
Federal Aviation Administration

DOT/FAA/AM-08/11
Office of Aerospace Medicine
Washington, DC 20591

# Vitreous Fluid and/or Urine Glucose Concentrations in 1,335 Civil Aviation Accident Pilot Fatalities

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May 2008

Final Report

OK-08-1997

# NOTICE



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**Technical Report Documentation Page**

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| DOT/FAA/AM-08/11 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Vitreous Fluid and/or Urine Glucose Concentrations in 1,335 Civil Aviation Accident Pilot Fatalities | May 2008 |
| | 6. Performing Organization Code |

| 7. Author(s) | 8. Performing Organization Report No. |
|---|---|
| Botch SR, Chaturvedi AK, Canfield DV, Forster EM | |

| 9. Performing Organization Name and Address | 10. Work Unit No. (TRAIS) |
|---|---|
| FAA Civil Aerospace Medical Institute<br>P.O. Box 25082<br>Oklahoma City, OK 73125 | 11. Contract or Grant No. |

| 12. Sponsoring Agency name and Address | 13. Type of Report and Period Covered |
|---|---|
| Office of Aerospace Medicine<br>Federal Aviation Administration<br>800 Independence Ave., S.W.<br>Washington, DC 20591 | 14. Sponsoring Agency Code |

15. Supplemental Notes

Work was accomplished under approved task AM-B-08-TOX-202.

16. Abstract

For aviation accident investigations at the Civil Aerospace Medical Institute (CAMI), vitreous fluid and urine samples from pilot fatalities are analyzed for glucose, and in those cases wherein glucose levels are elevated, blood hemoglobin $A_{1c}$ ($HbA_{1c}$) is measured. These analyses are conducted to monitor diabetic pilots to ensure that their disease was in control at the time of accidents and to discover other pilots with undiagnosed and unreported diabetes. In this study, the prevalence of elevated glucose concentrations in fatally injured civilian pilots is evaluated. Glucose and $HbA_{1c}$ are measured by hexokinase and latex immunoagglutination inhibition methodologies, respectively. The former was adopted at the beginning of 1998, while the latter in the middle of 2001. The analytical results are electronically stored in the CAMI Toxicology Database. This database was searched for pilots from whom samples were received during 1998–2005 and whose vitreous fluid and/or urine glucose concentrations were measured. $HbA_{1c}$ levels and information on diabetic pilots were also retrieved. The probable cause and contributing factors of the associated accidents were obtained from the National Transportation Safety Board's (NTSB's) Aviation Accident Database. Out of 1,335 pilots involving 363 vitreous fluid, 365 urine, and 607 vitreous fluid and urine analyses, 43 pilots had elevated glucose in vitreous fluid (> 125 mg/dL) and/or in urine (> 100 mg/dL). Of the 20 pilots whose blood samples were analyzed, 9 had > 6% $HbA_{1c}$—4 were known diabetics ($HbA_{1c}$: 7.1; 8.3; 10.8; and 12.4%), and 5 were not known diabetics ($HbA_{1c}$: 6.2; 8.2; 8.3; 8.6; and 13.0%). Urinary glucose levels were elevated in all 13 known hyperglycemic pilots. One pilot had a history of renal glycosuria (low renal threshold). The disease of the 13 diabetic pilots was not in control at the time of accidents. Additionally, there were a considerable number of pilots with elevated glucose (30 of 43) and $HbA_{1c}$ (5 of 20), suggesting undiagnosed and unreported diabetic conditions. However, health, medical condition(s), and use of medications (authorized or unauthorized) by pilots were determined by the NTSB to be the cause or a factor in 5 accidents: elevated glucose level of the pilot was a factor in 1 and incapacitation/impairment of the pilot was a cause and/or factor in 4. Greater attention is necessary in controlling diabetes by aviators in coordination with Aviation Medical Examiners.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Forensic Science, Toxicology, Glucose, Hemoglobin $A_{1c}$, Fatalities, Civil Aviation Accident Investigation | Document is available to the public through the Defense Technical Information Center, Ft. Belvior, VA 22060; and the National Technical Information Service, Springfield, VA 22161 |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 11 | |

