Firefighter Dies Several Months After Suffering A Heart Attack On-Scene – Pennsylvania

Executive Summary

On November 5, 2014, at 1653 hours, a 48-year-old male volunteer fire fighter (FF) was dispatched to an unattended trash fire. The FF assisted in advancing the hose line and extinguishing the fire. He then complained of chest pain and an ambulance was summoned. While being transported to the Emergency Department (ED) the FF became unresponsive. Cardiac monitoring revealed ventricular tachycardia and the FF was defibrillated. The FF regained a sinus rhythm but his heart rhythm reverted to ventricular fibrillation again as care was being transferred to ED staff. He was transferred to the cardiac catheterization laboratory for angiography and a stent was placed. The FF was transported by medical helicopter to a larger hospital for advanced cardiac care. He was subsequently admitted to other long-term care facilities and a major state hospital. On February 22, 2015, at 0555 hours the FF died.

The death certificate, completed by the Forensic Supervisor of the County Medical Examiner, listed ischemic cardiomyopathy as the immediate cause of death with severe coronary artery disease as the underlying cause. The autopsy revealed cardiomegaly, severe three vessel coronary artery atherosclerosis with diffuse calcification and greater than 75% luminal narrowing, prior stenting of the two coronary arteries, pulmonary congestion and edema, multiple organ failure, and clinical history of cardiac arrest (on November 5, 2014). NIOSH investigators concluded that the physical stress of responding to and participating in fire suppression activities triggered a heart attack that resulted in his cardiac arrest and ultimately his death approximately 14 weeks later.

Key Recommendations

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

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The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH Fire Fighter Fatality Investigation and Prevention Program, which examines line-of-duty deaths or on-duty deaths of fire fighters to assist fire departments, fire fighters, the fire service, and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with state or federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency's reports do not name the victim, the fire department or those interviewed. The NIOSH report's summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency's recommendations and is not intended to be definitive for purposes of determining any claim or benefit.

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 November 5, 2014, a 48-year-old FF suffered a cardiac at the scene of a residential trash fire and died after several months of care in acute and long-term medical facilities. The U.S. Fire Administration notified NIOSH of this fatality on February 24, 2015. NIOSH contacted the affected fire department (FD) on February 26, 2015, to gather additional information and on May 13, 2016, to initiate the investigation. On May 27, 2016, a contractor for the NIOSH Fire Fighter Fatality Prevention and Investigation Program (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Fire Chief
- Assistant Chief who served as chief of operations during the fire
- Recording Secretary of FD
- FF's wife

NIOSH personnel reviewed the following documents:
- FD standard operating guidelines
- FD incident report
- FD injury/illness investigation report
- FD medical evaluation records
- Emergency medical service (ambulance) report
- Air Medical Flight follow-up letter
- Hospital ED records
- Hospital catheterization laboratory records
- Hospital operation room records
- Hospital intensive care unit records
- Death certificate
- Autopsy report

Investigation

On November 5, 2014, at 1653 hours, a 48-year-old male volunteer FF was dispatched to a residence with an unattended fire in a fire pit. The FF responded on the Utility Truck and arrived on scene at approximately 1659 hours. It was a clear, cool fall day (47°F, 63% relative humidity, winds out of the west at 6 mph) [NOAA 2014]. The fire pit contained burning magazines, banking records, and some

wooden debris. The fire had advanced beyond the fire pit and included a pile of stacked firewood, leaf litter, and a privacy fence. On scene, the FF helped pull a 1-inch booster line from the utility truck and assisted in extinguishing the fire while wearing his bunker coat and pants. The fire was extinguished quickly (approximately 2 minutes). As the fire department was assisting the police department take photographs of the scene, the FF reported to his assistant chief that he was experiencing chest pain.

The assistant chief recalled the ambulance (1710 hours) that had just been released from the scene. The ambulance arrived on the scene at 1714 hours. The FF sat on the side door steps of the ambulance and suddenly became unresponsive. He was lifted and carried into the ambulance and placed on the cot. The FF began to experience seizure-like activity that continued for 2-3 minutes. He regained consciousness, was alert and complained of mid-sternal pain that he was unable to rate the severity. The FF was given oxygen via non-rebreather mask. The cardiac monitor was attached to the FF and showed sinus tachycardia with a heart rate of 120 beats per minute. The initial 12 lead electrocardiogram (ECG) showed ST segment depression and a 7 beat run of ventricular tachycardia. An intravenous line was placed. At 1725 hours the FF became unresponsive and the cardiac monitor showed ventricular fibrillation. The FF was defibrillated and the monitor showed asystole. Cardiopulmonary resuscitation (CPR) was initiated along with ventilation of 100% oxygen by bag-valve mask. The FF regained sinus rhythm and began breathing on his own. The ambulance departed the scene at 1725 hours and arrived at the ED at 1729 hours. The FF's heart rhythm went into ventricular tachycardia and he was again defibrillated. The FF's heart rhythm returned to sinus tachycardia and he was breathing on his own when care was transferred to the ED staff.

