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Abnormal Glucose Levels Found in Transportation Accidents

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16. Abstract

Purpose. The Federal Aviation Administration's Office of Aviation Medicine (OAM) is responsible for the certification of pilots with diabetic conditions. Therefore, it is essential for OAM to monitor pilots involved in fatal accidents for abnormal glucose levels, which might have caused performance impairment/ incapacitation. The present study evaluated the use of postmortem vitreous humor and urine glucose levels in transportation accident fatalities as indicators of potentially incapacitating medical conditions or performance impairment. **Methods.** Vitreous humor and/or urine from 192 accident fatalities were analyzed for glucose using a hexokinase method. Cases with values below the lower limit of detection (10 mg/dL) and above 3 standard deviations (SD) from the mean were not included in the final statistics. All cases more than 5 SD above the mean were deemed abnormal and a full case history was evaluated based on the available medical history. **Results.** The mean glucose concentration was 30 mg/dL (SD: 21 mg/dL) from 98 postmortem vitreous humor specimens, while it was 27 mg/dL (SD: 16 mg/dL) from 127 postmortem urine samples. Nine of the 192 cases were identified as having abnormal glucose levels. Abnormal glucose levels were found in 5 of the 8 cases with a known diabetic condition. Glycosuria or low renal threshold was reported in 2 fatal pilots; 1 of these pilots had an abnormal glucose level. **Conclusions.** Hyperglycemia can be established from the vitreous humor and urine glucose levels, but hypoglycemia cannot, because of the rapid postmortem drop in vitreous humor glucose levels. All of the pilot abnormal glucose cases detected were previously identified during the medical certification process or had a medical reason for the abnormal level. The elevated vitreous humor and urine glucose levels have proven useful in identifying individuals with a pre-existing diabetic condition that might have been a factor in the accident.

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Abnormal Glucose Levels Found in Transportation Accidents

INTRODUCTION

The Federal Aviation Administration's (FAA) Office of Aviation Medicine (OAM) is tasked with determining the fitness of diabetic pilots to fly. Therefore, it is important to monitor glucose levels in pilots involved in fatal aviation accidents to determine if abnormal glucose levels were a factor in the accident. The present study was undertaken to determine the concentration of glucose in postmortem vitreous humor and urine that could be considered abnormal. This information will provide accident investigators with medical information about the operator, which may help determine the cause of the accident and will allow OAM to closely monitor diabetic pilots who have been medically certified to fly.

Many research studies have addressed the issue of postmortem glucose levels (1-12). These researchers agree that hypoglycemia cannot currently be determined from postmortem specimens using existing procedures. However, postmortem vitreous humor has proven useful in predicting hyperglycemia because "the vitreous humor of the eye constitutes an isolated pool of material suitable for many analyses and is far less susceptible than the blood to rapid chemical changes or contamination" (6). Therefore, postmortem vitreous humor was chosen as a suitable specimen for use in this research to determine abnormal postmortem glucose levels in pilots.

A rapid decrease in vitreous humor glucose levels is caused by anaerobic degradation (glycolysis). An earlier study found vitreous humor glucose levels to fall 35% in 1 hour and 70% within 6 hours at room temperature (1). Glycolysis has been determined to be complete within 3.5 to 7 hours after death (11, 8). After 18 hours, the decrease in glucose levels stops (1). Cold temperatures retard glycolysis (7) and will delay the time for completion of glycolysis.

Most vitreous humor glucose studies conducted until now have utilized relatively fresh vitreous humor specimens (within 2 hours of death) to establish an abnormal vitreous humor glucose level. However, the collection of specimens and analysis of specimens by the FAA's Toxicology and Accident Research Laboratory takes no less then 48 hours and in most cases specimens are not actually analyzed until about 7 days or longer after death. Therefore, glycolysis in vitreous humor fluid should have been complete in most of the cases reported in this research. This study will define the abnormal vitreous humor glucose levels for specimens analyzed several days after death.

The rapid decrease in postmortem vitreous humor glucose levels makes it extremely difficult to accurately predict normal antemortem vitreous humor levels. Data collected by Coe (6) indicate that the normal antemortem glucose level is much higher than was first thought by Sturner (12). Coe suggests that the antimortem vitreous humor glucose level is 0.85 of the plasma values, which is much higher then the 0.50 proposed by Sturner (12). Antimortem blood glucose values above 200 mg/dL are considered diagnostic of diabetes mellitus (14). This would suggest, using the conservative estimates of Coe, that antimortem vitreous humor levels above 170 mg/dL are diagnostic of diabetes mellitus. Research by Dimaio and Dimaio (13) has shown that normal vitreous humor glucose levels do not exceed 200 mg/dL "even if intravenous glucose infusions are administered for hours prior to death." They have also found that postmortem vitreous humor glucose levels above 200 mg/dL are considered to be diagnostic of diabetes mellitus (13).

