2019
06

Death in the line of duty...

National Institute for Occupational Safety and Health NIOSH

A report from the NIOSH Fire Fighter Fatality Investigation and Prevention Program July 1, 2019

29-Year-Old Firefighter Suffers Cardiac Arrest After Two 24-hour Shifts—Wisconsin

Executive Summary

On April 1, 2018, a 29-year-old male career firefighter (FF) suffered a sudden cardiac arrest after having brunch with family members following a 48-hour shift. Friends called 911 and initiated cardiopulmonary resuscitation (CPR). An ambulance was dispatched at 1504 hours and arrived on scene at 1508 hours and initiated advanced cardiac life support, which was continued en route to the hospital emergency department (ED). The ambulance arrived at the hospital ED at 1543. Personnel continued resuscitation efforts unsuccessfully for approximately 25 minutes. The FF was pronounced dead at 1609 hours.

The Medical Examiner's report listed the cause of death as acute cardiac arrest with hypertensive heart disease as the underlying cause of death and obesity as a contributing factor. The autopsy report noted an enlarged heart (weight of 550 grams). National Institute for Occupational Safety and Health (NIOSH) investigators concluded that the FF suffered a sudden cardiac arrest from an unknown cause. The FF had an enlarged heart which may have made him more susceptible to an arrythmia. The FF was a 29 year old male, a non-smoker, and was very physically fit. The FF had a medical evaluation when he joined the fire department (FD) in 2012, and had an optional medical evaluation in 2013 and he received respiratory clearance every year. None of the available records indicate that the FF had elevated blood pressure or a diagnosis of hypertension. The FF was diagnosed with sleep apnea and used a continuous positive airway pressure (CPAP) machine.

Key Recommendations

NIOSH offers the following recommendations to help reduce the risk of sudden cardiac events among firefighters at this and other fire departments across the country.

- *Ensure that all firefighters receive an annual medical evaluation consistent with National Fire Protection Association (NFPA) 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments.
- *Ensure firefighters are cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by firefighters, and the various components of NFPA 1582.*
- *Phase in a mandatory comprehensive wellness and fitness program for firefighters.*

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For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Introduction

On April 1, 2018, a 29-year-old male career firefighter (FF) suffered sudden cardiac arrest after completing a 48-hour shift. The U.S. Fire Administration notified National Institute for Occupational Safety and Health (NIOSH) of this fatality on April 3, 2018. NIOSH contacted the affected fire department (FD) on July 9, 2018, and again on April 22, 2019, to gather additional information and to initiate the investigation. On May 2, 2019, a contractor for the NIOSH Fire Fighter Fatality Investigation and Prevention Program (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:

- Fire Chief
- Assistant Fire Chief
- Firefighters who worked with the FF
- Union President
- Mother of Firefighter

The NIOSH investigator reviewed the following documents:

- FD incident reports for calls on preceding shift days
- FD medical records
- EMS (ambulance) report
- Hospital emergency department (ED) records
- Death certificate
- Autopsy report

Investigation

On March 30, 2018, at 0700 hours a 29-year-old male career FF began the first of two 24-hour shifts. He was assigned to a two-person medic unit as a paramedic/firefighter of a medic unit. There were 4 other members at the station assigned to an engine. During the first 24-hour shift, the FF responded to 9 calls. The FF responded to 8 medical calls, one of which was a mother who could not be revived. The fire call was for a sparking electrical wire and the medic unit was cleared after 4 minutes (min) on

scene. Of the 9 calls the FF responded to on the first 24-hour shift, 6 of them occurred between 2200–0600 hours. During the second 24-shift the FF responded to 9 medical calls and 1 fire call. The fire call involved investigating a stove-top fire that was extinquished before the firefighters arrived. Significant medical calls included a call for a women in childbirth who had visible signs of crowning and was hypotensive; an extremely combative patient who had to be subdued by the FF and required law enforcement assistance during transport; and a victim who was stabbed during a large street fight involving several people. Of the 10 calls the FF responded to during the second 24-hour shift, 5 of them occurred between 2200–0600 hours.

The FF ended his 48-hour shift (two 24-hour shifts) at 0700 hours on April 1, 2018. Acccording to friends, he then drove approximately 2 hours to attend church with close friends. Following the service he went to brunch with his friends and then returned to their home. Shortly after returning from brunch, the FF went into the bathroom to change his clothes. The family heard a loud noise in the bathroom. When the FF did not respond or open the door, his friends broke down the locked door and found the FF slouched against the wall exhibiting what they described as seizure like activity. The FF's friends called 911. They repositioned the FF so he was lying on the floor and initiated cardiopulmonary resuscitation (CPR).