Inside the ED, the FF was able to communicate with the medical staff. He had a heart rate of 123 beats per minute (normal resting rate is 60–100 beats per minute), respiratory rate of 20 breaths per minute (normal resting rate is 6–12 breaths per minute), arterial oxygen saturation of 100% (normal resting rate is 94–100%), and blood pressure of 143/97 millimeters of mercury (mmHg) (normal resting systolic pressure is 90-119 mmHg and normal resting diastolic is 60-79 mmHg). The FF was treated for pain and angina in the ED and was given medication for nausea. A portable x-ray showed congestive heart failure. An ECG showed signs of an inferior wall myocardial infarction. His ECG also showed ST segment depression anterolaterally and ST segment elevation inferiorly with widening of the QRS complex. Reevaluation of his vital signs showed a heart rate of 70 beats per minute, a respiratory rate of 20 breaths per minute, and a blood pressure of 84/46 mmHg. The FF was experiencing symptoms of cardiogenic shock and was transported emergently to the cardiac catheterization lab (1818 hours).

The cardiac catheterization demonstrated a total thrombotic occlusion of the left circumflex artery, which was stented. An intraaortic balloon pump counterpulsation device was successfully placed. Severe elevation of left ventricular end diastolic pressure was noted during catheterization. The FF had significant elevation of ventricular diastolic pressure (up to 50 mmHg). During the catheterization, the FF had a cardiac arrest and CPR was performed for 33 minutes. The FF was then transported by life flight helicopter to a larger hospital for possible further revascularization.

The FF arrived at the second hospital unresponsive and with a blood pressure of 160/100 mmHg, a

heart rate of 112 beats per minute, a breathing rate of 24 breaths per minute, and oxygen saturation of 98%. He was intubated and on a ventilator. During the course of his stay at this hospital, the FF underwent balloon pump insertion with an Impella placement and additional cardiac catheterization. The FF had additional complications and also required tracheostomy and ventilator assistance for respiratory failure and an endoscopic gastrostomy tube for feeding. Additionally, he developed deep vein thrombosis in the lower extremities. After approximately 6 weeks of care, on December 24, 2015, the FF was transferred to an acute care facility for further treatment and management of his condition. At the time of discharge, the FF was prescribed 23 medications to manage his cardiac, respiratory and diabetic conditions.

The FF was transferred to an acute care facility for ongoing care and management. However, he developed health care associated pneumonia and was transferred to a third hospital, a large University-based hospital. After he was stabilized he was transported to a rehabilitation center.

On February 13, 2016, the FF was found unresponsive and he was readmitted to the University-based hospital. During this stay, the FF experienced cardiogenic shock and worsening heart failure, which led to multiorgan system failure. The FF was transitioned to comfort care and on February 22, 2016, at 0555 hours the FF died.

Medical Findings

The death certificate, completed by the Forensic Supervisor of the County Medical Examiner, listed ischemic cardiomyopathy as the immediate cause of death with severe coronary artery disease as the underlying cause. The autopsy revealed severe cardiomegaly (570 grams) with left ventricular dilation; severe coronary artery atherosclerosis with diffuse calcification and greater than 75% luminal narrowing in three vessels; prior stenting of the two coronary arteries; a large area of myocardial scarring indicating a prior myocardial infarction; pulmonary congestion and edema; multiple organ failure; and clinical history of cardiac arrest. See Appendix A for a more detailed description of the autopsy findings.

The FF had a history of coronary artery disease and diabetes mellitus. The FF had a pre-placement medical evaluation in March of 2011. At that time, it was noted that he had a previous myocardial infarction (in 2008), his ECG was abnormal, and his blood glucose was 311 milligrams per deciliter (mg/dL) (normal 74-106 mg/dL). The occupational medicine health care provider required that the FF receive cardiac clearance and recommended that the FF follow-up with his primary care physician (PCP) for the diabetes. The cardiologist who saw the FF noted that the FF had a prior inferior wall myocardial infarction but indicated that the FF was able to exercise to 12 metabolic equivalents (METs) without symptoms and thus the cardiologist indicated he could be considered for the job of a fire fighter but that he should be evaluated every 6 months. At his most recent fire department medical evaluation (February 2014) the FF had high blood pressure (140/91 mmHg), which was noted to be improved from the previous year (158/85 mmHg). Laboratory tests performed during this evaluation found that the FF also had total cholesterol of 209 mg/dL (desirable < 200 mg/dL), low density lipoprotein cholesterol of 107 mg/dL (optimal < 100 mg/dL) and triglycerides of 301 mg/dL (normal <

150 mg/dL) [NCEP 2002]. The occupational medicine health care provider again requested a cardiology consult to clear the firefighter for duty. Again, the cardiologist cleared the firefighter. At the time of this medical evaluation, the FF had a blood glucose of 350 mg/dL. The occupational medicine health care provider encouraged the FF to follow-up with his primary care physician regarding his high blood glucose. The FF was cleared for full firefighting duty.

