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Reporting Incidental Medical Findings in Autopsied U.S. Civilian Pilots Using the AA-IADS System

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16. Abstract

INTRODUCTION: This study examined incidental medical findings (IMFs) reported in the autopsies of pilots who died in U.S. aircraft accidents from April 2013 through March 2016, using the FAA CAMI Aerospace Accident Injury Analysis Data System (AA-IADS). Incidental medical findings are previously undiagnosed medical conditions that were incidentally discovered during the autopsy, which may or may not have been related to the cause of death or of the accident. Created in 2013, the AA-IADS database collects pilots' IMFs. By analyzing this data, it is possible to evaluate the prevalence and evolution of certain chronic medical conditions that may have an impact on aviation safety. **METHODS:** Data was extracted from the AA-IADS for all records available in the system where a pilot was involved in a fatal accident from April 2013 through March 2016, including all types of civilian operations. Records of pilots with the International Classification of Diseases, Version 10 (ICD-10) codes describing incidental medical findings, as well as medical conditions extracted from the CAMI Aerospace Medical Certification Division (AMCD) Document Imaging and Workflow System (DIWS), and toxicological information from the CAMI Forensic Toxicology database were collected in a dataset and prepared for statistical analysis. Finally, the NTSB database was searched to identify fatal accidents in which either a medical cause or a drug was cited as a probable cause or a contributory factor in the accident to determine if those pilots had any IMF reported in the autopsy. **RESULTS:** Out of the 601 selected pilots, 42% were found with IMFs reported in the autopsy. Incidental cardiac findings were reported in 84.5%. Cardiovascular abnormalities were the most common incidental finding in the autopsies (85%), followed by Gastrointestinal (11%), Fatty Liver (8%) and Benign Enlarged Prostate (6%). The NTSB determined that a medical issue was either the probable cause (PC) or a contributory factor (CF) in the IMFs of 31 pilots (12.2%). **CONCLUSIONS:** This study suggests that autopsy findings can support data-driven decision making in the aeromedical evaluation of medical conditions.

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“Autopsies give us the facts but not the truth.”

- **Richard Selzer**

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INCIDENTAL MEDICAL FINDINGS IN AUTOPSIED U.S. CIVIL AVIATION PILOTS INVOLVED IN FATAL ACCIDENTS

INTRODUCTION

Available scientific literature demonstrates that autopsies remain important procedures with great potential not only to advance medical knowledge and improve clinical practice, but also to demonstrate important unsuspected clinical diagnoses that may have negatively affected patient outcome (5, 28). When compared to clinical diagnoses obtained from either hospital discharge data or death certificates, autopsy diagnoses are more accurate, depending upon the condition of the remains (28). Also, it has been shown that autopsy information combined with medical records is the only reliable means for establishing cause of death from cardiovascular disease (29). Furthermore, incidental medical or pathological findings (IMFs) reported in autopsies have been used in epidemiologic studies to determine the prevalence of important chronic conditions such as biliary tract and abdominal aortic diseases, as well as a variety of common forms of cancer (31). In general, autopsy data analysis provides a significant benefit to the health care system by significantly improving vital statistics and other epidemiological data, as well as improving inaccuracies in clinical diagnoses, obtained from death certificates or hospital discharge reports (28).

To ensure rigorous accident investigations, U.S. legislation requires autopsy performance of all fatalities involved in civil aircraft accidents. As a result, the National Transportation Safety Board (NTSB) has the federal authority to conduct autopsies on any aircraft occupant who has been fatally injured in an aircraft accident (31). By reviewing medical records, toxicological testing results, and autopsy reports of fatally injured pilots, the NTSB's medical officers, in conjunction with accident investigators, help to determine if an airman's medical impairment or incapacitation contributed to the cause of the accident. The NTSB determination of medical issues related to the probable cause of the accident is a meticulous scientific process involving multidisciplinary analysis of the factual information available concerning the human, the machine, and the environment (33).

