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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *March, 2013*

Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

Executive Summary

On December 8, 2011, a 54-year-old male career fire fighter (FF) responded with his engine crew (Engine 4) to a structure fire. As the FF was preparing to enter the structure he suddenly collapsed. Fire Department (FD) members witnessed the collapse and after finding him unresponsive and pulseless, retrieved an external automated defibrillator (AED) from a nearby apparatus. The AED was attached to the FF and a shock was advised and delivered three times. Paramedics arrived on scene and provided advanced life support (ALS) which continued en route to the hospital's emergency department (ED). Despite early defibrillation, cardiopulmonary resuscitation (CPR) and ALS, the FF died. The death certificate and autopsy report listed the cause of death as "stenosing coronary arteriosclerosis: status post coronary artery stent and by-pass; cardiomegaly." NIOSH investigators conclude that given the FF's underlying coronary heart disease (CHD), responding to the structure fire alarm probably triggered his sudden cardiac death.

NIOSH offers the following recommendations to reduce the risk of heart attacks and sudden cardiac arrest among fire fighters at this and other fire departments across the country.

Ensure that all firefighters receive an annual medical evaluation in accordance 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.

Introduction & Methods

On December 8, 2011, a 54 year-old career FF suffered sudden cardiac death at the scene of a residential fire. NIOSH was notified of this fatality on December 8, 2011, by the U.S. Fire Administration. NIOSH contacted the affected FD on December 16, 2011, and again on October 25, 2012, to obtain additional information and to schedule the investigation. On January 23, 2013, a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) conducted an on-site investigation of the incident.

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

- Commissioner of the FD
- Deputy Commissioner of the FD
- Chief of Operations of the FD (served as the FF's Captain on the day of the incident)
- Crew members working with the FF
- Union president
- Primary care physician (PCP)
- FF's wife

Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

Introduction & Methods (cont.)

The NIOSH investigator reviewed the following documents in preparing this report:

- FD general operating procedures
- Ambulance pre-hospital care report
- Death certificate
- Medical examiner's report
- FD medical records
- PCP medical records
- Hospital records

Investigative Results

Incident. On December 8, 2011, the FF reported to work to begin a 24-hour shift at 0800 hours as the driver of Engine 4. From 0800 to 0040 hours, the Engine responded to five calls: two medical, two commercial fire alarms, and one structure fire. While en route to the structure fire, Engine 4 was called off.

At 0242 hours, the FD received a call for a structure fire. The fire was in the basement of a single-family home. Engine 4 was the third due engine and arrived on scene at approximately 0250 hours. FD operating procedures stipulate that the third due engine initially be assigned as the rapid intervention team so, upon arrival, the FF exited the engine and donned his bunker gear and self-contained breathing apparatus. The Captain of Engine 4 (along with the FF and the third firefighter on the engine) walked around to the front of the building to verify their assignment with the incident commander. The incident commander had already ordered a hoseline be taken into the building, but ordered Engine 4 crew to take a second hoseline into the building. As the FF reached down to turn on his air cylinder, he let out a yelp, and collapsed.

The incident commander requested an ambulance (0303 hours) and the Captain (trained as an Emergency Medical Technician) assessed the FF. The FF was unresponsive and pulseless. The Captain ordered retrieval of the AED from a nearby apparatus as he removed the FF's self-contained breathing apparatus and bunker coat. The AED was attached to the FF and a shock was advised and delivered. After the first shock, the FF sat up for approximately 5 seconds and then fell back to the ground. CPR was initiated and oxygen was provided via bag valve mask. The AED advised a second and third shock which were delivered as the FF was loaded onto a long-board and carried to the end of the block.

An ALS ambulance arrived on scene at 0308 hours. The crew found the FF to be unconscious, pulseless, and not breathing. The FF was attached to a cardiac monitor that showed a heart rhythm of ventricular fibrillation. The ambulance crew shocked the FF at 200 Joules two times with no change in his clinical status. Unable to intubate the FF or gain intravenous access, CPR continued as the ambulance left the scene at 0323 hours and arrived at the ED at 0327 hours.