The FF was a former smoker, he was an active individual with a job that required strenuous activity, and he had a history of participating in physical fitness training. It is unknown if he had a family history of cardiovascular disease. At the time of his last medical evaluation, he was 65 inches tall and weighed 175 pounds, giving him a body mass index of 29.1 kilograms per meters squared [CDC 2016].

Fire Department

At the time of the NIOSH investigation, the fire department consisted of approximately 50 uniformed personnel and one fire station. It served a population of approximately 15,000 persons in a geographic area of 24 square miles. In 2015, the fire department responded to over 350 calls.

Employment and Training

To join the fire department, an interested person must be at least 18 years of age and complete an application. An investigating committee of the fire department meets with the applicant and discusses experience and abilities, and describes the fire department requirements. The investigating committee also checks references. The Chair of the investigating committee then reports its findings to the fire department at a membership meeting. The applicant is then voted on by the membership. Once the membership votes to accept the applicant, a background check is performed and the candidate is scheduled for a medical evaluation. If the candidate passes the background check and medical evaluation, he or she is sworn in. Once the candidate joins the fire department, he or she is a probationary fire fighter for two years. To become a full member, the probationary fire fighter must complete 180 hours of training at a state-certified regional training Academy. Additionally, members attend monthly training sessions that include classroom and hands-on training. The FF had been a member of this fire department since 2011 and had also served as a volunteer firefighter in another community many years earlier.

Preplacement/Periodic Medical Evaluations

The City requires preplacement medical evaluations for all applicants. Evaluations are conducted by a contract occupational medical group for the City. Components of this evaluation include the following:

- Complete medical history
- Physical examination (height, weight, blood pressure, pulse, and respiratory rate)
- Complete blood count with lipid panel

- Urinalysis
- Urine drug screen
- Audiogram
- Vision test
- Respirator use questionnaire
- Spirometry
- Resting EKG (for those over 40 years of age).

Periodic medical evaluations are provided annually to all members. The evaluations contain the same components listed above except that a drug screen is not performed. Once the medical evaluation is complete, the contracted health care provider makes a determination regarding medical clearance for firefighting duties and forwards this decision to the fire department. The FF had a preplacement medical evaluation when he joined in 2011 and yearly evaluations thereafter. His last medical evaluation was in February, 2014, when he was cleared for full firefighting duty after a cardiology consult.

Wellness/Fitness Programs

The fire department does not have a comprehensive wellness/fitness program as recommended by the IAFF/IAFC Wellness Fitness Initiative [IAFF, IAFC 2008]. However, membership to any area fitness centers is provided. The FF participated in the voluntary fitness program (gym membership) regularly from mid 2011 to February 2013. He participated only one month in 2014.

Discussion

Sudden Cardiac Events

In the United States, atherosclerotic coronary heart disease is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development are grouped into non-modifiable and modifiable. Non-modifiable risk factors include age older than 45, male gender, and family history of coronary artery disease. Modifiable risk factors include diabetes mellitus, smoking, high blood pressure, high blood cholesterol, and obesity/physical inactivity [AHA 2015; NHLBI 2015]. The FF had known cardiovascular disease having suffered at least one heart attack and having had several stents. The FF also had uncontrolled diabetes mellitus and was found to have high blood pressure and high cholesterol during his medical evaluations. At autopsy the FF was found to have severe coronary artery atherosclerosis as well as evidence of a prior heart attack and several stents.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2013]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion. Heart attacks (myocardial infarctions) typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques [Libby 2013]. Establishing a recent (acute) heart attack requires any of the

following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, the FF had a coronary artery thrombus identified during cardiac catheterization that completely occluded the left circumflex artery.

Firefighting and Sudden Cardiac Death

Heart attacks and sudden cardiac death can be triggered by heavy physical exertion [Mittleman 1993; Willich 1993; Albert et al. 2000]. Among fire fighters, sudden cardiac events have been associated with or triggered by alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The FF responded to the alarm and performed firefighting activity (advancing a booster line from the utility truck) immediately prior to the onset of symptoms. These activities during expended about 8.0 metabolic equivalents, which is considered moderate physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011]. The FF's fatal heart attack was probably triggered by the physical exertion of fire fighting activities.

Occupational Medical Standards for Structural Fire Fighters

To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the National Fire Protection Association (NFPA) developed NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2013]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The FF had a pre-placement medical evaluation in 2011 and a yearly medical evaluation thereafter. Despite his significant history of coronary artery disease and uncontrolled diabetes mellitus he was cleared for duty.

