	0.05	...	...	...	...	U
2226-85	3	0.06	...	...	0.06	...	U
2591-86	4	0.06	...	...	...	...	U
2778-86	4	0.06	...	...	0.02	...	U
1318-88	4	0.06	...	...	0.05	...	U
2590-86	4	0.09	...	...	...	...	U
0311-88	4	0.11	...	...	0.07	0.01	E atyp
2116-86	4	0.14	...	...	0.14	...	U
2615-86	4	0.14	...	N	...	...	E only
1857-87	3	0.16	...	...	0.17	...	I hx
1628-88	4	0.16	...	...	...	...	U
3284-85	3	0.17	...	0.12	0.13	...	I typ
0511-87	3	0.19	...	0.07	...	...	I hx
1792-88	3	0.23	...	...	0.08	0.04	I typ
1574-86	3	0.29	...	...	0.32	...	I hx
0799-86	3	0.36	0.18	...	...	0.27	I hx

NOTE:
atyp = atypical partition ratio of urine and vitreous or bile.
hx = history.
only = only one fluid positive for ethanol.
typ = typical partition ratio of urine and vitreous or bile.

TABLE 3—*Number of fluids positive for alcohol.*

Number of fluids positive	Number of cases	Percentage
0	23	9.87%
1	28	12.02%
2	73	31.33%
3	66	28.33%
4	42	18.02%
5	1	0.43%
Total	233	100.00%

analytical results. Five cases were classified as alcohol ingestion on the basis history including one of only two cases with chest fluid negative for alcohol. One case also had blood present with alcohol present in typical partition ratios. Three cases were classified as ingestion on the basis of typical ratios for urine and bile. The other five cases were classified as unable to determine.

Two-hundred-twelve decomposed cases not already described had more than one fluid available to be analyzed for alcohol. No alcohol was detected in 22 of these cases (9.6%) from this group. The number of cases with fluids positive for alcohol is shown in Table 3.

In fourteen cases blood was the only body fluid positive for alcohol, the other fluid(s) being negative. These met the criteria for endogenous alcohol production used by Zumwalt, Bost, and Sunshine [*11*]. These fourteen cases, their Modified SMELLBAD scores, and their alcohol concentrations are presented in Table 4. The mean blood alcohol concentration was 0.03%. The highest blood concentrations were 0.06% and 0.07%. The chest fluid case classified as endogenous production is also included in this table. The chest fluid alcohol concentration was 0.14%.

Alcohol was present in multiple samples in 190 cases. Ratios were calculated for vitreous/blood, bile/blood, and urine/blood. These ratios were compared with the range of ratios found in the literature [*19–21*]. Cases with very low concentrations of alcohol and cases with differences of 0.01% between samples were not included in the group

TABLE 4—*Endogenous production of alcohol, blood positive, all other fluids negative.*

Count	DCME	Modified SMELLBAD Score	Fluid	Alcohol Conc %	Vitreous	Urine	Bile
1	3329-87	1	Blood	0.01	...	...	N
2	3334-87	2	Blood	0.01	N	N	N
3	3381-88	3	Blood	0.01	N	N	...
4	2869-86	1	Blood	0.01	N	...	...
5	0526-87	1	Blood	0.01	N	...	...
6	2739-87	1	Blood	0.01	N	...	...
7	3754-86	3	Blood	0.02	N	...	...
8	3173-88	1	Blood	0.02	N	...	...
9	1344-82	1	Blood	0.04	N	N	N
10	3085-84	4	Blood	0.05	N	...	...
11	0549-85	3	Blood	0.05	N	...	...
12	1608-88	3	Blood	0.05	N	...	N
13	2864-85	1	Blood	0.06	N	N	N
14	3936-86	4	Blood	0.07	N	...	...
15	2615-86	4	Chest	0.14	N	...	...

for which the range of ratios was used to reach a conclusion of endogenous production. Review of historical information and consideration of the metabolism of alcohol led us to conclude that cases with two or more atypical ratios should not be classified as endogenous production. Six such cases were classified as unable to determine.