Aviation pathology has been defined as "the discipline in which the findings from aviation-related autopsies are correlated with other aspects of the investigation, including the history and circumstances of the flight, the medical history of the pilot, the wreckage of the aircraft and the examination of any safety equipment which may have been used, in order to provide the accident investigators with as much information as possible to aid them in the determination of the probable cause of the accident (19)."

From an aviation safety perspective, a detailed and complete autopsy report is important for the following reasons: 1) *for the purpose of helping to determine the probable cause of the accident*, an autopsy usually reveals a pilot's pre-existing medical condition that may have either been directly related to the cause of the accident or a contributory factor to the accident by causing a "pilot error" or a fatal distraction; 2) *for accident reconstruction purposes*, in which any finding may help the investigator to determine the

cause and sequence of events of the accident, including any criminal event, with the hope of being able to prevent a similar accident from occurring in the future; and 3) *for injury analysis purposes*, which may lead to data-driven occupant protection recommendations with regard to improving survivability, so the likelihood of serious injuries or death is reduced (8, 19, 31).

The Federal Aviation Administration (FAA) Civil Aerospace Medical Institute (CAMI) established an Autopsy/Injury Database in 1997 with the purpose of developing "a system of collecting and organizing information regarding injuries and the causes of death in aviation accidents, so that this information could be applied to operational recommendations and research tasks (34)." In 2008, the FAA's Autopsy Program was centralized to CAMI with the purpose of supporting the FAA's Office of Accident Investigation and Office of Aerospace Medicine and the National Transportation Safety Board by coordinating, collecting, and storing autopsy information. Currently, one of the FAA registry systems is used by the Medical Case Review (MCR) and Autopsy Programs to store medical hazards identified in medical records, autopsies, and toxicological reports of all U.S. fatal accidents and to provide a report to the FAA investigator in charge (IIC), the Federal Air Surgeon, the Regional Flight Surgeon (RFS), and the NTSB IIC. A hazard, as defined in a MCR, is "any medical condition, medication, illicit drug, or toxin that could degrade a pilot's performance and result in sudden incapacitation or impairment of the pilot's ability to safely operate the aircraft (32)."

Little aeromedical research and few epidemiologic investigations have been devoted to describe postmortem pathological findings of pilots in the context of the airman's aeromedical certification process, particularly, the potential role of significant chronic medical conditions in accident causation.

About a dozen peer-reviewed articles on the topic of post-mortem examination of pilots involved in fatal accidents in the last six and a half decades were identified. Not surprisingly, most of these publications were focused on cardiovascular abnormalities reported in the autopsy. In aviation safety, cardiovascular disease (CVD) is important because of its potential to cause a pilot's in-flight sudden incapacitation or impairment. Cardiovascular disease is a group of diseases that affect both the heart and blood vessels, including coronary heart disease (CHD), coronary artery disease (CAD), and acute coronary syndrome (ACS) among several other conditions. Acute coronary syndrome is defined as atherosclerosis in coronary arteries and can be asymptomatic. Since CHD mortality is the outcome of CAD, some authors refer to CAD as CHD.

Epidemiological studies conducted in the U.S. general population of CVD prevalence in both men and women from 2007 to 2010 showed that age and CVD prevalence are correlated. As shown in Figure 1, an increase in age is directly related to an increase in CVD including CHD, hypertension, stroke, and heart failure (21).

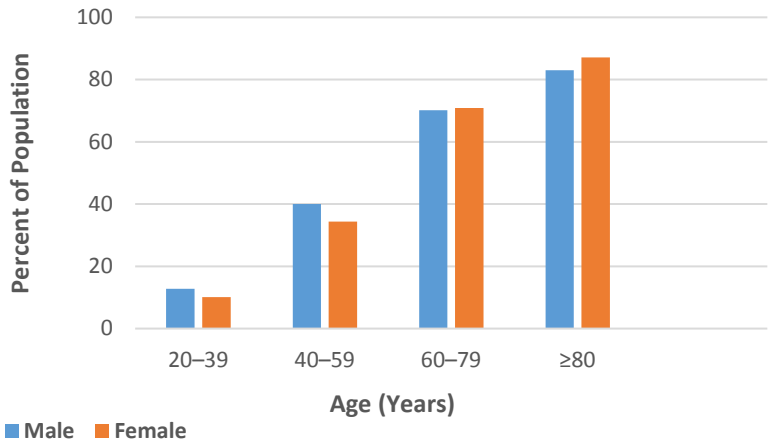

Figure 1. Prevalence of Cardiovascular Diseases in Adults by Age and Gender, U.S., 2007-2010 (21). Source: NHANES, 20078-2010, NCHS https://www.cdc.gov/nchs/nhanes/index.htm