Pilot medical certification includes the testing of urine for glucose. All urine glucose levels above 100 mg/dL are considered to be abnormal and would lead to further testing of the applicant. Therefore, urine was included as a part of this research.

METHODS AND MATERIALS

Samples

During the time of this study, vitreous humor, urine, blood, liver, kidney, muscle, heart, brain, bile, gastric, spinal fluid, and spleen from almost all fatal aviation accidents occurring in the USA were collected at the accident site and sent to the Civil Aeromedical Institute's (CAMI's) Toxicology and Accident Research Laboratory for analysis. In

addition, selected surface accidents were sent to the laboratory by the National Transportation Safety Board (NTSB) for analysis. Specimens are normally shipped to CAMI for analysis within 2 to 10 days after the death of the pilot or operator. The specimens are frozen and shipped with ice bags in an ice chest, the samples are normally received the next day. When shipped according to instructions, the temperature of the specimen is between 4° to 8° C. After receipt, the specimens are weighed and aliquoted into batches for the analysis of glucose, pharmacological agents, alcohol, carbon monoxide, and cyanide. The remaining specimens are stored in a walk-in freezer at -20° C, and the batches are stored at 4° C until tested. Batches are issued for analysis at the end of each week. Specimens are normally analyzed within 5 to 10 days after receipt.

Glucose Analysis

When available, urine and vitreous humor are tested for glucose using a Du Pont Analyst benchtop chemistry system, made by Du Pont Company (Medical Products, Willmington, DE). The measured glucose values are entered into a Microsoft Excel sheet for statistical analysis (Table 1).

In this study, vitreous humor and/or urine from 192 fatal accident victims were analyzed for the presence of glucose. Specimens were analyzed by a hexokinase method and standard glucose test strips. Cases with values below the lower limit of detection (LOD) of 10 mg/dL and above 3 standard deviations (SD) of the mean were not included in the final statistics. All cases more then 5 SD from the mean were deemed abnormal, and a full case history was evaluated. Accident case histories were obtained from the NTSB database. The medical history of the pilot was obtained from the Office of Aviation Medicine (OAM) Medical Certification Division, and the historical case aspects were compared with the glucose levels found. The cause of the accident reported by the NTSB was reviewed to check for possible in-flight medical incapacitation of the pilot in those cases with abnormal glucose levels.

RESULTS

The mean concentration of glucose in 98 postmortem vitreous humor specimens was found to be 30 mg/dL, with an SD of 21 mg/dL (Table 2). The median concentration occurred between 0 and 9 mg/dL (Fig. 1) for all 170 vitreous humor specimens tested. The mean concentration of glucose in 127 postmortem urine specimens was 27 mg/dL, with an SD of 16 mg/dL (Table 3). The median concentration occurred between 10mg/dL and 19 mg/dL (Fig. 1) for all 162 urine specimens tested.

Nine (5%) of the 192 cases were identified as having abnormal glucose levels. There were 8 (5%) of the 178 subjects with a known medical history who were found to have a diabetic condition. Abnormal glucose levels were found in 5 (63%) of the 8 known diabetic subjects. One case, with 189 mg/dL of glucose in urine, had a medical history of diabetes controlled by hypoglycemic drugs. Another case, with 256 mg/dL of glucose in vitreous humor and 8815 mg/dL of glucose in urine, had a medical history of diabetes controlled by diet. One diabetic pilot had an abnormal urine glucose level of 760 mg/dL and a vitreous humor glucose level of 119 mg/dL. The urine glucose level of another diabetic pilot was found to be 2315 mg/dL. A surface accident victim with diabetes had a urine glucose concentration of 1221 mg/dL. Glycosuria, or low renal threshold, was reported in 2 of the fatal pilots; one of these pilots had an abnormal glucose level in urine. This case had 3055 mg/dL of glucose in urine and a medical history of glycosuria with a low renal threshold. No prior reported medical history, which would account for an elevated glucose level, was found in 2 of the pilots. Both of these pilots survived the accident and received emergency medical treatment, which could account for the elevated glucose levels found in vitreous fluid (5). Eight subjects were known to have received emergency medical treatment (Table 1). Only 2 of these 8 subjects had elevated vitreous humor glucose levels, and none of them had elevated urine glucose levels.

DISCUSSION & CONCLUSION:

A level of 125 mg/dL of glucose in postmortem vitreous humor, approximately 5 SD above the mean, was defined as being an abnormally high glucose level. This value was established to minimize false positive individuals and because all the cases in this range were found to have a medical reason for the abnormal glucose level. Based on this research, it was decided that a glucose level above 125mg/dL in postmortem vitreous humor would be diagnostic of a potentially incapacitating illness. The abnormal

Table 1. Glucose data collected in this study. All glucose data reported in mg/dL. Interval is reported in days. Medical Refers to medical history of the individual: NO = No medical history for abnormal glucose levels; PA = Passenger no medical history on file; PM = Pilot no medical history on file; DI = Diabetic; EM = Emergency medical treatment; GL = Glycosuria or low renal threshold; SU = surface accident, no medical history on file.