Initial evaluation at the ED revealed that the FF was unresponsive and in asystole (no heart beat). The FF was intubated with an endotracheal tube and cardiac medications were administered per ALS protocols. After more than 30 minutes of continued resuscitation efforts in the ED, with no change in the FF's status, the FF was pronounced dead at 0406 hours.

Medical Findings. The death certificate and autopsy, both completed by the deputy medical examiner, listed the cause of death as "stenosing

Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

Investigative Results (cont.)

coronary arteriosclerosis: status post coronary artery stent and by-pass; cardiomegaly." The autopsy also indicated concentric hypertrophy of the left ventricle. There was no evidence of an acute intracoronary thrombus. See Appendix A for a more complete description of pertinent autopsy findings.

The FF had a history of hypertension, high blood cholesterol, and CHD. His hypertension was diagnosed in 1995 and treated with a beta-blocker (metoprolol), an angiotensin-converting-enzyme (ACE) inhibitor (Diovan® and Lotrel®), and a calcium-channel-blocker (Lotrel®). His most recent blood pressure, measured in December 2011, was 160/100 millimeters of mercury (mmHg) (normal less than 120/80 mmHg).

The FF's high blood cholesterol was diagnosed in 2001 and treated with a statin (Lipitor®) resulting in good control. His most recent total cholesterol, measured in November 2006, was 120 milligrams per deciliter (mg/dl) (normal less than 200 mg/dl).

The FF was diagnosed with CHD in 1995 when a coronary artery stent was placed. He had coronary artery by-pass surgery in 2001. He was on restricted duty and worked in the FD's Prevention Office for several years due to orthopedic issues. Wanting to return to full duty, the FF underwent an imaging exercise stress test in September 2009. The FF exercised for 8 minutes on a Bruce protocol achieving 9.4 metabolic equivalents. At peak exercise, his electrocardiogram (EKG) revealed 1.5 mm downsloping ST-segment depression, frequent premature ventricular contractions, and non-sustained ventricular tachycardia. The exercise test was terminated due to the arrhythmias and dyspnea. The nuclear imaging findings included a medium-sized fixed defect in the anterior wall, left ventricular dilation, and an ejection fraction of 43% (normal is typically >55%) with global hypokinesis. The FF also had an electrophysiology study that revealed no inducible ventricular tachycardia. His PCP cleared him for full duty in November, 2009. The FF was 71 inches tall and weighed 264 pounds, giving him a body mass index of 36.8 kilograms per meter squared [CDC 2013]. Since his by-pass surgery, the FF was asymptomatic.

Description of the Fire Department

At the time of the FF's death, the FD consisted of 137 uniformed fire fighters serving a population of 80,000 residents. The FD had four fire stations and served a geographic area of 4 square miles.

Employment and Training. FD candidates must take a written test. Candidates who pass the written exam are required to pass a physical agility test. Candidates who pass the physical agility test are then sent for a preplacement medical evaluation. Candidates who are cleared by the medical evaluation are brought in for interviews. Candidates must pass a drug test and background test before being hired.

Pre-placement Medical Evaluations. The FD requires a pre-placement medical evaluation for all fire fighter candidates. The pre-placement evaluation includes the following items:

- A medical history and questionnaire
- Height, weight, and vital signs
- Physical examination
- Vision test
- Hearing test
- Blood tests: metabolic panel, hepatic profile, lipid panel, CBC
- Urinalysis

Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

Description of the FD (cont.)

- Urine drug test
- Spirometry (lung function tests)
- Resting EKG
- Chest X-ray

These evaluations are performed by a contract physician to the FD or by a member's PCP, who makes a decision regarding medical clearance for firefighting duties.