According to the CDC's National Vital Statistic Report, CVD is the leading cause of death in adults in the US (6), and the 2016 Heart Disease and Stroke Statistics update of the American Heart Association (AHA) estimated that approximately every 42 seconds, an American will be affected by a myocardial infarction. However, from 2003 to 2013, the annual death rate attributable to CHD declined 38.0% and the actual number of deaths declined 22.9% (20). About one-half of the reduced CHD mortality has been attributed to factors such as better treatment options, including secondary preventive measures after MI or revascularization, initial treatments for ACS, therapy for heart failure, and revascularization for chronic angina. The other half of this reduction is explained by changes in risk factors, including reductions in total cholesterol (24%), systolic blood pressure (20%), smoking (12%), and physical inactivity (5%; (14). Unfortunately, the improvements listed have been partly counterbalanced by increases in both body mass index (BMI) and the prevalence of diabetes in the U.S. population (15).

Although previous autopsy-based studies have reported a reduced prevalence of CHD over time in both the general population and military personnel, this condition still remains responsible for approximately one-third of all deaths in individuals over age 35 (27).

As shown in Table 1, the first known study evaluating postmortem pathological findings in crewmembers was published in 1959 by Glantz et al. After analyzing the autopsies of 222 military pilots received at the Armed Forces Institute of Pathology, they reported an incidence of "moderate and advanced" coronary artery disease (CAD) in 21% of cases (16).

Over the last three and a half decades, only four studies have been published on the topic of post-mortem findings of cardiovascular abnormalities in U.S. civilian pilots involved in fatal accidents using autopsy data from the Civil Aerospace Medical Institute (CAMI). These included Booze et al. in 1981 and 1987 (3, 4), Taneja and Wiegmann in 2002 (30), and Ricaurte and DeJohn in 2007 (23).

The present study examined incidental medical findings (IMFs) reported in the autopsies of pilots who died in aircraft accidents from April 2013 through March 2016, using the Aerospace Accident Injury Analysis Data System (AA-IADS). Incidental medical findings are defined as previously undiagnosed medical conditions that were incidentally discovered during the autopsy. Although IMFs may or may not have been related to the cause of death or of the accident, they are reported in the autopsy by the medical examiner (ME), coroner, or pathologist, provided that the body was not severely fragmented. Incidental findings have proven to be valuable for providing a better understanding of the natural evolution of untreated diseases and the real prevalence of medical conditions or lesions in the general population, including pilots (22).

METHODS

Subjects

Pilots and licensed passengers who died on board an airplane during an aircraft accident were included in the study, provided that an adequately performed autopsy report was collected by the FAA CAMI Autopsy Program Team.

Material

The AA-IADS database is an FAA CAMI system created in 2013 with the main purpose of conducting systematic and continuous monitoring of aircraft accident injury data and pilots' incidental medical findings to identify and code injuries, determine injury patterns, and ultimately formulate recommendations to mitigate those injuries in the future. By analyzing pilots' incidental medical findings as reported either in autopsy reports or hospital medical records and entered into AA-IADS, it is possible to evaluate the prevalence and evolution of certain chronic medical conditions that may have an impact on aviation safety. Data was manually extracted from the AA-IADS for all records available in the system where a pilot was involved in a fatal accident in the U.S. from April 2013 through March 2016, including all types of civilian operations. Passengers holding a valid pilot certificate were also included. Records of pilots with the International Classification of Diseases, Version 10 (ICD-10) codes describing incidental medical findings, as well as medical conditions extracted from the CAMI Aerospace Medical Certification Division (AMCD) Document Imaging and Workflow System (DIWS), and toxicological information from the CAMI Forensic Toxicology database were collected in a dataset and prepared for statistical analysis. Finally, the NTSB database was searched to identify fatal accidents in which either a medical cause or a drug was cited as a probable cause or a contributory factor in the accident to determine if those pilots had any IMF reported in the autopsy.