**Form DOT F 1700.7** (8-72) Reproduction of completed page authorized

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# Vitreous Fluid and/or Urine Glucose Concentrations in 1,335 Civil Aviation Accident Pilot Fatalities

## INTRODUCTION

During aviation accident investigations at the Federal Aviation Administration (FAA's) Civil Aerospace Medical Institute (CAMI), vitreous fluid and urine samples from pilot fatalities are analyzed for glucose (1–3). In those fatalities (cases) wherein glucose levels are elevated, blood hemoglobin $A_{1c}$ ($HbA_{1c}$) is also measured (3,4). Concentrations of glucose > 125 mg/dL in vitreous fluid and > 100 mg/dL in urine are considered elevated (2). These glucose and $HbA_{1c}$ analyses are conducted to monitor diabetic pilots to ensure that their disease was in control at the time of accidents and to discover other pilots with unreported diabetes. Such analyses of postmortem samples from aviation accident pilot fatalities are useful in determining whether hyperglycemia-induced performance impairment was the probable cause or a contributory factor in a particular accident.

At CAMI, vitreous fluid and urine glucose analysis was implemented in the beginning of 1998 and blood $HbA_{1c}$ in the middle of 2001. However, information on the prevalence and causal effects of elevated glucose and $HbA_{1c}$ in fatal civil aviation accidents is not documented. In this study, elevated glucose and $HbA_{1c}$ in fatally injured civil aviators from whom biological samples were received at CAMI during 1998–2005 were evaluated by retrieving and analyzing necessary information from relevant databases. The possible causal effects of the elevated glucose and $HbA_{1c}$ in the associated accidents were also retrieved during the database searches. The findings thus obtained are presented herein.

## MATERIALS AND METHODS

### Postmortem Biological Specimens

Autopsied biological samples (blood, urine, liver, kidney, vitreous fluid, and other body specimens) collected from fatally injured pilots of U.S. civil aviation accidents are submitted to CAMI for toxicological analyses for the investigation of aircraft accidents occurring within the jurisdiction of the United States (1,3). These aviation accidents entail accidents involving registered, as well as unregistered aircraft. Not all of the aviators involved in these accidents held airman medical and/or flying certificates required to legally pilot an aircraft. Collected postmortem samples are submitted to CAMI in the FAA's TOX-BOX evidence containers (3). Submissions of the postmortem samples are coordinated through the FAA's Office of Accident Investigation by the National Transportation Safety Board (NTSB). The NTSB is responsible for investigating all U.S. civilian aircraft accidents.

### Biological Specimen Analyses

In addition to routine toxicological analyses of the submitted specimens following standard procedures of the CAMI Toxicology Laboratory, vitreous fluid and urine samples are analyzed for glucose and blood for $HbA_{1c}$ (3–5). Glucose analysis is performed by a hexokinase method using a Du Pont Analyst Benchtop Chemistry Station (Du Pont Company Medical Products, Wilmington, DL). Blood $HbA_{1c}$ is measured by a latex immunoagglutination inhibition using a DCA 2000+ Analyzer and DCA 2000 $HbA_{1c}$ Reagent Kit (Bayer Corporation, Elkhart, IN). The glucose analysis in the Laboratory was implemented in the beginning of 1998 and the $HbA_{1c}$ in the middle of 2001. The $HbA_{1c}$ analysis was performed in those cases wherein vitreous fluid and/or urine glucose concentrations were elevated (2,4) and wherein suitable blood samples were available.

### Database Search

Including glucose and $HbA_{1c}$ analytical values, all toxicological results of civil aircraft accident pilot fatalities are electronically stored in a database maintained at CAMI in Oklahoma City, OK. The CAMI Toxicology Database was searched for an 8-year period (1998–2005) for pilot fatalities from whom postmortem samples were submitted and their vitreous fluid and urine samples were analyzed for glucose. Blood $HbA_{1c}$ and toxicological findings were also retrieved from this database.