CaseNum	Urine	Vitreous	Accident Date	Date of Result	Interval	Medical
9800301001	11	0	12-Oct-98	18-Nov-98	37	DI
9800134001	28	43	26-May-98	18-Aug-98	84	DI
9800186001	189	45	26-Jun-98	18-Aug-98	53	DI
9900049001	38	97	22-Mar-99	12-Apr-99	21	DI
9800332001	760	119	04-Dec-98	13-Jan-99	40	DI
9800290001	8815	256	25-Sep-98	17-Nov-98	53	DI
9910012001	1221		03-Jun-99	08-Jul-99	35	DI
9900097001	2315		19-May-99	25-May-99	6	DI
9900038001	19	0	08-Mar-99	19-Mar-99	11	EM
9800251001		0	12-Sep-98	25-Sep-98	13	EM
9800289001	24	10	10-Oct-98	17-Nov-98	38	EM
9800311001	23	20	10-Nov-98	17-Nov-98	7	EM
9900051001	44	40	24-Mar-99	12-Apr-99	19	EM
9900147001	39	71	03-Jul-99	20-Jul-99	17	EM
9800216001	65	147	31-Jul-98	18-Aug-98	18	EM
9900047001		194	10-Mar-99	12-Apr-99	33	EM
9800208001	3055	12	05-Jul-98	19-Aug-98	45	GL
9800312001		14	03-Nov-98	17-Nov-98	14	GL
9300152001	0	0	28-Jun-93	19-Jul-93	21	NO
9800209001	0	0	26-Jul-98	18-Aug-98	23	NO
9800333001	0	0	29-Nov-98	13-Jan-99	45	NO
9800338001	0	0	12-Dec-98	13-Jan-99	32	NO
9900041001	0	0	15-Mar-99	12-Apr-99	28	NO
9900050001	0	0	26-Mar-99	12-Apr-99	17	NO
9900053001	0	0	03-Apr-99	12-Apr-99	9	NO
9800317002	11	0	12-Nov-98	13-Jan-99	62	NO
9800328001	12	0	21-Nov-98	13-Jan-99	53	NO
9900067001	12	0	22-Apr-99	11-May-99	19	NO
9900162001	12	0	17-Jul-99	27-Jul-99	10	NO
9900017001	13	0	26-Dec-98	05-Feb-99	41	NO
9800212001	14	0	31-Jul-98	18-Aug-98	18	NO
9800317001	14	0	12-Nov-98	13-Jan-99	62	NO
9900017002	15	0	26-Dec-98	05-Feb-99	41	NO
9900040001	15	0	13-Mar-99	12-Apr-99	30	NO
9900087001	15	0	08-May-99	25-May-99	17	NO
9800217001	17	0	02-Aug-98	18-Aug-98	16	NO
9800305001	18	0	02-Nov-98	18-Nov-98	16	NO
9800267001	19	0	08-Sep-98	17-Nov-98	70	NO
9800279001	19	0	01-Oct-98	17-Nov-98	47	NO
9900119001	19	0	28-May-99	21-Jun-99	24	NO
9900083001	20	0	04-May-99	11-May-99	7	NO
9800284001	21	0	09-Oct-98	17-Nov-98	39	NO
9900026001	22	0	05-Feb-99	01-Mar-99	24	NO
9800228001	23	0	15-Aug-98	01-Sep-98	17	NO

Table 1. (Continued)