Periodic Medical Evaluations. The FD strongly recommends, but does not require, annual medical evaluations for all fire fighters. This medical evaluation, provided by the FD, has the same components as the pre-placement evaluation except the drug screen is not performed. Members may also use their own physician to complete the medical evaluation in which case the firefighters are provided with an information sheet that describes the testing recommended by the NFPA 1582 Standard [NFPA 2007; 2013]. As described in the Medical Findings section of this report, the FF had his last FD medical evaluation in November 2009.

Medical Clearance. A fire fighter injured at work or who has a serious illness must be evaluated and cleared for "return to work" either by the FD physician or their PCP.

Fitness/Wellness Programs. All fire houses have exercise (strength and aerobic) equipment. Fire fighters can use the aerobic equipment while on duty, but can only use the strength training equipment on their off-days. The FF did not regularly participate in an exercise program.

Discussion

Coronary Heart Disease (CHD) and the Pathophysiology of Sudden Cardiac Death. The FF suffered a cardiac arrest while preparing to enter a structure fire. The most common risk factor for cardiac arrest and sudden cardiac death is CHD, defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2012]. The FF had multiple risk factors for CHD (hypertension, high cholesterol, obesity, lack of exercise) and had CHD as evidenced by his stent placement in 1995, his by-pass surgery in 2001, and his autopsy findings.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2005]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Most heart attacks occur when a vulnerable plaque ruptures, causing a blood clot to form and occlude a coronary artery. 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 did not have a heart rhythm to conduct an EKG tracing, he died before cardiac enzymes would become elevated, and no thrombus was identified at autopsy. However, heart attacks can occur without evidence of a coronary thrombus [Davies 1992; Farb et al. 1995]. Thus, although not confirmed, a heart attack could have been responsible for the FF's sudden cardiac death. It is more likely, however, that he had a primary cardiac arrhythmia. The FF had several risk factors for a primary cardiac arrhythmia including CHD, left ventricular hypertrophy (LVH) (discussed below), cardiomegaly, and

Discussion (cont.)

non-sustained ventricular tachycardia during his 2009 exercise stress test [Levy et al. 1990].

Left Ventricular Hypertrophy (LVH). The autopsy revealed that the LT had concentric LVH. Hypertrophy of the left ventricle is relatively common among individuals with long-term hypertension, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The FF had a history of hypertension for an unknown duration, but the finding of concentric hypertrophy strongly suggests that longstanding hypertension was responsible for his LVH [Levy et al. 1990].

Physiological Stress of Firefighting. Firefighting is widely acknowledged to be physically demanding. Firefighting activities require fire fighters to work at near maximal heart rates for long periods. An increase in heart rate typically occurs in response to the initial alarm and persists throughout the course of fire suppression activities [Barnard and Duncan 1975; Lemon and Hermiston 1977; Manning and Griggs 1983; Smith et al. 2001]. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 beats per minute) owing to the insulative properties of the personal protective clothing [Smith et al. 1995].

Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and/or sudden cardiac death [Tofler et al. 1992; Middleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Epidemiologic studies among fire fighters have shown that fire suppression, training, alarm response, or strenuous physical activity on the job in the preceding 12 hours, increases the risk for a sudden cardiac event [Kales et al. 2003; Hales et al. 2007; Kales et al. 2007]. Some authors have also suggested that activation of the sympathetic nervous system (adrenaline surge) associated with alarm response and emergency operations may contribute to the triggering of cardiac events in fire fighters [Soteriades et al. 2011]. Increases in heart rate of 12 to 117 beats per minute have been reported within 15–30 seconds of an alarm response [Barnard and Duncan 1975]. Furthermore, approximately 13% of cardiac line-of-duty deaths occur during the emergency response [Kales et al. 2007].

The FF collapsed on the scene of a structure fire as he prepared to enter the building. NIOSH concludes that given his underlying CHD, responding to the structure fire alarm probably triggered his sudden cardiac death.

Occupational Medical Standards for Structural Firefighting. 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 2007, 2013]. This voluntary industry standard provides (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria. According to NFPA 1582, members with CHD should be precluded from unrestricted fire fighting because of the risk of sudden incapacitation [NFPA 2007] if any of the following apply:

Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

Discussion (cont.)