Procedure

Pre-existing pathology codes, as available from the DIWS records, were compared to autopsy findings. Cases were divided into two groups based upon whether or not incidental medical findings were present in their records: IMF Pilots and Non-IMF Pilots.

Cases excluded from the analysis included: 1) Passengers, 2) Cases with missing or insufficient information, 3) Inadequate or incomplete autopsies, and 4) Non-U.S. accidents.

Statistical analyses

Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 24.0 (1).

RESULTS

A total of 702 fatal accidents or events were extracted from the AA-IADS. From those events, 887 occupants were identified. After applying the exclusion criteria, 601 unique pilots and passengers holding a pilot certificate were selected and reviewed on case-by-case basis. Out of these 601 subjects, 253 (42%) were found with IMFs reported in the autopsy (see Fig. 2). Out of the 253 pilots, 249 were males (98%) and 4 were females (1.5%). Incidental cardiac findings were reported in 214 out of 253 cases (84.5%). In more than half of all cases (58%) no IMF was reported.

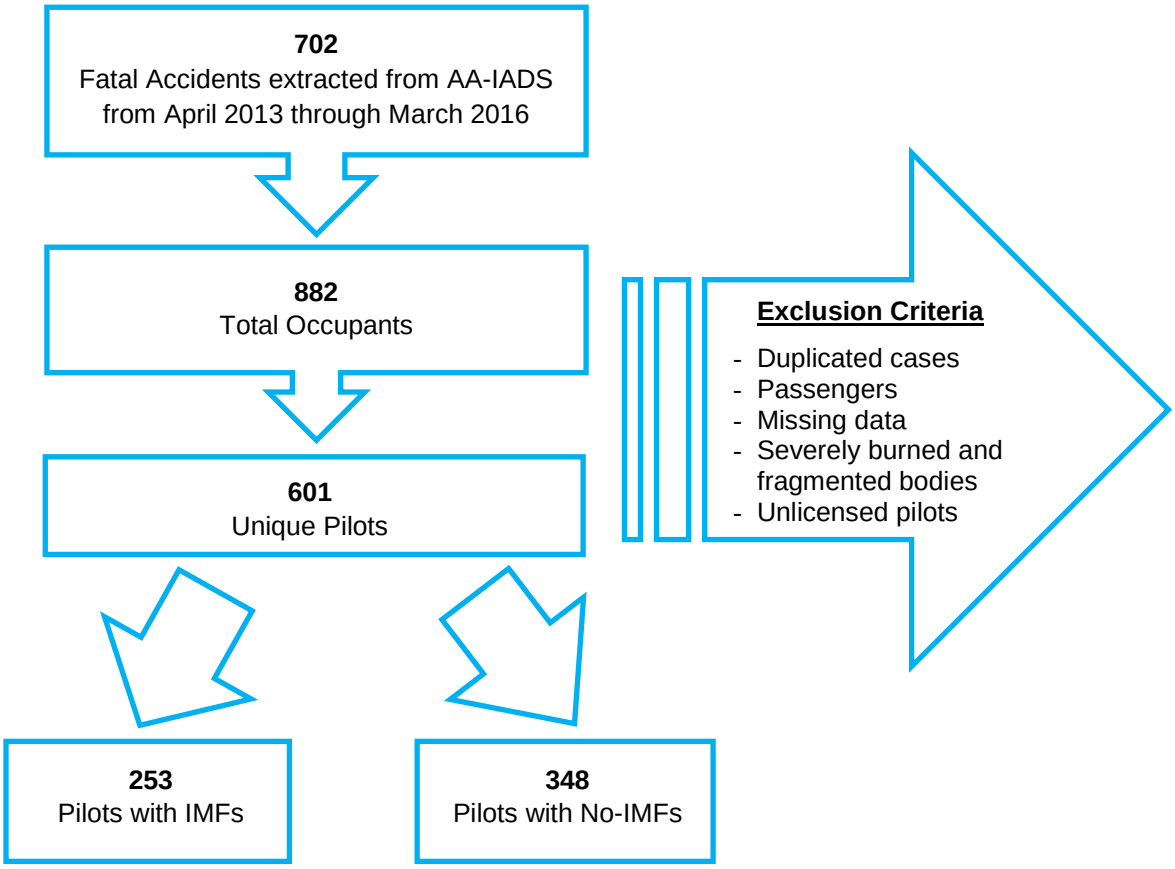

Figure 2. Study Overview. IMF: Incidental Medical Finding

Demographics

The average age of Non-IMFs pilots (n= 348) was 51.6 years old (SD = 15.4) with a minimum age of 16 and a maximum of 88. In contrast, pilots with IMFs (n = 253), had an average age of 58 years old (SD = 13.4). The mean age in incidental cardiovascular findings (ICFs) pilots was 60 years old (SD = 12.9), compared to 51 years old in Non-ICFs pilots (SD = 14.1).

More than half of pilots with ICFs held a third-class medical certificate (58%), followed by second-class (23%) and first-class (11%).

As shown in table 1, the majority of pilots with IMFs (89%) were older than 40 years, with more than half (51. 9%) of the cases between 60-79 years.