CaseNum	Urine	Vitreous	Accident Date	Date of Result	Interval	Medical
9900082001	26	0	23-Apr-99	11-May-99	18	NO
9800202001	27	0	20-Jul-98	18-Aug-98	29	NO
9900016001	28	0	27-Jan-99	05-Feb-99	9	NO
9800342001	29	0	23-Dec-98	13-Jan-99	21	NO
9800285001	33	0	06-Oct-98	17-Nov-98	42	NO
9900060001	35	0	17-Apr-99	27-Apr-99	10	NO
9900036001	36	0	11-Feb-99	19-Mar-99	36	NO
9800339001	39	0	15-Dec-98	13-Jan-99	29	NO
9800232001	45	0	20-Aug-98	07-Sep-98	18	NO
9800235001	48	0	22-Aug-98	07-Sep-98	16	NO
9900108001	48	0	29-May-99	08-Jun-99	10	NO
9900118001	64	0	07-Jun-99	21-Jun-99	14	NO
9800233001	65	0	21-Aug-98	07-Sep-98	17	NO
9900088001		0	03-May-99	25-May-99	22	NO
9900097002		0	19-May-99	25-May-99	6	NO
9800164001		0	06-Jun-98	18-Aug-98	73	NO
9800230001		0	19-Aug-98	01-Sep-98	13	NO
9800249002		0	06-Aug-98	25-Sep-98	50	NO
9800268001		0	23-Sep-98	17-Nov-98	55	NO
9800329001		0	24-Nov-98	13-Jan-99	50	NO
9800330001		0	08-Nov-98	13-Jan-99	66	NO
9800331001		0	29-Nov-98	13-Jan-99	45	NO
9800343001		0	25-Dec-98	13-Jan-99	19	NO
9800345001		0	10-Oct-98	13-Jan-99	95	NO
9900005001		0	06-Jan-99	23-Feb-99	48	NO
9900010001		0	19-Jan-99	23-Feb-99	35	NO
9800229001	87	10	12-Aug-98	01-Sep-98	20	NO
9900168001		10	17-Jul-99	27-Jul-99	10	NO
9800248001	12	11	07-Sep-98	25-Sep-98	18	NO
9800236001	15	11	19-Jul-98	07-Sep-98	50	NO
9900120001	22	11	08-Jun-99	21-Jun-99	13	NO
9800242002	23	11	29-Aug-98	07-Sep-98	9	NO
9800281001	29	11	08-Oct-98	17-Nov-98	40	NO
9900136001		11	19-Jun-99	08-Jul-99	19	NO
9800222001	21	12	11-Aug-98	18-Aug-98	7	NO
9800224001	24	12	15-Aug-98	01-Sep-98	17	NO
9800250001	27	12	02-Sep-98	25-Sep-98	23	NO
9800226001	39	12	14-Aug-98	01-Sep-98	18	NO
9600285001		12	31-Oct-96	28-Feb-97	120	NO
9900080001	0	13	02-May-99	11-May-99	9	NO
9800231001	12	13	31-Jul-98	01-Sep-98	32	NO
9900142001	23	13	25-Jun-99	08-Jul-99	13	NO
9900073001		13	23-Apr-99	11-May-99	18	NO
9900135001	13	14	18-Jun-99	08-Jul-99	20	NO
9800314001	16	14	07-Nov-98	17-Nov-98	10	NO
9800242001	21	14	29-Aug-98	07-Sep-98	9	NO
9800181001	0	15	25-Jun-98	18-Aug-98	54	NO
9900012001	15	15	22-Jan-99	23-Feb-99	32	NO
9900068001	19	15	22-Apr-99	11-May-99	19	NO
9800187001	20	15	01-Jul-98	18-Aug-98	48	NO
9900123001		15	03-Jun-99	21-Jun-99	18	NO
9800198001	22	16	16-Jul-98	18-Aug-98	33	NO
9800255001		16	09-Sep-98	25-Sep-98	16	NO

Table 1. (Continued)

CaseNum	Urine	Vitreous	Accident Date	Date of Result	Interval	Medical
9800151001	16	17	04-Jun-98	18-Aug-98	75	NO
9800241002	64	17	29-Aug-98	07-Sep-98	9	NO
9900056001	12	18	01-Apr-99	12-Apr-99	11	NO
9800225001	15	18	15-Aug-98	01-Sep-98	17	NO
9900144001		18	29-Jun-99	08-Jul-99	9	NO
9800247001		18	04-Sep-98	25-Sep-98	21	NO
9800275001		18	04-Oct-98	17-Nov-98	44	NO
9800295001	13	19	18-Oct-98	17-Nov-98	30	NO
9800234001	18	19	04-Aug-98	07-Sep-98	34	NO
9800215001	44	19	04-Aug-98	18-Aug-98	14	NO
9900059001		19	17-Apr-99	27-Apr-99	10	NO
9900008001	18	20	04-Jan-99	23-Feb-99	50	NO
9800272001		20	03-Oct-98	17-Nov-98	45	NO
9900169001	20	21	28-Jun-99	27-Jul-99	29	NO
9900121001	43	21	05-Jun-99	21-Jun-99	16	NO
9800221001	13	22	09-Aug-98	18-Aug-98	9	NO
9900091001		22	09-May-99	25-May-99	16	NO
9800308001		22	04-Nov-98	17-Nov-98	13	NO
9800294001	19	23	17-Oct-98	17-Nov-98	31	NO
9900144002		23	29-Jun-99	08-Jul-99	9	NO
9900011001	14	25	21-Jan-99	23-Feb-99	33	NO
9900009001	34	25	27-Dec-98	23-Feb-99	58	NO
9800277001	30	26	05-Oct-98	17-Nov-98	43	NO
9900153001	29	27	07-Jul-99	20-Jul-99	13	NO
9900064001		28	14-Apr-99	27-Apr-99	13	NO
9800276001	17	30	05-Oct-98	17-Nov-98	43	NO
9800241001		30	29-Aug-98	08-Sep-98	10	NO
9800302001	23	31	01-Nov-98	18-Nov-98	17	NO
9800309001	23	32	06-Nov-98	17-Nov-98	11	NO
9900095001		32	11-May-99	25-May-99	14	NO
9900146001		32	02-Jul-99	20-Jul-99	18	NO
9800170001		33	19-Jun-98	18-Aug-98	60	NO
9800259001		34	18-Sep-98	17-Nov-98	60	NO
9900054001	28	36	01-Apr-99	12-Apr-99	11	NO
9900004001		36	02-Jan-99	23-Feb-99	52	NO
9800196001		41	15-Jul-98	18-Aug-98	34	NO
9800326001	37	46	21-Nov-98	13-Jan-99	53	NO
9900062001	15	49	15-Apr-99	27-Apr-99	12	NO
9800288001	0	50	13-Oct-98	17-Nov-98	35	NO
9800243001	30	52	29-Aug-98	07-Sep-98	9	NO
9900169002	22	55	28-Jun-99	27-Jul-99	29	NO
9900027001		57	12-Feb-99	01-Mar-99	17	NO
9900139001		59	23-Jun-99	08-Jul-99	15	NO
9800207001		59	25-Jul-98	19-Aug-98	25	NO
9800192001	13	60	30-Jun-98	18-Aug-98	49	NO
9900003001		63	18-Dec-98	13-Jan-99	26	NO
9800188001	29	66	10-Jul-98	18-Aug-98	39	NO
9900030001	67	66	20-Feb-99	01-Mar-99	9	NO
9800213002	27	69	02-Aug-98	18-Aug-98	16	NO
9800260001		72	18-Sep-98	17-Nov-98	60	NO
9900100001	23	76	20-May-99	08-Jun-99	19	NO
9800166001		77	16-Jun-98	18-Aug-98	63	NO
9900150001		81	11-Jul-99	20-Jul-99	9	NO
9800258001		89	16-Sep-98	17-Nov-98	62	NO