Emergency medical services (EMS) was dispatched for a male patient having a seizure at 1304 hours and arrived on scene at 1308 hours. Paramedics found the FF on the floor, still partially in the bathroom with CPR in progress. The FF was pulseless and not breathing and was bleeding from the nose. Paramedics slid the FF into the kitchen (approximately 10ft) to permit better evaluation and resuscitation efforts. EMS took over manual CPR. The FF was attached to a cardiac monitor. The initial rhythm was fine ventricular fibrillation (VFIB) and a shock was delivered. Throughout treatment the rhythm changed to asystole. The FF was placed on an automated compression devise (Autopulse). An orophanengeal tube was inserted and the FF was provided with oxygen via bag-valve mask. Suction was used as needed to clear the airway. Intraosseous access was gained at the right tibia and intravenous access was gained at the left antecubital vein. The paremedics (assisted by additional personnel) continued advanced cardiac life support protocols, including CPR (by automated machine), ventilations, shocks (2 at 150 joules, 1 time with dual dequential defibrillation between CPR cycles), and medications. Medications were administered per protocol and included Amiodarone (2 times), Epinephrine (5 times), Narcan (2 times) and sodium bicarbonate. At 1543 hours, the ambulance departed the scene. Advanced cardiac life support (ACLS) protocols were continued en route.

The ambulance arrived at the ED at 1545 hours. A physical exam performed upon arrival found that the FF was unresponsive, with pupils fixed, dilated and nonresponsive. There was no spontaneous cardiac activity or spontaneous respiratory effort. The FF was bleeding from the nose and throat. The FF was placed on a Lucas devise (automated compression) for continued CPR. ED personnel had difficulty obtaining an advanced airway due to fluid and debris in the orophyarynx and nasophyranx. After several attemps and suctioning, a fast track laryngeal mask airway (LMA) was placed for ventilation. The FF's cardiac rhythm was asystole or pulseless electrical activity (PEA) in the ED. A bedside ultrasound revealed no cardiac activity. At 1609 hours, over an hour after his collapse, the FF was pronounced dead.

29-Year-Old Firefighter Suffers Cardiac Arrest After Two 24-Hour Shifts—Wisconsin

Medical Findings

The medical examiner listed acute cardiac arrest as the cause of death on the death certificate with the underlying cause listed as hypertensive cardiovascular disease. The autopsy, performed by a pathologist, reported the cause of death as hypertensive cardiovascular disease with obesity listed as a contributing factor. The autopsy was performed post-tisse donation but did note cardiomegaly with left ventricular hypertrophy. The heart was further examined post tissue donation and a separate cardiac pathology report was obtained. The heart weight was 550 grams (borderline cardiomegaly) with left ventricular hypertrophy (1.5 centimeters [cm]). The myocardium had focal mature fibrosis in the left ventricles. Myocardial bridging was evident in the left anterior descending artery. There was no thrombosis identified and the coronary arteries were free of significant atherosclerosis.

The FF was a Division I college football player and continued to exercise regularly; it is reported he exercised 5–6 times per week emphasizing weight training but also performing aerobic exercise. The FF was not a smoker, and had no known history of cardiovascular disease. Medical records from his pre-employment medical evaluation, performed in August of 2012, included a chest X-ray that was within normal limits and spirometry testing that was normal. The FF performed an exercise stress test on the treadmill using the Bruce protocol. He achieved stage V on the treadmill, exercising for 12:32 min and achieving an estimated 14.4 metabolic equivalents (METs). Exercise was stopped due to achieving predicted HR and the FF had no symptoms, no arrhythmias, no ST changes, and a normal blood pressure response. At his preplacement medical evaluation, the FF had a blood pressure of 126/84 millimeters of mercury (mmHg) (normal is < 120/80, elevated systolic blood pressure/prehypertension is 120–129/< 80, and hypertension is considered ≥ 130 systolic and/or ≥ 80 diastolic) [Whelton et al. 2017]). Blood work indicated the FF had a “borderline high” level of total cholesterol (total cholesterol = 232 milligrams per deciliter [mg/dL]; desirable < 200 mg/dL), a “near or above normal” level of low density lipoprotein (LDL) (LDL = 150; optimal < 100 mg/dL), a high level of triglycerides (TG) (TG = 202 mg/dL (normal < 160 mg/dL), and blood glucose (93 mg/dL) within the normal range (75–115 mg/dL) [Kratz et al. 2004]. At the time of his preplacement medical evaluation, the FF was approximately 76 inches tall and weighed 293 pounds, giving him a body mass index (BMI) of 35.6 kilograms per meter squared (kg/m^2). A BMI over 30 kg/m^2 is considered to be overweight [NHLBI no date-a]; however, it was reported that the FF was very muscular and had a typical physique of a football linebacker.