Table 1. Distribution of IMFs cases by Age Groups

Age Group	No. of Cases
<20	2 (0.9%)
20-39	21 (6.1%)
40-59	98 (36.9%)
60-79	122 (51.9%)
>80	9 (3.7%)
Missing data	1 (0.5%)
Total	253 (100%)

The average BMI in Non-IMFs pilots (n = 325) in this study was 27.4 (SD = 4.06) compared to 28.7 (SD = 4.37) in IMFs pilots.

Cardiovascular Abnormalities.

As shown in table 2, cardiovascular abnormalities were the most common incidental finding in the autopsies (85%) followed by Gastrointestinal (11%), Fatty Liver (8%) and Benign Enlarged Prostate (6%). Preexisting myocardial infarctions were found in 14 cases (6%), substances of abuse and alcohol were found in 4% and cancer in 3% of the cases.

Table 2. IMFs Reported in the 253 Autopsies.

Condition	Frequency (%)
ICF	214 (84.6%)
Gastro Intestinal	27 (10.7%)
Fatty Liver	20 (7.9%)
Enlarged Prostate	15 (5.9%)
Preexisting Myocardial Infarction (MI)	14 (5.5%)
Kidney	14 (5.5%)
Renal Sclerosis	12 (4.7%)
Substances/Drugs/Alcohol	11 (4.3%)
Emphysema	8 (3.1%)
Neoplasia	7 (2.7%)
Pulmonary Edema	4 (1.5%)
Presence of Prostheses (pacemaker, prosthetic knee, or unspecified)	3 (1.1%)
Diabetes	2 (0.7%)
Neuro-Psychiatry	2 (0.7%)
Other	14 (5.5%)

Within the cases reported with ICFs, coronary artery disease was the most common finding (76%), followed by cardiomegaly (37%), aortic atherosclerosis (13%), and hypertension (10%) (see table 3).

Table 3. Frequency of Medical Conditions in the 214 pilots with ICFs.

ICF Findings	Frequency (%)
CAD	162 (75.7%)
Cardiomegaly	79 (36.9%)
Aortic Atherosclerosis	28 (13%)
Hypertension (HTN)	21 (9.8%)
Preexisting Myocardial Infarction	14 (6.5%)
Coronary Angioplasty Implant/Graft	10 (4.6%)
Myocarditis	10 (4.6%)
Non-rheumatic aortic valve disorder	5 (2.3%)
Cardiomyopathy	4 (1.8%)
Cerebral Atherosclerosis	3 (1.4%)
Heart Failure	1 (0.5%