Table 1. (Continued)

CaseNum	Urine	Vitreous	Accident Date	Date of Result	Interval	Medical
9800265001	42	102	26-Sep-98	17-Nov-98	52	NO
9800335001	18	105	04-Dec-98	13-Jan-99	40	NO
9900037001	65	113	08-Mar-99	19-Mar-99	11	NO
9800336001	0		04-Dec-98	13-Jan-99	40	NO
9900071001	0		22-Apr-99	11-May-99	19	NO
9900007001	10		16-Jan-99	23-Feb-99	38	NO
9900149002	12		09-Jul-99	20-Jul-99	11	NO
9900149001	14		09-Jul-99	20-Jul-99	11	NO
9900164001	14		05-Jul-99	27-Jul-99	22	NO
9900126001	15		11-Jun-99	21-Jun-99	10	NO
9900109001	16		29-May-99	08-Jun-99	10	NO
9900112001	16		30-May-99	08-Jun-99	9	NO
9900110001	17		29-May-99	08-Jun-99	10	NO
9900159001	17		12-Jul-99	20-Jul-99	8	NO
9900076001	18		28-Apr-99	11-May-99	13	NO
9900105001	18		25-May-99	08-Jun-99	14	NO
9900089002	22		07-May-99	25-May-99	18	NO
9900101001	22		25-May-99	08-Jun-99	14	NO
9900089001	23		07-May-99	25-May-99	18	NO
9900090002	23		02-May-99	25-May-99	23	NO
9900157001	27		11-Jul-99	20-Jul-99	9	NO
9800271001	29		01-Oct-98	17-Nov-98	47	NO
9900085002	29		01-May-99	11-May-99	10	NO
9900111001	31		29-May-99	08-Jun-99	10	NO
9900104001	32		23-May-99	08-Jun-99	16	NO
9800270001	39		26-Sep-98	17-Nov-98	52	NO
9900115001	45		24-May-99	21-Jun-99	28	NO
9900070001	100		21-Apr-99	11-May-99	20	NO
9800217002	27	0	02-Aug-98	18-Aug-98	16	PA
9900118002	71	0	07-Jun-99	21-Jun-99	14	PA
9900012002	14	13	22-Jan-99	23-Feb-99	32	PA
9900009002	35	13	27-Dec-98	23-Feb-99	58	PA
9800221002	14	16	09-Aug-98	18-Aug-98	9	PA
9800166002		21	16-Jun-98	18-Aug-98	63	PA
9800218001		25	08-Aug-98	18-Aug-98	10	PA
9800276002	27	27	05-Oct-98	17-Nov-98	43	PA
9800325001	0		21-Nov-98	13-Jan-99	53	PA
9800282002	16		09-Oct-98	17-Nov-98	39	PA
9100106001	0	0	06-Apr-91	19-Apr-91	13	PM
9900048001	15	0	21-Feb-99	12-Apr-99	50	PM
9800294002	16	0	17-Oct-98	17-Nov-98	31	PM
9800257001	66	0	16-Sep-98	25-Sep-98	9	PM
9300146001	0	73	18-Jun-93	19-Jul-93	31	PM
9810006001		0	20-Jun-98	18-Aug-98	59	SU
9990001001	10	33	04-Jun-99	21-Jun-99	17	SU
9910011002	21		03-Jun-99	08-Jul-99	35	SU
9910006001	121		15-Mar-99	12-Apr-99	28	SU

Table 2. Calculation of standard deviation and mean for postmortem vitreous humor.