Additionally, the CAMI Toxicology Database search entailed the numbers of all U.S. civil aviation accidents and pilot fatalities, including the airman flying and medical certificates of those pilots and the flight categories of the associated accidents. Some additional information related to airman flying certificates and flight categories, along with the probable cause and contributing factors in the accidents, was obtained from the NTSB's Aviation Accident Database (Washington, DC). The cause and factors-related information included in the study is based on the findings reported in the NTSB Database through December 2006. Aviators that did not have airman medical and/or flying certificates were also part of the study.

## RESULTS

### Pilot Fatalities and Accidents

During 1998–2005, postmortem samples from 2,487 pilot fatalities were submitted to CAMI. This number of fatalities corresponded to the equivalent number of aviation accidents in which pilot fatalities had occurred and their postmortem samples were toxicologically evaluated. Of the 2,487 accidents, 2,210 were of general aviation, 107 air taxi and commuter, 20 ultralight vehicle, and 32 public use categories (6). The remaining 118 accidents were associated with air carrier, agricultural, and other categories.

### Elevated Glucose and $HbA_{1c}$

Vitreous fluid and/or urine specimens from 1,335 (54%) of the 2,487 pilot fatalities (cases) were analyzed for glucose in 1998–2005. In the remaining 1,152 (46%) cases, vitreous fluid and urine samples were either not submitted, not available in sufficient amounts, or not of analytical quality to perform glucose analyses. Analyses of the 1,335 cases consisted of 363 vitreous fluid, 365 urine, and 607 vitreous fluid and urine specimens (Fig. 1). Although the majority of the glucose concentrations found in vitreous fluid and urine ranged from 0 to 99 mg/dL (Fig. 2), there were 26 vitreous fluid and 39 urine samples wherein the glucose concentrations were determined to be ≥100 mg/dL.

As given in Table I, 43 pilots had elevated glucose in vitreous fluid (> 125 mg/dL) and/or in urine (> 100 mg/dL). In 29 of the 43 cases, both vitreous fluid and urine samples were analyzed—3 had elevated glucose in vitreous fluid only, 19 in urine only, and 7 in vitreous fluid, as well as in urine. In 3 cases, only vitreous fluid was received and analyzed. In 11 cases, only urine was received and analyzed. Glucose was found to be elevated in these 14 samples.

Of the 20 pilots whose blood samples were analyzed for $HbA_{1c}$, 9 had > 6% $HbA_{1c}$—4 were known diabetics ($HbA_{1c}$: 7.1; 8.3; 10.8; and 12.4%), and 5 were not known diabetics ($HbA_{1c}$: 6.2; 8.2; 8.3; 8.6; and 13.0%). Urinary glucose concentrations were elevated in all 13 known hyperglycemic pilots.

Analytical toxicology failed to disclose the presence of drugs and/or ethanol in 26 of the 43 pilots. However, drugs were detected in the remaining 17 pilots. Drugs found were amitriptyline, amphetamines, atropine, β-adrenergic blockers, calcium channel blockers, $H_1$- and $H_2$-antagonists, lidocaine, midazolam, narcotic and non-narcotic analgesics, pentobarbital, and sildenafil.

### Flight Categories

Of the 43 accidents, a highest number of 37 accidents were associated with general aviation flights, followed by 3 air taxi and commuter, 2 ultralight vehicle, and 1 public use flights. Under the general aviation category, vitreous fluid glucose was elevated in 4 pilots, urine glucose in 28, and vitreous fluid and urine glucose in 5 (Table II). Of the 9 pilots with elevated $HbA_{1c}$ (> 6%), 7 were involved with general aviation flights and 1 each in ultralight vehicle and public use flights.