Medical Issue as a Probable Cause or Contributory Factor of IMFs in Pilots Involved in Fatal Accidents

As shown in Table 4, the NTSB determined that a medical issue was either the probable cause (PC) or a contributory factor (CF) in the IMFs of 31 pilots (12.2%). In addition, medical issues were mentioned in 2 cases (both were diagnosed with cardiac disease and one also had depression), but no final determination was made as to whether the accident was caused by a medical incapacitation related to those conditions or another non-medical cause. Sedating medication was the most common medical issue reported by the NTSB either as PC or a CF in 42% of the IMF pilots (13/31), followed by the use of alcohol, illicit drugs, marijuana, and cocaine (29%), cardiac disease (19%), and neuropsychiatric conditions and stroke (16%). Cardiovascular disease was the most common medically related PC of fatal accidents, followed by the use of alcohol or illicit drugs, including marijuana and cocaine. Suicide and neuropsychiatric conditions, were reported as the PC of the accident in 10% (3/31) of the pilot's IMFs.

After matching the airman aeromedical records from DIWS to the NTSB medical cause of the accident, it was found that 16% of the IMF Pilots (5/31) had a medical issue known by the AMCD that was related to the accident either as a cause or a contributing factor. These five NTSB fatal events were: ERA13LA281; CEN13LA377; WPR14FA124; CEN14FA163; and CEN16FA054. In two out of four pilots with a preexisting myocardial infarction (MI), a cardiac event was related to the cause of the accident. One out of these four pilots had an aeromedical history of preexisting MI and coronary angioplasty implant and graft in DIWS; however, the NTSB mentioned sedating antihistamine and pilot's fatigue as the cause of the accident. Matching the NTSB medical cause of the accident to DIWS data and toxicological findings showed 11 pilots (35%) had a positive toxicological

report for at least one monitored substance (7). One case of alcohol consumption had toxicological findings consistent with his aeromedical history and the NTSB cause of the accident.

Table 4. Medical Issues as a Probable Cause or Contributory Factor in 31 IMFs Pilots Involved in Fatal Accidents.

NTSB Probable Cause (PC)	**No. of Conditions**
Cardiac Disease	6
Alcohol, Illicit Drugs, Marijuana, Cocaine	3
Sedating Medication	3
Suicide	2
Neurological, Stroke, Psychiatric Disease	1
NTSB Contributory Factor (CF)	
Sedating Medication	10
Alcohol, Illicit Drugs, Marijuana, Cocaine	6
Neurological, Stroke, Psychiatric Disease	4
Fatigue	3
Hearing Aid	1
Total Medical Issues	39

DISCUSSION

Our results confirmed previous findings showing that coronary artery disease is the most common incidental medical finding reported in the autopsies of airmen who died in aviation accidents. The second most common pathological finding was gastrointestinal abnormalities (11%), followed by fatty liver (8%). Neoplastic lesions accounted for 3% of cases. A recent study of medico-legal histopathological examinations conducted at a tertiary hospital revealed that atherosclerosis was the most common incidental pathological finding reported in autopsies (27.2%), followed by fatty liver (19.8%), while neoplasia findings accounted for 2.47% (22).

Coronary Heart Disease and Aviation Safety

In-flight medical incapacitations caused by acute coronary events in commercial operations are rare, however, when it does happen, since the FAA requires two pilots onboard for commercial operations, the other pilot who is part of the operating crew is expected to carry out the flight duties and land the airplane if needed. Unfortunately, in single pilot general aviation operations, the outcome of this type of event is usually catastrophic. Coronary artery disease continues to be critical in aviation safety because of its potential to be asymptomatic with no previous manifestations before the catastrophic event occurs. Recent epidemiological studies showed that in 15% of patients with CHD, sudden cardiac death (SCD) is the initial coronary event (17, 27). Sudden cardiac death (SCD) is defined as death due to cardiac causes occurring within 1 hour of the symptoms (18). As a whole, CAD is the most common underlying cause of SCD in the western world, being responsible for 75–80 % of cases (11, 24). European statistics on official death causes revealed that in Germany alone, 44.2% of deaths were attributable to CVD (12).