Observ. #	X-Vitreous	X-Mean	(X-Mean)^2
1	10	-20.18	407.38
2	10	-20.18	407.38
3	10	-20.18	407.38
4	11	-19.18	368.01
5	11	-19.18	368.01
6	11	-19.18	368.01
7	11	-19.18	368.01
8	11	-19.18	368.01
9	11	-19.18	368.01
10	12	-18.18	330.65
11	12	-18.18	330.65
12	12	-18.18	330.65
13	12	-18.18	330.65
14	12	-18.18	330.65
15	12	-18.18	330.65
16	13	-17.18	295.28
17	13	-17.18	295.28
18	13	-17.18	295.28
19	13	-17.18	295.28
20	13	-17.18	295.28
21	13	-17.18	295.28
22	14	-16.18	261.91
23	14	-16.18	261.91
24	14	-16.18	261.91
25	14	-16.18	261.91
26	15	-15.18	230.54
27	15	-15.18	230.54
28	15	-15.18	230.54
29	15	-15.18	230.54
30	15	-15.18	230.54
31	16	-14.18	201.18
32	16	-14.18	201.18
33	16	-14.18	201.18
34	17	-13.18	173.81
35	17	-13.18	173.81
36	18	-12.18	148.44
37	18	-12.18	148.44
38	18	-12.18	148.44
39	18	-12.18	148.44
40	18	-12.18	148.44
41	19	-11.18	125.07
42	19	-11.18	125.07
43	19	-11.18	125.07
44	19	-11.18	125.07
45	20	-10.18	103.71
46	20	-10.18	103.71
47	20	-10.18	103.71
48	21	-9.18	84.34
49	21	-9.18	84.34
50	21	-9.18	84.34
51	22	-8.18	66.97
52	22	-8.18	66.97
53	22	-8.18	66.97
54	23	-7.18	51.61
55	23	-7.18	51.61
56	25	-5.18	26.87
57	25	-5.18	26.87
58	25	-5.18	26.87
59	26	-4.18	17.50
60	27	-3.18	10.14
61	27	-3.18	10.14
62	28	-2.18	4.77
63	30	-0.18	0.03
64	30	-0.18	0.03
65	31	0.82	0.67
66	32	1.82	3.30
67	32	1.82	3.30
68	32	1.82	3.30
69	33	2.82	7.93
70	33	2.82	7.93
71	34	3.82	14.56
72	36	5.82	33.83
73	36	5.82	33.83
74	40	9.82	96.36

Levey-Jennings Chart

Conf +99% ----- 94	+3SD
Conf +95% ----- 73	+2SD
Conf +68% ----- 51	+1SD
Mean ---------- 30	
Conf -68% -------- 9	-1SD
Conf -95% ----- -12	-2SD
Conf -99% ----- -34	-3SD

Statistics

N=	98
Mean	30
Variance	452
SD	21
CV	70

Table 2. (Continued)

Observ. #	X-Vitreous	X-Mean	(X-Mean)^2
75	41	10.82	116.99
76	43	12.82	164.26
77	45	14.82	219.52
78	46	15.82	250.16
79	49	18.82	354.05
80	50	19.82	392.69
81	52	21.82	475.95
82	55	24.82	615.85
83	57	26.82	719.12
84	59	28.82	830.38
85	59	28.82	830.38
86	60	29.82	889.01
87	63	32.82	1076.91
88	66	35.82	1282.81
89	66	35.82	1282.81
90	69	38.82	1506.71
91	71	40.82	1665.97
92	72	41.82	1748.61
93	73	42.82	1833.24
94	76	45.82	2099.14
95	77	46.82	2191.77
96	81	50.82	2582.30
97	89	58.82	3459.36
98	97	66.82	4464.42