Thirty-four cases were classified as endogenous production of alcohol by concentrations of alcohol in an atypical ratio of another body fluid and blood, and/or by review of history and scene information demonstrating that ingestion was unlikely. These cases are listed in Table 5 in ascending order by the blood alcohol concentration in the case. The mean blood alcohol concentration in the group was 0.07% with a standard deviation of 0.07%. The highest blood alcohol concentration without history of alcohol ingestion was 0.16%, and this case had a vitreous alcohol concentration of 0.02% with no other fluids available. The absence of a history of alcohol ingestion was less reliable in the cases of the two highest blood alcohols in the group. The history was limited and the deaths occurred in circumstances which are frequently alcohol-related. Two other cases were classified as endogenous production on the basis of C3 alcohol in the analytical results.

One case with negative blood alcohol concentrations was classified as endogenous production of alcohol on the basis of an atypical ratio of vitreous or urine to bile [*20*]. Fourteen other cases with negative blood alcohol concentrations were classified as unable to determine with other fluid alcohol concentrations up to 0.06%.

Discussion

We conclude that postmortem formation of alcohol occurred in 55 (19.2%) of the total 286 decomposed cases, similar to the 18.7% found in the original study of Zumwalt, Bost, and Sunshine [*11*]. Alcohol concentrations in 39 (13.6%) cases were negative and were classified as ingestion in 130 (45.5%). In the remaining 62 (21.7%) cases we were unable to determine if the alcohol concentration was the result of ingestion, or endogenous formation, or a combination of both mechanisms.

Postmortem production of alcohol in decomposing bodies has been attributed to bacterial action. Bacteria have been identified in blood [*1,2,4,5,7*] much more often than in vitreous in postmortem samples [*11,22*]. Most studies of postmortem synthesis of alcohol by bacteria have identified enteric organisms [*1,2,4,5,7,8*].

In this study in the cases of endogenous production of alcohol, it was observed that alcohol concentrations were elevated in the blood and bile while vitreous and urine alcohol concentrations were negative or so much lower as to give an atypical ratio of vitreous/blood or urine/blood. This would be expected if alcohol is formed earliest in the blood and bile, and later diffuses into or is formed in the urine and vitreous fluid. Bacterial contamination occurs in blood before vitreous fluid [*11,22*]. Further work needs to be done to clarify this observation.

Other explanations may account for the presence and distribution of alcohol in a few of our cases. It is possible that some of the cases reflect recent ingestion with incomplete distribution and others may reflect prior ingestion with alcohol only detectable in urine and/or bile. It is unlikely that all or most of the cases of alcohol attributed to endogenous production were in one or the other of these end-stages of absorption or metabolism of ethanol.

Postmortem redistribution does not seem a probable explanation for most of the alcohol attributed to endogenous production in this study. The previous study by Plueckhahn had not found much difference between sites in individual cases. Alcohol was found in all eight of his cases which were undergoing decomposition. In four of these ingestion was unlikely and in two it was virtually certain not to have occurred [*1*]. Prouty and Anderson, comparing femoral and heart blood, found the specimens to be suspect

TABLE 5—*Endogenous production of alcohol, more than one fluid positive for alcohol, one atypical ratio*.*