1. Current angina pectoris even if relieved by medication
2. Persistent significant stenosis in any coronary artery (>70% lumen diameter narrowing) following treatment
3. Lower than normal left ventricular ejection fraction as measured by radionuclide scan, contrast ventriculography, or echocardiography
4. Maximal exercise tolerance of < 42 milliliters of oxygen per minute per kilogram or < 12 metabolic equivalents
5. Exercise-induced ischemia or ventricular arrhythmias observed by radionuclide stress test during an evaluation reaching at least a 12-metabolic equivalents workload
6. History of myocardial infarction, angina, or coronary artery disease with persistence of modifiable risk factor(s) for acute coronary plaque rupture (e.g., tobacco use, hypertension despite treatment or hypercholesterolemia with cholesterol ≥ 180 or low density lipoproteins ≥ 100 despite treatment, or glycosylated hemoglobin > 7 despite exercise and/or weight reduction).

The FF did not meet items #3, #4, #5, and #6. Thus, if the guidance offered by NFPA 1582 would have been followed, the FF would not have been cleared for duty in 2009. Although the FF primarily served as a driver/operator, not an interior structure fire fighter, NFPA does not distinguish between driver/operators and fire fighters with regard to medical fitness for duty. Indeed, during this fire response, the FF was expected to be a member of the rapid intervention team and perform interior structure fire suppression.

Recommendations

NIOSH investigators offer the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters.

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

The FD encourages and pays for annual medical evaluations for all fire fighters, but the evaluations are not required. To ensure improved health and safety of candidates and members and to ensure continuity of medical evaluations, NIOSH investigators recommend the FD follow the guidance provided in NPFA 1582 [NFPA 2007; NFPA 2013].

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.

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 [NFPA 2007; NFPA 2013, IAFF/IAFC 2007]. 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 op-

Recommendations (cont.)

erations. In addition, this physician should oversee all fitness for duty recommendations provided by PCPs and have the final authority for all medical fitness for duty decisions. To ensure the FD physician or other PCP is familiar with NFPA 1582, the NIOSH investigators recommend the FD provide a copy or a link to the NFPA website where a copy could be purchased or viewed on-line at no charge.

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

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, and in Firefighter Fitness: A Health and Wellness Guide [IAFF, IAFC 2008; NFPA 2008; 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 [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce coronary artery 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 nonoccupational healthcare costs [Kuehl 2007]. The FD currently has a voluntary wellness/fitness program. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program. During exercise time, employees should be taken out of service to ensure uninterrupted participation.

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Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

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Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

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Autopsy Findings

- Hearty Size &Structure
  - Heart weight = 730 grams (ranges between 325 g and 566 g as a function of sex, age, and body weight) [Silver and Silver 2001]
  - Atria and ventricles moderately dilated
  - Left atrium auricular appendage has externally attached lipoma (5x3x3 cm)
  - Concentric left ventricular hypertrophy
    - Lateral wall = 1.5 cm
    - Interventricular septum = 1.5 cm (normal by autopsy 0.76–0.88 cm) [Colucci and Braunwald 1997]
- Coronary Arteries
  - Calcified arteriosclerosis with stenosis:
    - 80% narrowing of proximal left anterior descending coronary artery with patent bypass connecting to the mid portion of the left anterior descending coronary artery.
    - 60% narrowing of left circumflex coronary artery with a stent
    - 50% narrowing of right coronary artery
  - No acute occlusive thrombus identified
- Microscopic examination
  - Extensive patchy interstitial fibrosis with focal myocardial fiber hypertrophy
  - Arteriosclerotic plaques with cavity in lipid core in right coronary artery.
  - Arteriosclerotic marked intimal proliferation and thickening of arterial lumen and focal medial calcifications.
  - No luminal thrombosis or arterial wall inflammation.
- No drugs of abuse detected
- No pulmonary thomoembolus

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Fire Fighter Collapses at Residential Fire due to Sudden Cardiac Event – New York

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).