Cardiomegaly

The autopsy revealed that the FF had cardiomegaly [570 grams]. The FF had a history of hypertension and probably had ischemia due to his underlying coronary heart disease. Cardiomegaly increases the risk for a primary cardiac arrhythmia and sudden cardiac death [Levy et al. 1990].

Diabetes Mellitus

NFPA 1582 provides guidance for fire department physicians when treating fire fighters with diabetes [NFPA 2013]. The standard states that fire fighters with diabetes mellitus that is controlled by diet, exercise, or oral hypoglycemic agents should be restricted from duty unless the member meets all of the following criteria:

- has had hemoglobin A1C measured at least 4 times a year over the last 12 months prior to evaluation if the diagnosis of diabetes has been present over 1 year
- if on oral hypoglycemic agents, has had no episodes of severe hypoglycemia (defined as requiring assistance of another in the preceding year)
- has achieved a stable blood glucose as evidenced by hemoglobin A1C level less than 8% during the prior 3-month period
- has a dilated retinal exam by a qualified ophthalmologist or optometrist that shows no higher grade of diabetic retinopathy than microaneurysms

- has normal renal function on the basis of a calculated creatinine clearance greater than 60 milliliters per minute and absence of proteinuria
- has no autonomic or peripheral neuropathy
- has normal cardiac function without evidence of myocardial ischemia on cardiac stress testing (to at least 12 METs) by ECG and cardiac imaging.

The FF had uncontrolled diabetes with blood glucose levels of 350 mg/dL at his last exam. In 2013, the occupational medicine health care provider required that the FF be cleared by his primary care physician for diabetes mellitus. At that time his hemoglobin A1C was 9.3% (normal 4-5.6%; increased risk for diabetes 5.7-6.4%; diabetes ≥ 6.5%).

Recommendations

Recommendation #1: Ensure that all fire fighters 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 and in the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008; NFPA 2013]. These evaluations are performed to determine a fire fighter's medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. This medical evaluation should be consistent with the requirements of NFPA 1582.

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

Discussion: According to NFPA 1582 and the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, the FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty [IAFF/IAFC 2008; NFPA 2013]. The physician should review job descriptions and essential job tasks required for all FD positions to understand the physiological and psychological demands of firefighting and the environmental conditions under which fire fighters perform, as well as the personal protective equipment they must wear during various types of emergency operations. In addition, this physician should oversee all fitness for duty recommendations provided by primary care physicians and have the final authority for all medical fitness for duty decisions.

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

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*, the IAFF/IAFC *Fire Service Joint Labor Management Wellness/Fitness Initiative*, the U.S. Fire Administration *Health and Wellness Guide for*

the Volunteer Fire and Emergency Services, and in *Firefighter Fitness: A Health and Wellness Guide* [IAFF, IAFC 2008; USFA 2009; Schneider 2010; NFPA 2015]. 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 [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce coronary heart disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future non-occupational healthcare costs [Kuehl et al. 2013]. The fire department does not have a wellness/fitness program. However, regular gym membership is provided and the FF participated in this voluntary program. Nonetheless, NIOSH recommends a mandatory wellness/fitness program to ensure all members receive the benefits of a wellness/fitness program.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Denise L. Smith, Ph.D, led the investigation and coauthored the report. Dr. Smith is professor of Health and Exercise Sciences, and Director of the First Responder Health and Safety Laboratory at Skidmore College. She is 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, Cardiovascular Disease Component during this investigation. Thomas Hales, MD, MPH, provided medical consultation and coauthored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Health, and Vice Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

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Appendix A
Autopsy Findings

- Atherosclerotic Cardiovascular Disease
  - Cardiomegaly with left ventricular dilation (heart weighed 570 grams; predicted normal weight is 349 grams [ranges between 265 and 461 grams as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Severe three vessel coronary artery atherosclerosis with diffuse calcification and greater than 75% luminal narrowing
  - Prior stenting involving the left circumflex coronary artery and the first diagonal branch of the left anterior descending coronary artery
  - Left ventricular myocardium is mottled dark red to light tan with multiple areas of myocardial fibrosis
  - Pulmonary congestion and edema
  - Multiple organ failure
    - Soft mottled kidneys
    - Pale liver
    - Congestion of the spleen
    - Ascites (450 ml)
    - Pleural effusion
- Cardiac Arrest while fighting a fire (November 5, 2014)
- Microscopic examination
    - Sections of left ventricular myocardium with necrotic myocytes, contraction bands, hemorrhage, and intra-parenchymal neutrophils
    - Sections of coronary arteries show a marked degree of luminal stenosis with myointimal hyperplasia, cholesterol deposition, mineralization and foci of chronic inflammation.
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Negative blood test for drugs and alcohol

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