DCME	Modified SMELLBAD Score	Alcohol Concentration %				Ratios		
		Blood	Vitreous	Bile	Urine	VI/BL	BI/BL	UR/BL
1166-85	1	0.01	0.03	...	...	3.00*	...	...
0566-86	1	0.01	0.00	0.03	0.01	...	3.00*	1.00
1593-86	2	0.01	...	0.03	0.00	...	3.00*	...
1793-86	3	0.01	0.01	0.03	0.01	1.00	3.00*	1.00
2064-86	1	0.01	...	0.03	...	...	3.00*	...
1583-88	3	0.01	0.03	...	...	3.00*	...	...
0149-88	3	0.02	...	0.05	0.05	...	2.50*	2.00
0216-87	1	0.04	0.07	0.04	0.17	1.50	1.00	4.25*
0995-88	3	0.04	...	0.09	...	...	2.25*	...
1147-88	1	0.04	...	...	0.01	...	...	0.25*
2563-88	4	0.04	0.01	0.10	0.03	0.50	2.50*	1.00
0618-88	4	0.04	...	0.01	0.03	...	0.25*	1.00
3033-84	4	0.05	0.02	...	0.01	0.60	...	0.20*
2875-85	1	0.05	...	...	0.01	...	...	0.20*
1452-86	3	0.05	0.00	0.02	...	...	0.40*	...
0043-87	3	0.05	0.01	0.05	...	0.20*	1.00	...
2719-87	3	0.05	0.01	0.03	0.00	0.20*	0.80	...
2008-87	3	0.05	0.02	0.11	...	0.60	2.20*	...
2639-84	3	0.06	0.01	0.03	...	0.17*	0.67	...
1607-88	4	0.06	...	0.09	0.02	...	1.33	0.33*
1062-86	2	0.06	0.02	0.07	0.01	0.50	1.00	0.17*
3619-86	3	0.07	0.09	0.06	0.18	1.14	1.00	2.57*
3003-88	2	0.07	0.04	0.06	0.02	0.17	1.00	0.29*
1230-87	3	0.08	0.02	0.12	...	0.25*	1.38	...
2874-87	4	0.08	...	0.04	...	...	0.50*	...
3036-86	3	0.08	0.02	0.11	...	0.25*	1.25	...
0417-87	3	0.08	0.01	...	...	0.13*	...	...
2653-87	3	0.08	0.06	0.18	...	0.87	2.25*	...
0038-87	1	0.09	0.06	0.04	0.09	0.78	0.44*	1.00
0178-87	3	0.09	0.03	...	...	0.33*	...	...
3945-87	3	0.13	0.12	0.25	0.35	1.00	1.85	2.69*
1392-87	2	0.16	0.02	...	...	0.13*	...	...
3031-84	4	0.24	0.25	0.70	0.30	1.00	2.92*	1.21
0910-88	4	0.27	0.04	0.24	0.24	0.15*	0.93	0.93

in cases in which differences were greater than 0.02% [*15*]. In a case study by Jones and Pounder, the greatest difference among ethanol concentrations from ten vascular sites was only 0.024% between the pulmonary vein and left subclavian vein [*23*].

The use of chest fluid as a specimen was examined briefly. The hypothesis is that chest fluid alcohol concentrations are approximately equivalent to blood alcohol concentrations. Both blood and chest fluid were examined in only two cases. Alcohol concentration in the chest fluid was slightly higher (0.01%) in one and much higher in the other case (0.18%) than it was in blood. Alcohol was present in all but two chest fluid specimens. This is a higher proportion of positive specimens than any other fluid. More comparisons would be necessary to assess this question more thoroughly. It appears that since decomposing fluid from the chest will commonly contain alcohol, it is not a reliable specimen to test to determine if alcohol ingestion has occurred. However, concentrations >0.15% may be suggestive of ingestion. Only one case in this group had a chest fluid alcohol concentration of 0.16% with no history of ingestion, atypical distribution, or C3 alcohol in the analytical results.

For the majority of cases this study agrees with the observations of Corry [*4*], Mayes [*7*], and Kuhlman [*12*] that the concentration of alcohol in body fluids which can be attributed to putrefaction without additional historical, scene, and specimen-handling information can be as high as 0.15%. Use of this concentration would include 22/23 (95.6%) cases from the original study by Zumwalt, Bost, and Sunshine [*11*]. It would include 54/55 (98.2%) of our non-suspect cases of alcohol concentrations attributed to endogenous production.

Higher concentrations might arise from endogenous production or a combination of ingested alcohol and endogenous production. In the USS Iowa Disaster, the highest level attributed to postmortem formation was 0.19% [*13*]. In our study one case with additional information was as high as 0.16% and two others were higher but were suspect. Only one of the cases in the original study by Zumwalt, Bost, and Sunshine had an alcohol concentration greater than 0.15% attributed to endogenous production [*11*]. Scene, historical, and specimen-handling information are necessary for an accurate, scientific interpretation. Extreme caution should be exercised in interpreting postmortem alcohol results, especially in results obtained from decomposing bodies.

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