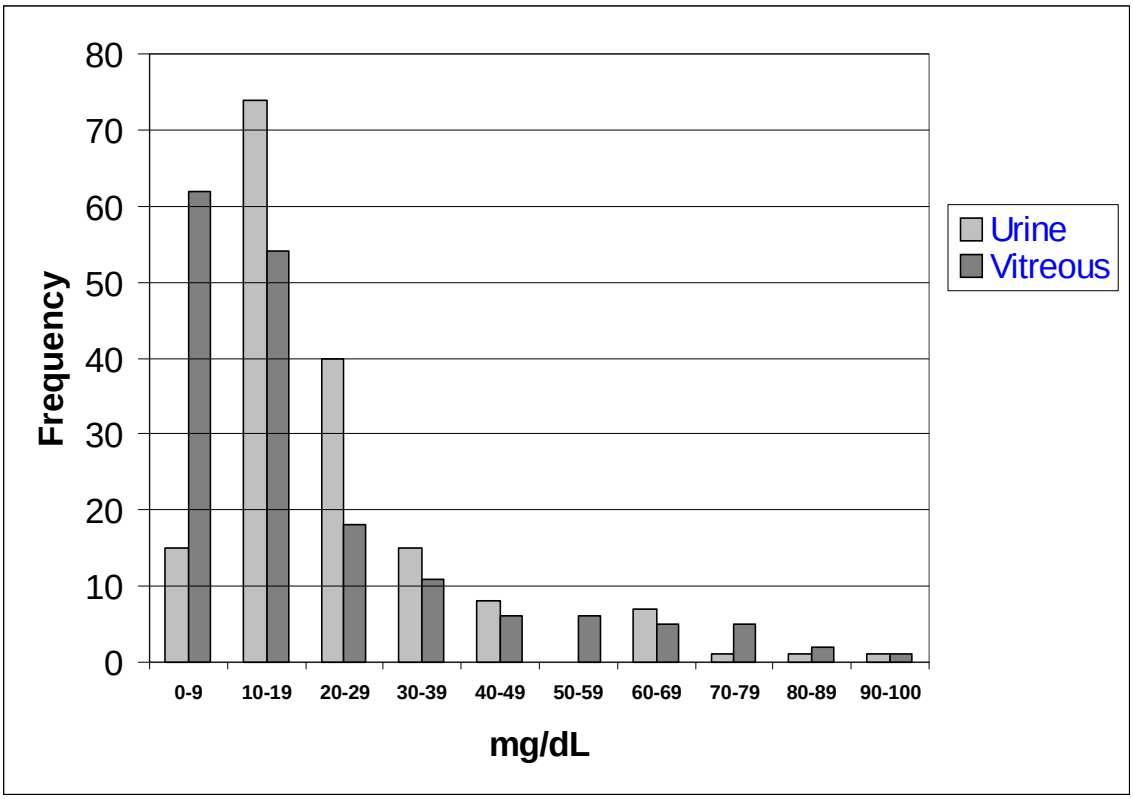

Figure 1. Glucose Frequency Chart

Table 3. Calculation of standard deviation and mean for postmortem urine.

Observ. #	X-Urine	X-Mean	(X-Mean)^2
1	10	-16.67	277.87
2	10	-16.67	277.87
3	11	-15.67	245.53
4	11	-15.67	245.53
5	12	-14.67	215.19
6	12	-14.67	215.19
7	12	-14.67	215.19
8	12	-14.67	215.19
9	12	-14.67	215.19
10	12	-14.67	215.19
11	12	-14.67	215.19
12	13	-13.67	186.85
13	13	-13.67	186.85
14	13	-13.67	186.85
15	13	-13.67	186.85
16	13	-13.67	186.85
17	14	-12.67	160.51
18	14	-12.67	160.51
19	14	-12.67	160.51
20	14	-12.67	160.51
21	14	-12.67	160.51
22	14	-12.67	160.51
23	14	-12.67	160.51
24	15	-11.67	136.17
25	15	-11.67	136.17
26	15	-11.67	136.17
27	15	-11.67	136.17
28	15	-11.67	136.17
29	15	-11.67	136.17
30	15	-11.67	136.17
31	15	-11.67	136.17
32	15	-11.67	136.17
33	16	-10.67	113.83
34	16	-10.67	113.83
35	16	-10.67	113.83
36	16	-10.67	113.83
37	16	-10.67	113.83
38	16	-10.67	113.83
39	17	-9.67	93.50
40	17	-9.67	93.50
41	17	-9.67	93.50
42	17	-9.67	93.50
43	18	-8.67	75.16
44	18	-8.67	75.16
45	18	-8.67	75.16
46	18	-8.67	75.16
47	18	-8.67	75.16
48	18	-8.67	75.16
49	19	-7.67	58.82
50	19	-7.67	58.82
51	19	-7.67	58.82
52	19	-7.67	58.82
53	19	-7.67	58.82
54	19	-7.67	58.82
55	20	-6.67	44.48
56	20	-6.67	44.48
57	20	-6.67	44.48
58	21	-5.67	32.14
59	21	-5.67	32.14
60	21	-5.67	32.14
61	21	-5.67	32.14
62	22	-4.67	21.80
63	22	-4.67	21.80
64	22	-4.67	21.80
65	22	-4.67	21.80
66	22	-4.67	21.80
67	22	-4.67	21.80
68	23	-3.67	13.46
69	23	-3.67	13.46
70	23	-3.67	13.46
71	23	-3.67	13.46
72	23	-3.67	13.46
73	23	-3.67	13.46
74	23	-3.67	13.46

Levey-Jennings Chart

Conf +99% ----- 76	+3SD
Conf +95% ----- 59	+2SD
Conf +68% ----- 43	+1SD
Mean ---------- 27	
Conf -68% ------ 10	-1SD
Conf -95% ------- -6	-2SD
Conf -99% ----- -22	-3SD