### Airman Medical and Flying Certificates

Of the 43 pilots, 1 held First-Class, 21 Second-Class, and 18 Third-Class airman medical certificates. The other 3 pilots were without valid medical certificates. The pilot with the First-Class medical certificate was involved in a general aviation accident. Of the 21 Second-Class medical certificate holders, 17 were involved in general aviation accidents, followed by 3 in air taxi and commuter, and 1 in public use accidents. Out of the 18 pilots with Third-Class medical certificates, 17 were involved in general aviation and 1 in ultralight vehicle accidents. Of the 3 non-certificated pilots, 2 were involved in general aviation accidents and 1 in an ultralight vehicle accident. Except the First-Class pilot, all pilots with elevated glucose in vitreous fluid and/or urine and with elevated $HbA_{1c}$ were holders of Second- and Third-Class medical certificates (Table III). The majority of these Second- and Third-Class pilots had commercial and private flying ratings, respectively (Table IV).

With respect to flying ratings, 19 pilots held private, 16 commercial, and 7 airline transport certificates. One pilot was non-certificated. Of the 19 private pilots, 18 were involved in general aviation accidents, while 1 in an ultralight vehicle accident. In the 16 commercial pilots, 12 were involved in general aviation, 3 in air taxi and commuter, and 1 in public use accidents. All 7 pilots with airline transport pilot certificates were involved in general aviation accidents.

### Pilot Medical History and Accident Cause/Factor

Out of the 43 pilots, 14 had an aeromedical history of hyperglycemia—1 had renal glycosuria (low renal threshold) and 13 known history of diabetes (Table I). According to the history, diabetes should have been controlled by diet in 5 pilots, by hypoglycemic drugs in 5, by diet and hypoglycemic drugs in 1, and by insulin with oral hypoglycemic drugs in 2. The remaining 29 pilots did not have history of hyperglycemia.

Of the 43 accidents, health, medical condition(s), and/or use of mediation(s)—authorized or unauthorized—of aviators have been established by the NTSB to be the cause or a factor in 5 accidents.

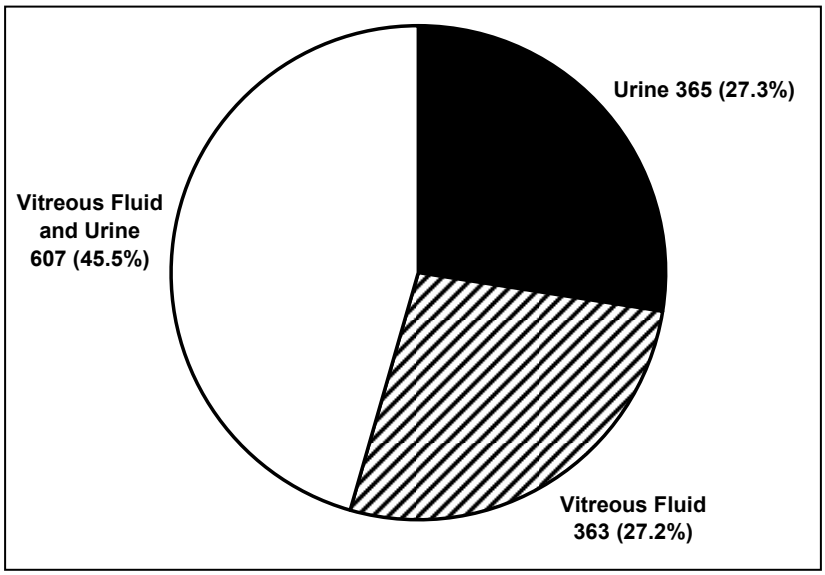


**Figure 1.** Proportion of vitreous fluid, urine, and vitreous fluid and urine samples in the 1,335 cases analyzed for glucose.