Other European studies showed that in those affected with CAD, an acute MI or sudden cardiac death occur as their first-time clinical manifestation in 40–60% of the cases (13, 25, 35).

Furthermore, a comprehensive review of relevant scientific literature on the in-flight medical incapacitation and impairment of airline pilots revealed that myocardial infarctions, cardiac arrhythmias, and epileptic seizures constitute the leading causes of in-flight medical events (9). The same authors studying in-flight medical incapacitations and impairments in U.S. airline pilots from 1993 through 1998 found that cardiac events were the second most frequent category of incapacitations after loss of consciousness (10).

The first case of a deadly in-flight heart attack in a thirty-five year old military pilot was reported in 1937 (2). However, only eight peer-reviewed studies on autopsy findings of cardiovascular abnormalities in both military and civilian pilots have been found to be published since 1959. Over the last three and half decades, only four studies of U.S. civilian pilots involved in fatal accidents have been conducted using data from the Civil Aerospace Medical Institute (CAMI) to investigate cardiovascular abnormalities (3, 4, 30). (See Table 5).

The results of this study, and previous studies of autopsied pilots, appear to imply that CAD prevalence and severity has increased over the years. However, valid comparisons of CAD severity across studies has been difficult due to differences in methodologies, especially a standardized classification by MEs, coroners, and pathologists. Therefore, it has not been possible to reliably determine trends in CAD prevalence and severity over time.

For example, as shown in Table 5, CAD prevalence reported in a 2013 study by Dumser et al. on 21 autopsies of military crewmembers was 66% (11). These results were similar to the 1987 CAMI study by Booze, which reported a prevalence of 69% (2). However, as previously mentioned, an effective comparison of CAD prevalence and severity across these two studies is difficult because the methods used to assess luminal narrowing across studies, as well as the classification system applied were different. Also, Dumser's study included a detailed morphometric evaluation (microscopic) of coronary cross-sections in addition to a macroscopic evaluation, which was lacking in previous studies. In the future, post-mortem microscopic examination of coronary atherosclerosis may result in more accurate estimation of severity (11).

Finally, a 2007 review of 871 autopsy reports from the CAMI Autopsy database, reported that ICFs were found in 43% of pilots (375/871). From a total number of 503 cardiovascular pathological conditions found in these pilots, coronary artery disease was the most common (61% or 308/503), followed by aortic atherosclerosis (21% or 104/503), ventricular hypertrophy (6% or 28/503), MI (3% or 15/503), myocardial fibrosis (3% or 15/503), and cardiomegaly (3% or 13/503; (23, 31). In the present study, cardiovascular pathologies were the most common incidental finding in the autopsies with a prevalence of 85%, and CAD and MI prevalence of 76% and 7% respectively.

Table 5. List of peer-reviewed post-mortem analysis articles published on the topic of IMFs, ICFs, and CAD prevalence since 1959.