Statistics

N= ---------	127
Mean --------	27
Variance --	266
SD ----------	16
CV ----------	61

Table 3. (Continued)

Observ. #	X-Urine	X-Mean	(X-Mean)^2
75	23	-3.67	13.46
76	23	-3.67	13.46
77	24	-2.67	7.13
78	24	-2.67	7.13
79	26	-0.67	0.45
80	27	0.33	0.11
81	27	0.33	0.11
82	27	0.33	0.11
83	27	0.33	0.11
84	27	0.33	0.11
85	27	0.33	0.11
86	28	1.33	1.77
87	28	1.33	1.77
88	28	1.33	1.77
89	29	2.33	5.43
90	29	2.33	5.43
91	29	2.33	5.43
92	29	2.33	5.43
93	29	2.33	5.43
94	29	2.33	5.43
95	30	3.33	11.09
96	30	3.33	11.09
97	31	4.33	18.76
98	32	5.33	28.42
99	33	6.33	40.08
100	34	7.33	53.74
101	35	8.33	69.40
102	35	8.33	69.40
103	36	9.33	87.06
104	37	10.33	106.72
105	38	11.33	128.38
106	39	12.33	152.05
107	39	12.33	152.05
108	39	12.33	152.05
109	39	12.33	152.05
110	42	15.33	235.03
111	43	16.33	266.69
112	44	17.33	300.35
113	44	17.33	300.35
114	45	18.33	336.01
115	45	18.33	336.01
116	48	21.33	455.00
117	48	21.33	455.00
118	64	37.33	1393.58
119	64	37.33	1393.58
120	65	38.33	1469.24
121	65	38.33	1469.24
122	65	38.33	1469.24
123	66	39.33	1546.90
124	67	40.33	1626.57
125	71	44.33	1965.21
126	87	60.33	3639.79
127	100	73.33	5377.39

postmortem vitreous humor value was set at approximately 5 SD above the mean to remain conservative and reduce the risk of including individuals with normal glucose levels. All the subjects tested with a postmortem vitreous humor glucose concentration above 125 mg/dL had a previous medical history that would account for the elevated levels. Postmortem glucose blood levels above 200 mg/dL are considered diagnostic of hyperglycemia (11). Therefore, postmortem vitreous humor glucose levels above 170 mg/dL, which is 85% of the blood glucose level (10), should be diagnostic of hyperglycemia. The rapid loss of 70% of glucose in postmortem vitreous humor within the first 6 hours (7) after death would suggest that postmortem vitreous humor glucose levels above 51 mg/dL in samples tested more than 6 hours after death should be considered abnormal. The frequency chart (Fig. 1) indicates that very few cases (<15%) were found with a postmortem vitreous humor glucose level above 51 mg/dL. Our results are consistent with earlier reports for normal glucose levels of 30-80 mg/dL in human postmortem vitreous humor (12).

A level of 100 mg/dL of glucose in postmortem urine, approximately 5 SD above the mean, was considered to be abnormal. This value was chosen to avoid false positive results and because pilots with a urine glucose level above 100 mg/dL at the time of their physical would be considered abnormal. Postmortem urine glucose concentrations above 100 mg/dL were determined to be abnormal and indicators of a medical abnormality. This is based on the mean postmortem glucose level of 27 mg/dL and the SD of

16 mg/dL for all accident victims. All of the subjects tested with a postmortem urine glucose concentration above 100 mg/dL had a previous medical history that could account for the elevated levels.

Elevated glucose levels in postmortem vitreous humor and urine can help identify transportation operators with pre-existing medical conditions that may have been an important factor in accident causation. Hyperglycemic conditions can be tracked using postmortem vitreous humor and urine glucose levels. Hypoglycemic conditions cannot be determined using postmortem vitreous humor glucose levels due to the rapid drop in postmortem vitreous humor glucose levels. This was determined by comparing the median postmortem vitreous humor glucose level of 0 to 9 mg/dL and the normal antimortem vitreous humor glucose level (63 mg/dL to 90 mg/dL).

Emergency medical treatment has been considered as a possible cause for elevated glucose levels (5), and this study did find 2 subjects with abnormal vitreous humor glucose levels who received emergency medical treatment. However, the majority (75%) of the victims receiving emergency medical treatment did not have elevated vitreous humor glucose levels. None of the individuals receiving emergency medical treatment had elevated urine glucose levels.

It is important to note that all of the cases with an elevated glucose level had been identified during the normal medical certification process or could be explained by post-accident medical treatment. This is a 100% success rate for the medical certification process in identifying medical conditions that result in abnormal glucose levels. The NTSB determined that the mishap associated with a glucose level of 3055 mg/dL in the urine and a 12 mg/dL of glucose in vitreous humor was caused by pilot error. The remaining accidents are still under investigation by the NTSB.

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