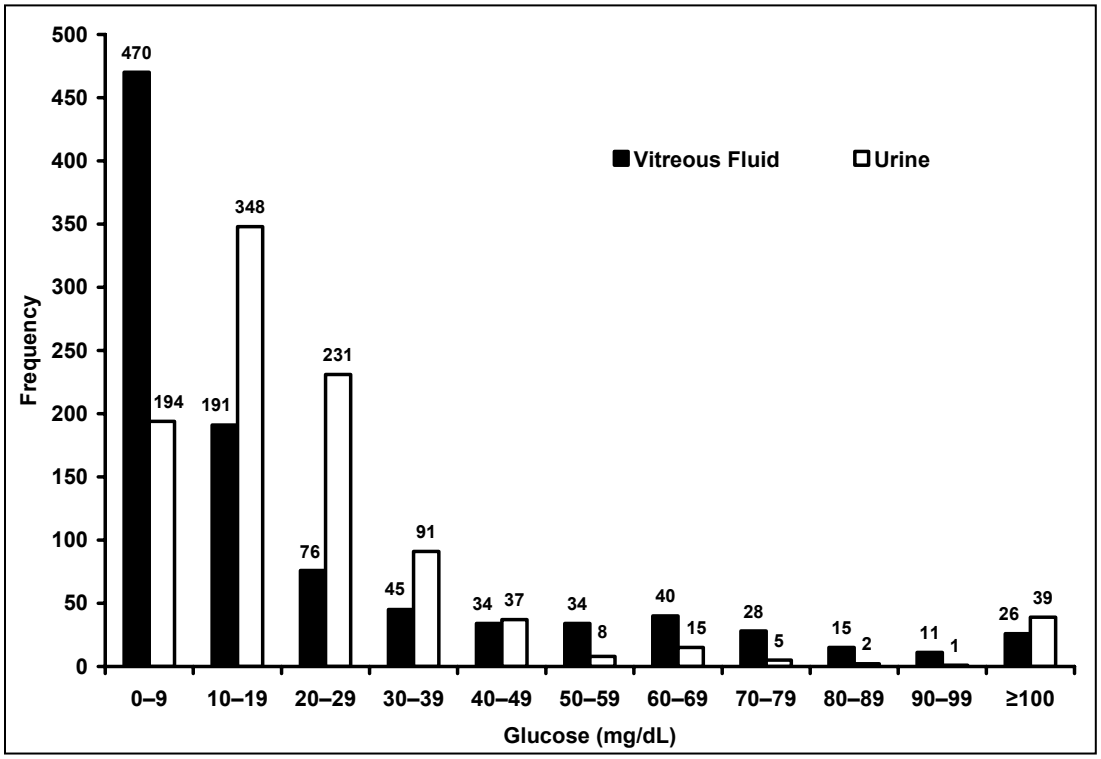


**Figure 2.** Frequency of glucose concentrations in vitreous fluid and urine specimens from the 1,335 pilot fatalities.

**Table I.** Glucose and HbA1c Concentrations and Hyperglycemic Medical History of 43 Fatally Injured Pilots and Their Health and/or Medical Conditions as Cause/Factors in Those Civil Aviation Accidents (1998–2005)

| Pilots | Vitreous Fluid Glucose (mg/dL) | Urinary Glucose (mg/dL) | Blood $HbA_{1c}$ (%)* | Hyperglycemic Medical History | Pilot's Health and/or Medical Conditions as the Cause/Factors in the Accidents as Determined by the NTSB |
|---|---|---|---|---|---|
| | | | *1998* | | |
| 1 | 45 | 189 | –† | Diabetes controlled by hypoglycemic drugs | --- |
| 2 | 12 | 3055 | – | Glycosuria (low renal threshold) | --- |
| 3 | 147 | 65 | – | --- | --- |
| 4 | 256 | 8815 | – | Diabetes controlled by diet | --- |
| 5 | 119 | 760 | – | Diabetes controlled by hypoglycemic drugs | --- |
| | | | *1999* | | |
| 6‡,§ | 194 | – | – | --- | --- |
| 7 | 163 | 156 | – | --- | Factor: Pilot's incapacitation due to illegal substances |
| 8 | 0 | 105 | – | --- | --- |
| | | | *2000* | | |
| 9 | 180 | 7182 | – | Diabetes controlled by hypoglycemic drugs | --- |
| 10 | 42 | 165 | – | --- | --- |
| 11 | – | 1438 | – | Diabetes controlled by diet | --- |
| 12¶ | 47 | 525 | – | --- | Cause: Pilot's impairment due to the use of unapproved medication |
| 13 | 228 | 24 | – | --- | --- |
| 14 | 132 | – | – | --- | --- |
| 15 | 0 | 1175 | – | Diabetes controlled by diet | Factor: Pilot's elevated glucose level |
| 16 | 76 | 265 | – | --- | --- |
| | | | *2001* | | |
| 17 | 43 | 365 | – | --- | --- |
| 18 | 333 | 31 | 4.7 | --- | Cause: Pilot's incapacitation (cardiovascular) |
| | | | *2002* | | |
| 19 | 230 | 1870 | 8.6 | --- | --- |
| 20 | 301 | 6050 | 12.4 | Diabetes controlled by insulin and by oral hypoglycemic drugs | --- |
| 21 | 265 | 4487 | 8.2 | --- | Factor: Hypoxia |
| 22 | 71 | 302 | 5.4 | --- | --- |