Author(s) and Year of Publication	Length of Study (years)	Type of Operation	Data Source	No. of Autopsies	Autopsies Rate %	CAD Prevalence %	Grading Levels	Severe CAD %
Dumser T, Borsch M, Wonhas C. (2013)	1997-2007	Military Aircrew Members	German AF Inst. of Av Med's Forensic Med.	21	100	66%	Booze et al., AFIP, Slauson et al., Kryer & Pickard JAR- FCL 3	Up to 48%
Madan, Subramanya, and Jalpota (2006)	1975-2004	Military and Civilian pilots, other crew/passengers	Institute of Aerosp. Med., India	1956	90	49%	Grade 0: normal coronaries Grade I: 50% or less narrowing Grade II: severe lumen reduction Grade III: calcification and or complete occlusion	22%
Taneja N. and Wiegmann, D.A. (2002)	1996-1999	Part 91	CAMI	534	44	38%	Grade I: <33% occlusion Grade II: 33-66% occlusion Grade III: >66% occlusion	36%
Shkrum, M.J., Hurlbut, D.J., Young, J.G. (1996)	1985-1989	GA, gyroplane, ultralight and glider	Files of the Chief Coroner for Ontario and reports of the Transportation Board of Canada	60	1	51%	Minimal Moderate Severe	11%
Booze, C.F. and Staggs C.M. (1987)	1980-1982	Part 91	CAMI	710	34	69%	Grade I: <33% occlusion Grade II: 33-66% occlusion Grade III: >66% occlusion	2.50%
Booze, C.F., Pidkowics, A.W., Davis A.W., and Bolding , F.A. (1981)	1975-1977	Part 91	CAMI	764	*	51%	Grade I: <33% occlusion Grade II: 33-66% occlusion Grade III: >66% occlusion	5%
Underwood Ground (1981)	1968-1979	Military aicrew, commercial and private pilots, controls	RAF	288	*	*	Grade 0: normal artery; Grade 0 + - Grade 1: <50% occlusion Grade 2: >50% occlusion Grade 3: necrosis, liquefaction, recanalization, or calcification.	17% military, 25% commercial, 22% private
Pettyjohn and McMeeking (1975)	1960-1974	Military and civilian pilots	AFIP	6500	*	89%	Descriptive Minimal CAD Moderate CAD Severe CAD	5%
Mason (1963)	Case Review	Military Aircrew, professional, and private pilots	RAF	275	*	25%	Grade 0: Normal Grade 1: < 50% occlusion Grade 2: > 50% occlusion Grade 3: atheroma with degenerative changes	22%
Stevens (1963)	1956-1963	Military, civilian pilots and other aircrew	RAF	140	*	66%	Minimal Moderate Severe	21%

Author(s) and Year of Publication	Length of Study (years)	Type of Operation	Data Source	No. of Autopsies	Autopsies Rate %	CAD Prevalence %	Grading Levels	Severe CAD %
Glantz & Stembridge (1959)	1	Military	AFIP	222	*	70%	None: No occlusion Minimal: increase in the thickness of the intima Moderate: incipient narrowing of the lumen Moderately advanced: marked luminal narrowing Advanced: complete occlusion	21%

CONCLUSIONS

Epidemiological reports have shown that death rates attributable to CHD have declined in the U.S. over the last decades, but the burden remains high because it accounted for about one-third of all deaths in people older than 35 years (20, 26). Based on 2013 data, CHD alone was responsible for about 1 of every 7 deaths and it has been estimated that approximately every 34 seconds one American has a coronary event, resulting in one death every one minute 24 seconds (20).

Because of the difficulties in comparing post-mortem CAD trends in pilots over the years, the results of the present study could not reliably determine if the prevalence or severity of CAD decreased. Nevertheless, early CAD detection is important in aviation safety because of the potential risk of an in-flight sudden incapacitation. The results of the present study support the recommendations of previous studies that cardiac risk detection programs should be prioritized, particularly in general aviation pilots over 50 years old (31). Applicants with a medical history of severe cardiovascular conditions and a previous MI need further evaluation to assess the risk of a sudden medical incapacitation.

Implementation of a standard post-mortem CAD severity classification system, which addresses morphologic changes and composition of plaque, is recommended to be able to track trends in CAD prevalence in civilian pilots. In addition, although pilots with a combined history of diabetes, hypertension, hyperlipidemia, heart failure, and angina are classified as at "higher risk" of developing an in-flight acute coronary event by the FAA CAMI's Aerospace Medical Certification Division (AMCD), further research in the post-mortem findings of pilots with the presence of combined chronic conditions is recommended.

This study suggests that autopsy findings can support data-driven decision making in the aeromedical evaluation of medical conditions. This includes the comparison of clinically diagnosed and treated conditions to actual pathological findings and the determination of the prevalence of untreated conditions that may pose a serious threat to aviation safety.

Finally, this study confirms the need for the FAA to continue supporting and maintaining a system to collect and analyze pilot IMF information to determine the risk posed by the presence of chronic pathological conditions to flight safety. Development and use of a standardized grading system to evaluate luminal narrowing of coronary cross-sections, including both macroscopic and microscopic pathological evaluations, is highly recommended.

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