The most recent medical evaluation that was available to NIOSH was from the FF’s respiratory fit test in October of 2014. At that time the FF had a blood pressure of 118/69 mmHg and was 299 pounds. He reported that he had no cardiovascular/heart problems and no symptoms related to cardiovascular or heart disease. He also indicated that he was not taking any prescription medication. Records indicate that had purchased a continuous positive airway pressure (CPAP) machine for sleep apnea in March of 2018, and his crew reported that he used it at the fire station.

Fire Department

At the time of the NIOSH investigation, the career fire department consisted of 14 fire stations with approximately 386 uniformed personnel. The FD served a population of approximately 270,000 in a

120 square mile area.

Employment and Training

Applicants must be a United States citizen, at least 18 years of age, have a high school diploma or equivalent, and possess a valid state driver's license. Applicants first take a video-based multiple choice exam that includes three components (a mechanical aptitude test, a math test, and a reading ability test). Those who pass the exam and performed well may progress through a series of interviews including a community member board, a department board and the fire chief. Those who successfully progress through these interviews are given a physical ability test (PAT). Those who pass the PAT are given a conditional offer of employment. A background check is performed and candidates must pass a medical evaluation. Successful candiates attend a city training academy that lasts 16–24 weeks. The FF joined the department in 2012.

Preplacement/Periodic/Return to Work Medical Evaluations

The FD requires preplacement medical evaluations for applicants. The evaluations are performed by a clinic that provides the medical evaluations on a contract basis. Components of the medical evaluation include the following:

- Complete medical history
- Physical examination (height, weight, blood pressure, pulse, and respiratory rate)
- Complete blood count
- Urinalysis
- Urine drug screen
- Audiogram
- Vision test
- Respirator use questionnaire
- Spirometry
- Resting electrocardiogram (EKG)
- Exercise stress test
- Chest X-ray.

The FD does not require annual medical evaluations for members, but the FD does offer annual medical evaluations at no cost to the members on a voluntary basis. Members do receive a respiratory fit test through the City Occupational Health clinic. Members are required to provide medical clearance from a personal physician or the City Occupational Health clinic following a serious injury or illness.

Wellness/Fitness Programs

The FD does not offer a comprehensive wellness/fitness program as recommended by the International Association of Fire Fighters//International Association of Fire Chiefs Wellness Fitness Initiative [IAFF and IAFC 2013]. Members do have access to health maintenance programs through the City Employee Assistance Program (EAP). The FD has aerobic and strength training equipment in the fire stations and firefighters are permitted to work out on duty. It is reported that the FF regularly worked out on duty days.

Discussion

Sudden Cardiac Events

Sudden cardiac events are most often caused by myocardial infarction (heart attack) or cardiac arrest (fatal arrhythmias). In the United States, atherosclerotic coronary heart disease (coronary artery disease) is the most common risk factor for cardiac arrest and sudden cardiac death [Myerburg and Castellanos 2008]. Risk for the development of atherosclerosis is grouped into non-modifiable and modifiable risk factors. Non-modifiable risk factors include age older than 45, male sex, and family history of coronary artery disease. Modifiable risk factors include diabetes mellitus, smoking, high blood pressure (hypertension), unhealthy blood cholesterol levels, and obesity/physical inactivity [AHA 2016; NHLBI no date-b]. The FF had one non-modifiable risk factors (male sex) and one known modifiable risk factor (obesity). A structurally enlarged heart (cardiomegaly or left ventricular hypertrophy) is also common among many individuals who die of sudden cardiac events [Tavora et al. 2012]. Among hypertensives, modification/regression is possible with blood pressure control, but may not be the only "driving force" behind these structural changes [Diamond and Phillips 2005].