**Table I (continued).** Glucose and HbA1c Concentrations and Hyperglycemic Medical History of 43 Fatally Injured Pilots and Their Health and/or Medical Conditions as Cause/Factors in Those Civil Aviation Accidents (1998–2005)

| Pilots | Vitreous Fluid Glucose (mg/dL) | Urinary Glucose (mg/dL) | Blood $HbA_{1c}$ (%)* | Hyperglycemic Medical History | Pilot's Health and/or Medical Conditions as the Cause/Factors in the Accidents as Determined by the NTSB |
|---|---|---|---|---|---|
| 23 | 98 | 4700 | 10.8 | Diabetes controlled by diet and by hypoglycemic drugs | --- |
| 24 | 11 | 162 | 8.3 | --- | --- |
| 25 | – | 1548 | – | Diabetes requiring insulin and oral hypoglycemic mediation | Cause: Pilot's incapacitation<br>Factor: The pilot and medical examiner providing false information on the pilot's medical applications |
| | | | | *2003* | |
| 26 | 97 | 435 | 5.0 | --- | --- |
| 27 | 100 | 139 | 5.2 | --- | --- |
| 28 | 16 | 264 | 5.3 | --- | --- |
| 29 | 122 | 162 | – | --- | --- |
| 30 | – | 369 | 5.8 | Diabetes controlled by hypoglycemic drugs | --- |
| 31 | – | 530 | 5.1 | --- | --- |
| 32‡ | 126 | 4700 | 13.0 | --- | --- |
| | | | | *2004* | |
| 33 | 0 | 1750 | – | Diabetes controlled by diet | --- |
| 34 | – | 5700 | – | --- | --- |
| 35 | 174 | – | 6.2 | --- | --- |
| 36 | – | 5450 | – | --- | --- |
| 37 | 0 | 786 | 6.0 | --- | --- |
| 38 | – | 377 | 5.9 | --- | --- |
| | | | | *2005* | |
| 39 | – | 3350 | 7.1 | Diabetes controlled by diet | --- |
| 40 | – | 2585 | 8.3 | Diabetes controlled by hypoglycemic drugs | --- |
| 41 | – | 120 | 4.4 | --- | --- |
| 42 | – | 630 | – | --- | --- |
| 43 | 101 | 473 | 5.1 | --- | --- |

*$HbA_{1c}$ analysis was implemented in 2001.

†No analysis.

‡Unregistered aircraft.

§Without medical and flying certificates.

¶Without medical certificate.

**Table II.** Aviation Accident Flight Categories With Elevated Glucose and $HbA_{1c}$ Concentrations in Pilot Fatalities (1998–2005)

| Flight Categories | Pilot Fatalities[†] | | |
|---|---|---|---|
| | Vitreous Fluid Glucose (> 125 mg/dL) | Urine Glucose (> 100 mg/dL) | Blood $HbA_{1c}$ (> 6%)[‡] |
| General Aviation (Part 91)[§] | 9 | 33 | 7 |
| Air Taxi and Commuter (Part 135) | 0 | 3 | 0 |
| Ultralight Vehicle (Part 103)[¶] | 2 | 1 | 1 |
| Public Use[**] | 1 | 1 | 1 |

[*]See reference (6).

[†]In 7 fatalities (cases), glucose was elevated in vitreous fluid as well as in urine.

[‡]Blood $HbA_{1c}$ analysis was implemented in 2001.

