National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

WPR22FA350

MEDICAL

Specialist's Factual Report

August 16, 2024

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A. ACCIDENT

Location: Reno, Nevada
Date: September 18, 2022

B. MEDICAL SPECIALIST

Specialist: Turan Kayagil, MD, FACEP
National Transportation Safety Board
Washington, DC

C. DETAILS OF THE INVESTIGATION

1.0 Purpose

This investigation was performed to evaluate the pilot for potentially impairing substances and potentially impairing medical conditions.

2.0 Methods

The pilot's Federal Aviation Administration (FAA) medical certification file and the final FAA medical case review were reviewed, as were the pilot's autopsy and toxicology reports. Selected investigator reports and relevant regulation and medical literature were also reviewed.

D. FACTUAL INFORMATION

1.0 FAA Medical Certification Records

According to FAA records, the 61-year-old male pilot's last aviation medical examination was June 14, 2022. At that time, he reported 2,431 total civilian flight hours. He was 71 inches tall and weighed 202 pounds. His reported medical history included high blood pressure, which the aviation medical examiner (AME) noted was under good control and met Conditions AMEs Can Issue (CACI) criteria. The pilot's reported medical history also included low testosterone treated with medication, and a previous episode of chest pain in 2016 that led to a diagnosis of non-obstructive coronary artery disease; for these conditions, the pilot had been granted Authorization for Special Issuance of medical certification by the FAA. At his most recent aviation medical examination, the pilot reported using the medications losartan and amlodipine (prescription medications used to treat high blood pressure), testosterone and anastrozole (prescription medications used to treat low testosterone), and valacyclovir (a prescription antiviral medication used as needed to treat cold sores). No significant issues were identified, and the pilot was issued a

second-class medical certificate with the limitation, "Not valid for any class after 06/30/2023."

The pilot's FAA medical certification records documented that he underwent cardiac catheterization for coronary angiography in October 2017, after an abnormal nuclear stress test in 2016 for an episode of atypical chest pain. The 2017 cardiac catheterization demonstrated mild multivessel coronary artery disease (maximum stenosis approximately 25-30%), not requiring intervention, with intact left ventricular function. In November 2018, the pilot completed the process to obtain an Authorization of Special Issuance for third-class medical certification for non-obstructive coronary artery disease, low testosterone, and use of medication. Subsequent Authorizations were issued August 2019 (for third-class medical certification), September 2020 (for second-class medical certification), and July 2021 (for second-class medical certification). Additional cardiac testing documented in FAA files included a May 2019 nuclear stress test, May 2020 echocardiogram, June 2020 and June 2021 exercise stress tests, and (most recently) April 2022 exercise stress echocardiogram. These tests were without diagnostic findings of ischemia. The 2020 echocardiogram showed mild left ventricular hypertrophy with a normal ejection fraction. The April 2022 stress echocardiogram was interpreted by a cardiologist as being normal (including normal left ventricle size and systolic function, without evidence of inducible ischemia) and representative of very good exercise tolerance.

The pilot's two most recent Special Issuance Authorization letters included the warning, "Your heart disease places you at increased risk of in-flight cardiac impairment and sudden incapacitation when performing maneuvers involving increased G-forces. This is in addition to the baseline risk of G-induced loss of consciousness (G-LOC). For further information, please refer to FAA Advisory Circular AC-91-61 which can be downloaded here: [web address provided]."[1]

2.0 Autopsy Report

The Washoe County Regional Medical Examiner's Office performed the pilot's autopsy. According to the pilot's autopsy report, his cause of death was blunt force injuries and his manner of death was accident. The extent of the pilot's injuries prevented structural evaluation of the heart and lungs, and the brain was not available for examination. Within these severe limitations, the autopsy did not identify significant natural disease.

[1] As of November 1, 2018, the FAA began including this warning in the Special Issuance Authorization letters of all pilots with heart disease. This action was taken in response to NTSB Safety Recommendation A-15-11 to the FAA to "Restrict all pilots with medical conditions that could affect their g-tolerance from performing aerobatic maneuvers or air racing at events requiring a certificate of waiver or authorization for an aviation event." Safety Recommendation A-15-11 was classified Closed - Acceptable Alternate Action in December 2019. More information about this recommendation is available from the NTSB website. FAA Advisory Circular AC-91-61, "A Hazard in Aerobatics: Effects of G-Forces on Pilots," is available from the FAA website.