Hypertensive Heart Disease

Interactions between genetic factors and hemodynamic factors cause hypertensive heart disease in individuals with arterial hypertension [Diamond and Phillips 2005]. Hypertensive heart disease includes anatomical and functional changes to the heart and vessels as a consequence of long-standing hypertension. Left ventricular hypertrophy (LVH), due to myocyte enlargement with or without fibrosis, is a reflection of hypertensive end-organ damage, which can lead to increased ventricular mass, abnormal perfusion, congestive heart failure, and arrhythmias [Prisant 2005]. Increased heart mass predisposes to fatal arrhythmias [Kahan and Bergfeldt 2007; Tavora et al. 2012], which was presumed to be the mechanism for the sudden cardiac arrest experienced by this firefighter. However, records from his medical evaluation in 2012 and 2014 indicate that the FF did not have hypertension at that time.

Left Ventricular Hypertrophy/Cardiomegaly

As discussed above, elevated blood pressure can lead to increased left ventricular mass or left ventricular hypertrophy (LVH). In addition to chronic hypertension, LVH can also be caused by a heart valve problem (the FF had no evidence of this at autopsy), obesity, or cardiac ischemia (reduced blood and oxygen supply to the heart muscle) [Siegel 1997; Tavora et al. 2012]. LVH is also associated with sleep apnea [Smith et al. 2018]. The autopsy reported a heart weight of 550 grams which meets the common clinical definition of cardiomegaly (heart weight greater than 450 grams).

However, heart weight is influenced by body size and the FF was a large man. The expected range of heart weight for a person of his size is 316–551 grams.

Athlete's Heart

Increased ventricular thickness can develop in ultra-endurance athletes [Shave et al. 2017]. This type of hypertrophy, sometimes called "Athlete's Heart", is considered physiologic and not pathologic. It is generally thought to result from increased myocyte mass without an increase in the extracellular space [McDiarmid et al. 2016]. Most research suggests that Athlete's Heart does not involve fibrosis, reduced blood flow, or impaired function, and does not increase the risk of ventricular ectopy/PVCs [Hegde and Solomon 2015]. However, there is some controversy as to where the ventricular remodeling that accompanies Athlete's Heart may be arrhythmogenic [Rowland 2011]. The FF was a Division I college football player and continued to exercise regularly. His exercise programs emphasized strength training.

Sudden Cardiac Death of Unknown Cause

In some cases, the cause of sudden cardiac death is unclear at autopsy. Most victims of sudden cardiac events have previously unknown or unrecognized cardiac abnormalities, with coronary artery disease, hypertrophic cardiomyopathy, ventricular hypertrophy, and valvular stenosis being relatively common findings [Wever and Robles de Medina 2004]. Sudden cardiac death in individuals without coronary artery disease or structural heart disease may be due to electrical conduction problems (such as inherited channelopathies) or coronary artery spasm [Katritsis et al. 2016]. At autopsy it was revealed that the FF had borderline cardiomegaly and "moderately abnormal" LVH (based on echocardiography; Oh et al. 2007). However, his values were not particularly high and do not easily explain his sudden cardiac arrest.

Myocardial Bridging

At autopsy, the FF had evidence of myocardial bridging in the left anterior descending (LAD) coronary artery. Myocardial bridging is a congenital anomaly in which a portion of a coronary artery (usually the LAD) tunnels under the myocardium, creating a "bridge" of heart muscle overlying the coronary artery [Lee and Chen 2015]. Myocardial bridging is relatively common, having been reported in 40% to 80% of autopsy cases [Mohlenkamp et al. 2002]. Compression of the coronary artery due to the muscular band occurs during systole (contraction) and sometime extends into diastole (relaxation). Myocardial bridging has been associated with sudden cardiac death [Cutler and Wallace 1997; Morales et al. 1980], ischemia [Ge et al. 1994; Schwarz et al. 1996], myocardial infarction [Bestetti et al. 1987; Feldman and Baughman 1986; Vasan et al. 1989], arrhythmia [Kracoff et al. 1987; Feld et al. 1991], and coronary artery spasm [Teragawa et al. 2003]. Autopsy and intravascular ultrasound studies have shown that the proximal segment of the "tunneled" coronary artery is prone to developing atherosclerosis, likely due to altered blood flow patterns in this area [Corban et al. 2014]. It is unclear if the myocardial bridging found at autopsy may have played any role in the FF's sudden cardiac arrest.