[§]Five pilots had elevated glucose in both vitreous fluid and urine.

[¶]Pilots flying unregistered aircraft were also included. One pilot had elevated glucose in both specimen types (vitreous fluid and urine).

[**]Used for the federal, state, and local government agencies. One pilot had elevated glucose in both specimen types.

**Table III.** Airman Medical Certificate Categories With Elevated Glucose and $HbA_{1c}$ Levels in Aviation Accident Pilot Fatalities, 1998–2005

| Medical Certificate Categories[*] | Pilot Fatalities[†] | | |
|---|---|---|---|
| | Vitreous Fluid Glucose (> 125 mg/dL) | Urine Glucose (> 100 mg/dL) | Blood $HbA_{1c}$ (> 6%)[‡] |
| First-Class | 0 | 1 | –[§] |
| Second-Class | 8 | 19 | 4 |
| Third-Class | 3 | 16 | 5 |

[*]See reference (7).

[†]Three pilots without medical certificates are not included. There were 7 pilots (6 Second-Class and 1 Third-Class pilots) wherein glucose was elevated in vitreous fluid as well as in urine.

[‡]Blood $HbA_{1c}$ analysis was implemented in 2001.

[§]No analysis.

**Table IV.** Airman Flying Ratings With Elevated Glucose and $HbA_{1c}$ Concentrations in Aviation Accident Pilot Fatalities, 1998–2005

| Airman Flying Ratings[*] | Pilot Fatalities[†] | | |
|---|---|---|---|
| | Vitreous Fluid Glucose (> 125 mg/dL) | Urine Glucose (> 100 mg/dL) | Blood $HbA_{1c}$ (> 6%)[‡] |
| | First-Class Medical Certificate-Holding Pilots | | |
| Airline Transport | --- | 1 | –[§] |
| Commercial | --- | --- | – |
| Private | --- | --- | – |
| | Second-Class Medical Certificate-Holding Pilots | | |
| Airline Transport[¶] | 3 | 4 | 2 |
| Commercial[**] | 5 | 12 | 2 |
| Private | 0 | 3 | 0 |
| | Third-Class Medical Certificate-Holding Pilots | | |
| Airline Transport | --- | 1 | – |
| Commercial | 0 | 2 | 1 |
| Private[††] | 3 | 13 | 4 |

[*]See reference (7).

[†]Two pilots without medical and flying certificates and 1 pilot without medical certificate are not included.

[‡]Blood $HbA_{1C}$ analysis was implemented in 2001.

[§]No analysis.

[¶]Two pilots had elevated glucose in vitreous fluid and in urine.

[**]Four pilots had elevated glucose in vitreous fluid and in urine.

[††]One pilot had elevated glucose in vitreous fluid and in urine.

1. In 1 accident, the elevated glucose level of the pilot was a factor. This pilot had a history of diabetes that should have been controlled by diet. The pilot's urinary glucose concentration was 1,175 mg/dL. No drugs and ethanol were found in this case
2. In 3 accidents, incapacitation of the pilot was the probable cause or a contributing factor.
    a. The pilot of the 1st accident had elevated urine (156 mg/dL) and vitreous (163 mg/dL) glucose levels with no reported history of diabetes. The NTSB determined that a factor in the accident was the pilot's incapacitation due to illegal substances. Toxicological analysis reveled amphetamine and methamphetamine in the pilot's blood, urine, and brain.
    b. The NTSB determined the cause of the 2nd accident to be "Incapacitation of the pilot (cardiovascular) resulting in his inability to fly the airplane." In addition to autopsy findings of "Fresh posteroseptal myocardial infarction; stenotic coronary atheroscleroisis," the toxicological examination revealed that hydrocodone, dihydrocodeine, and hydromorphone were present in the urine. The pilot's glucose levels were 333 mg/dL in the vitreous and 31 mg/dL in the urine with no reported history of diabetes.
    c. The NTSB established the cause of the 3rd accident to be the incapacitation of the pilot with a contributing factor being the pilot and the Aviation Medical Examiner (AME) providing false information on the pilot's medical applications. The NTSB stated that the pilot had multiple serious medical conditions, including congestive heart failure; coronary heart disease, requiring angioplasty and bypass surgery; and diabetes, requiring insulin and oral hypoglycemic medication. However, neither the pilot nor his AME reported his medical conditions to the FAA, which was known to both individuals at the time of application. The pilot's urinary glucose level was 1,548 mg/dL.
3. In the last accident, the NTSB attributed the pilot's impairment to the use of unapproved medication as the cause of the accident. The pilot's glucose levels were 525 mg/dL in the urine and 47 mg/dL in the vitreous. The pilot had no reported history of diabetes. Toxicological analysis revealed the presence of propoxyphene, amitriptyline, and diphenhydramine in the blood.