3.0 Toxicology

3.1 NMS Labs Toxicology

At the request of the Medical Examiner's Office, NMS Labs performed postmortem toxicological testing of muscle tissue from the pilot. Caffeine was presumptively detected (detected by an initial screening test without a second test to confirm). No other tested-for substances were detected.[2]

3.2 FAA Toxicology

The FAA Forensic Sciences laboratory also performed toxicological testing of postmortem specimens from the pilot.[3] This testing detected amlodipine in muscle and heart tissue. No blood was available for testing.

3.3 Descriptions of Detected Substances

Caffeine is a central nervous system stimulant that is commonly ingested, including in coffee, tea, soft drinks, and chocolate; it is also an ingredient in certain anti-drowsiness medications and headache medications. Caffeine is not generally considered impairing.

Amlodipine is a prescription long-acting dihydropyridine calcium channel blocker medication that can be used to treat high blood pressure and certain types of coronary artery disease.[4] Amlodipine is not generally considered impairing, and is one of the acceptable medications under the FAA's CACI criteria for hypertension.[5] However, because amlodipine acts by dilating peripheral blood vessels, in theory the

[2] NMS Labs tested muscle tissue according to Test Code 8052TI. A carbon monoxide-iron ration profile was also performed, which involves estimating carboxyhemoglobin (a marker of carbon monoxide exposure) from carbon monoxide and iron measured in a tissue specimen; no carbon monoxide was detected (normal).

[3] The FAA Forensic Sciences laboratory has the capability to test for around a thousand substances including toxins, prescription and over-the-counter medications, and illicit drugs.

[4] National Institutes of Health National Library of Medicine. Norvasc. DailyMed. https://dailymed.nlm.nih.gov/dailymed/drugInfo.cfm?setid=abd6a2ca-40c2-485c-bc53-db1c652505ed. Updated January 15, 2019. Accessed August 16, 2024.

[5] Federal Aviation Administration. Decision Considerations - Aerospace Medical Dispositions Item 36 Heart – Hypertension. Guide for Aviation Medical Examiners. https://www.faa.gov/ame_guide/app_process/exam_tech/item36/amd/hypertension. Updated March 23, 2023. Accessed August 16, 2024.

drug may adversely affect G tolerance.[6] The US Air Force does not permit amlodipine use by its high-performance aviators.[7]

4.0 Effects of High Positive Vertical G Force on Pilots

To a seated pilot, high positive vertical G force feels like being pushed down into the seat. Such force may be experienced during maneuvers such as high-speed turns or pull-up maneuvers. High positive vertical G force makes it harder for the heart to effectively pump blood to the brain. In some cases, this may result in brain hypoxia and G-induced loss of consciousness (G-LOC). Generally, when blood pressure to the brain drops too low, the body attempts to compensate by reflexively increasing heart rate and the volume of blood pumped with each heartbeat, and by constricting peripheral blood vessels. However, this response typically takes at least 6-9 seconds, and sometimes is not enough to prevent G-LOC. The physiologic reserve of brain function in the absence of blood flow is about 4-6 seconds.[8]

In G-LOC, a pilot loses awareness, muscle control, and consciousness, and is unable to control the airplane. Once the vertical G force is reduced, a pilot who has experienced G-LOC will remain absolutely incapacitated by unconsciousness for a period, and then, upon regaining consciousness, will experience an additional period of relative incapacitation by confusion and disorientation. This results in a period averaging about 20-30 seconds after G force is reduced during which the pilot remains unable to control the airplane. Upon recovery from G-LOC, a pilot may not realize that it has occurred.[8,9]

Vision loss ("tunnel vision," "gray-out," or "blackout") due to diminished retinal blood flow might also occur with exposure to high positive vertical G force. Such vision loss may precede G-LOC, but does not reliably do so, particularly with rapid onset of high positive vertical G force, which can cause G-LOC to develop without warning. It is also possible for pilots to experience "almost loss-of-consciousness" (A-

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[6] North Atlantic Treaty Organization Research and Technology Organization. *Medication for Military Aircrew: Current Use, Issues, and Strategies for Expanded Options*. 2001. RTO-TR-014. https://www.sto.nato.int/publications/STO%20Technical%20Reports/RTO-TR-014/TR-014-$$ALL.pdf. Accessed August 16, 2024.