Occupational Medical Standards for Structural Firefighters

Nearly half of all firefighter duty-related deaths are caused by sudden cardiac death. Fire fighting results in multiple cardiovascular changes that could lead to plaque rupture or arrhythmogenic changes

in individuals with underlying cardiovascular disease [Smith et al. 2016]. Research relying on autopsy data suggests that the majority of firefighter duty-related sudden cardiac deaths have atherosclerosis and/or cardiomegaly [Smith et al. 2018] and this is also true for young firefighters [Yang et al. 2013]. To reduce the risk of sudden cardiac events or other incapacitating conditions among firefighters, the National Fire Protection Association (NFPA) developed 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2013, 2018]. Guidance in the 2018 edition of the 1582 Standard recommends annual risk assessment of all firefighters ≥ 40 years old with a "Heart Risk Calculator" that takes into account age, sex, blood pressure, smoking status, etc., to estimate 10-year risk of sudden cardiac events or stroke [ACC/AHA 2019; NFPA 2018]. Firefighters with elevated risk (e.g., 10%–19%) are recommended to undergo futher evaluation with an EST [NFPA 2018]. The FF received an NFPA compliant medical evaluation when he joined the FD, approximately 6 years before his death. At that time, he achieved 14.4 METs, had no signs or symptoms, had no arrhythmias or ST changes. Based on his age and overall health, an exercise test would not have been recommended.

NIOSH offers the following recommendations to help reduce the risk of sudden cardiac events among firefighters at this and other fire departments across the country.

Recommendations

***Recommendation #1: Ensure that all firefighters receive an annual medical evaluation consistent with NFPA 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments.**

Discussion: Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2018]. These evaluations are performed to determine a firefighter's medical ability to perform duties without presenting a significant risk to the safety and health of himself/herself or others. This medical evaluation should be consistent with the requirements of NFPA 1582.

Recommendation #2: Ensure firefighters are cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by firefighters, and the various components of NFPA 1582.

Discussion: According to NFPA 1582, the FD should require that physicians are familiar with the physical demands of fire fighting and the risks that firefighters encounter and should guide, direct, and advise members with regard to their health, fitness, and suitability for duty [NFPA 2018]. The physician should review job descriptions and essential job tasks required for all FD positions to understand the physiological and psychological demands of fire fighting and the environmental conditions under which firefighters perform, as well as the personal protective equipment they must wear during various types of emergency operations.

Recommendation #3: Phase in a mandatory comprehensive wellness and fitness program for firefighters.

Discussion: Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, *Standard on*

Health-Related Fitness Programs for Fire Fighters [NFPA 2015], the *IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative (WFI)* [IAFF and IAFC 2008], and *Firefighter Fitness: A Health and Wellness Guide* [Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Aldana 2001; Stein et al. 2000]. Health promotion programs for firefighters have been shown to reduce coronary heart disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005].

The FD has exercise equipment available to members but does not have a wellness/fitness program. The FF regularly exercised on his own, so this recommendation would not have affected the outcome of this case; however, NIOSH recommends that all firefighters have access to a well-structured health and wellness program such as the IAFF/IAFC WFI.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical Line-of-Duty Deaths (LODD) Investigations Team, located in Cincinnati, Ohio. Denise L. Smith, Ph.D., led the investigation and authored the report. Dr. Smith is Professor of Health and Human Physiological Sciences and Director of the First Responder Health and Safety Laboratory at Skidmore College, where she holds the Tisch Family Distinguished Professorship. She is also a member of the NFPA Technical Committee on Occupational Safety and Health. Dr. Smith was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical LODD Investigations Team, during this investigation. Wendi Dick, MD, MSPH, provided medical consultation and contributed to the report. Dr. Dick is Lead for the Cardiac and Medical LODD Investigations Team in Cincinnati.

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Appendix A
Autopsy Findings

Structural

- Borderline cardiomegaly (heart weighed 550 grams)
- Concentric left ventricular hypertrophy (left ventricular thickness of 1.5 cm)
- No necrosis

Microscopic

- Focal mature fibrosis of left ventricle
- Isolated focus of chronic inflammation with possible myocyte damage on lateral portion of left ventricle
- Scattered areas of hypertrophic myocytes; myocytes well-ordered

Coronary arteries

- No intracoronary thrombus
- Coronary arteries free of significant luminal narrowing
- Midsegment of left anterior descending coronary artery has myocardial bridging (2 mm deep)

Normal cardiac valves

No evidence of a pulmonary embolus (blood clot in the lung arteries)

Blood analysis

- Negative for drugs of abuse

Author's Discussion:

Predicted normal heart weight 452 grams (ranges between 342 and 595 grams as a function of sex and body weight), according to research in Silver and Silver [2001].

Left ventricular thickness of 1.5 centimeters (cm) is high on the basis of postmortem studies by Kitzman et al. [1988] (normal range 1.07 cm–1.39 cm, average 1.23 cm).

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