In 36 accidents, health, medical condition(s), or use of medications by aviators was not determined by the NTSB to be the cause or a factor. Two accidents were not investigated by the NTSB.

## DISCUSSION

Postmortem vitreous fluid and urine can be used for glucose analysis to establish diabetes (2,8). Concentrations of glucose > 125 mg/dL in vitreous fluid and > 100 mg/dL in urine are considered as elevated glucose levels (2,4) and are thus indicative of hyperglycemia. Since initial rapid decrease in vitreous humor glucose levels has been reported after death (8–11), a vitreous glucose concentration of ≤ 125 mg/dL would not necessarily suggest a normal glucose level at the time of death. However, glucose values > 125 mg/dL in vitreous fluid and/or > 100 mg/dL in urine would certainly be indicative of hyperglycemia. In addition to renal glycosuria and diabetes, elevation of glucose could be related to transit hyperglycemia associated with trauma, stress, and/or medical intervention. For diabetics, the elevated glucose does not provide information on how well the disease had been controlled, but long-term diabetic controls can easily be established by measuring $HbA_{1c}$ in postmortem blood samples (4). $HbA_{1c}$ values > 6.0% correlated well with a known history of diabetes and with the elevated vitreous fluid and/or urine levels in pilots (4). Therefore, such elevated $HbA_{1c}$ values would suggest that diabetes was not properly controlled by the patients.

Only 3.2% of the 1,335 pilots found to be hyperglycemic suggested a very small number of associated aviation accidents. The urinary glucose findings in 13 (30%) of the 43 pilots were consistent with their aeromedical history of diabetes—this number did not include the pilot who had renal glycosuria (low renal threshold). Blood $HbA_{1c}$ analyses of 4 of the 13 known diabetic pilots revealed that their disease was not well controlled, as their $HbA_{1c}$ values were > 6.0%. Furthermore, a considerable number of pilots (30 of 43) had elevated vitreous fluid and/or urine glucose concentrations and were not known to be hyperglycemic (or diabetic). Blood $HbA_{1c}$ analysis of 15 of the 30 non-diabetic pilots indicated that diabetes in 5 aviators was not in control, as the $HbA_{1c}$ levels were > 6.0%.

The highest number of pilots with elevated glucose held Second-Class medical certificates, followed by pilots with Third-Class medical certificates. These 2 groups of pilots were correspondingly rated as commercial and private pilots. The observation of the majority (86%) of the 43 glucose-associated accidents found to be of the general aviation category was consistent with the observations reported in previous studies (5, 12–15).

Of the 2 pilots with known diabetic conditions, the pilot's elevated glucose was a factor in 1 accident. The incapacitation of the pilot as the cause of the second accident may not necessarily be attributed to only hyperglycemia.

The incapacitation might have been the resultant of the medical conditions, hyperglycemia, hypertension, and ulcer, as postmortem toxicology also disclosed the presence of metoprolol and ranitidine in the pilot.

Overall, the findings from this study revealed that the disease of the diabetic pilots was not in control at the time of accidents. Additionally, there were a considerable number of pilots with elevated glucose and $HbA_{1c}$ concentrations, suggesting undiagnosed and unreported diabetic conditions. Therefore, greater attention is necessary in controlling diabetes by aviators in coordination with Aviation Medical Examiners.

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