[7] United States Air Force. *Aerospace Medicine Waiver Guide*. June 21, 2024. https://www.afrl.af.mil/Portals/90/Documents/711/USAFSAM/Air%20Force%20Waiver%20Guide%20Compendium.pdf. Accessed August 16, 2024.

[8] Banks RD, Brinkley JW, Allnutt R, Harding RM. Human response to acceleration. In: Davis JR, Johnson R, Stepanek J, Fogarty JA, eds. *Fundamentals of Aerospace Medicine*. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2008:83-109.

[9] Kirkham WR, Wicks SM, Lowrey DL. *G incapacitation in aerobatic pilots: A flight hazard*. Federal Aviation Administration. DOT/FAA/AM-82/13. October 1982. https://www.faa.gov/sites/faa.gov/files/data_research/research/med_humanfacs/oamtechreports/AM82-13.pdf. Accessed August 16, 2024.

LOC) after short-duration, rapid-onset pulses of positive vertical G force. A-LOC is characterized by cognitive impairment, disorientation, and sensorimotor disturbance of shorter duration than G-LOC.[8]

Up to a point, higher magnitude and more rapid onset of positive vertical G-force may lead more quickly to G-LOC, but at intense enough exposures the G-LOC response becomes essentially independent of further increases in magnitude or onset rate. A 2013 study of 888 centrifuge-induced G-LOC episodes in healthy individuals found the average time to G-LOC (using a rapid onset rate profile) was just over 9 seconds at magnitudes of 7 G and greater or onset rates of 1 G per second and faster. [10] The fastest time to onset of G-LOC of any exposure in the study was 5 seconds. With gradual G-force onset, positive vertical G forces that produced G-LOC ranged from 3.6 G to 11.7 G, with an average of 7.6 G. A 1954 study of 1,000 relaxed subjects not using anti-G suits found that, at a 1-G-per-second onset rate, positive vertical G forces that produced unconsciousness ranged from 3 G to 8.4 G, with an average of 5.4 G.[11] Multiple variables affect an individual's G tolerance at any given time, including heart-to-brain distance, use of anti-G measures (such as an anti-G suit or an anti-G straining maneuver), hydration, nourishment, fatigue, physical conditioning (although aerobic conditioning without resistance training may actually decrease a person's ability to compensate for G force), medical conditions, use of substances, experience and recency of G force exposure, and other factors.[8,9,12 – 16]

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[10] Whinnery T, Forster EM. The +Gz-induced loss of consciousness curve. *Extrem Physiol Med*. 2013;2(1):19. doi:10.1186/2046-7648-2-19.

[11] Cochran LB, Gard PW, Norsworthy ME. *Variations in human G tolerance to positive acceleration*. USN SAM/NASA/NM 001-059.020.10. Pensacola, 1954.

[12] Mohler SR. *G effects on the pilot during aerobatics*. Federal Aviation Administration. DOT/FAA/AM-72/28. July 1972. https://www.faa.gov/sites/faa.gov/files/data_research/research/med_humanfacs/oamtechreports/AM72-28.pdf. Accessed August 16, 2024.

[13] Federal Aviation Administration. *A Hazard in Aerobatics: Effects of G-Forces on Pilots*. Advisory Circular AC-91-61. February 1984. https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC%2091-61.pdf. Accessed August 16, 2024.

[14] Federal Aviation Administration. *Acceleration in Aviation: G-Force*. Aeromedical Safety Brochure OK-21-0375. December 2021. https://www.faa.gov/sites/faa.gov/files/pilots/safety/pilotsafetybrochures/Acceleration.pdf. Accessed August 16, 2024.

[15] Northrup S. Pulling Gs. *FAA Safety Briefing*. May/June 2022: 5. https://www.faa.gov/sites/faa.gov/files/2022-04/MayJun2022.pdf. Accessed August 16, 2024.

[16] Federal Aviation Administration. Fitness for flight. In: *Aeronautical Information Manual (AIM) Basic with Change 1 and 2*. Washington, DC: United States Department of Transportation, Federal Aviation Administration, Mission Support Services, Policy Directorate, AJV−P; 2024. https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap8_section_1.html. Accessed August 16, 2024.

E. SUMMARY OF MEDICAL FACTS

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