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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 *December, 2013*

Fire Fighter Suffers Sudden Cardiac Death While Responding to Residential Structure Fire – Michigan

Executive Summary

On February 26, 2013, a 22-year-old male volunteer fire fighter ("FF") responded to his fire station for a structure fire call. He and a crew member loaded coolers of water bottles into his pickup truck and responded toward the scene; the crew member was driving. A few blocks from the fire station, the FF began to have difficulty breathing and became unresponsive. Despite cardiopulmonary resuscitation (CPR) and advanced life support on the scene, in transport, and at the hospital, the FF died. The death certificate and the autopsy completed by the county medical examiner listed "sudden cardiac event (probable cardiac arrhythmia) of unknown etiology" as the cause of death. The FF's autopsy showed an enlarged heart with left ventricular hypertrophy, but no "characteristic gross or histologic features of hypertrophic cardiomyopathy." Given the FF's previously undiagnosed heart disease, NIOSH investigators concluded that the physical exertion of loading the coolers into his truck and/or the stress of responding to the structure fire may have triggered an arrhythmia that resulted in his sudden cardiac death.

The following recommendations would not have prevented the FF's death. Nonetheless, NIOSH investigators offer these recommendations to address general safety and health.

Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Ensure that fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, 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.

Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's medical evaluation program.

Introduction & Methods

On February 26, 2013, a 22-year-old male volunteer fire fighter died while responding to a structure fire. NIOSH contacted the affected fire department (FD) on February 28, 2013, to gather information and on July 9, 2013, to initiate the investigation. On July 29, 2013, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire chief
- FD administrative assistant
- Crew members
- FF's family

NIOSH personnel reviewed the following documents:

- FD standard operating procedures

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Introduction & Methods (cont.)

- FD annual report for 2012
- FD incident report
- Emergency medical service (ambulance) report
- Hospital emergency department (ED) report
- Death certificate
- Autopsy
- FD medical evaluation records
- Primary care physician records

Investigative Results

Incident. On February 26, 2013, at 1829 hours, the FD was dispatched to a garage fire. One engine, one aerial ladder, and two pumper-tankers responded, arriving on the scene at 1840 hours. Weather conditions included a temperature of 33° Fahrenheit, relative humidity of 92%, wind speed of 7 miles per hour, with fog and minimal snow accumulation [NOAA 2013]. The FF arrived at the fire station after the units had left the station.

Units arrived on the scene at 1840 hours, found a fully involved garage attached to a residence, and began fire suppression. One occupant was transported to the hospital's burn unit. At approximately 1850 hours, the FF and a crew member loaded coolers filled with water bottles weighing about 20 pounds and other supplies into the FF's pickup truck for on-scene rehab. The FF reported to the crew member that he "had been vomiting that afternoon and had low blood sugar," but that he wanted to assist at the fire scene. With the crew member driving, the two left the station. About 1 minute later the FF began to have difficulty breathing and appeared to have a seizure. The crew member pulled the truck into a parking lot and called 911 (1856 hours). An ambulance and the FD quick response vehicle were dispatched (1857 hours) for a male with low blood sugar. The FD quick response vehicle responded and arrived at 1858 hours. The two quick response crew members found the FF unresponsive with a weak pulse. A check of his blood sugar revealed a level of 118 milligrams per deciliter (mg/dL). The quick response crew members checked again for a pulse and found none. They pulled the FF from the truck and started CPR. An automated external defibrillator was applied, but no shock was advised and CPR continued.

The ambulance arrived on the scene at 1908 hours and found the FF unresponsive, not breathing, and pulseless with CPR in progress. A cardiac monitor was applied, revealing asystole (no heart beat). The FF was intubated with tube placement verified by auscultation, but not capnography, as recommended [Neumar et al. 2010]. An intravenous line was placed through which cardiac resuscitation medications were administered; the FF's heart rhythm changed to pulseless electrical activity. The FF was loaded into the ambulance, which departed the scene at 1915 hours en route to the nearest hospital.

The ambulance arrived at the hospital's ED at 1935 hours. Inside the ED, CPR and advanced life support efforts continued. The FF was re-intubated with a different endotracheal tube, and tube placement was verified by capnography. Laboratory tests revealed a blood glucose level of 230 mg/dL (normal is 70–99 mg/dL). Resuscitation efforts continued for 30 minutes without a change in the FF's clinical status. At 2006 hours the FF was pronounced dead by the attending physician, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy completed by the county medical exam-

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Investigative Results (cont.)

iner listed "sudden cardiac event (probable cardiac arrhythmia) of unknown etiology" as the cause of death. The FF's autopsy showed an enlarged heart with left ventricular hypertrophy, but no "characteristic gross or histologic features of hypertrophic cardiomyopathy." The electrical system of the heart was examined by a forensic pathologist at a referral hospital. Both the gross and microscopic examination of his heart's atrioventricular (AV) node revealed moderate narrowing of the distal AV node artery, but no pathologic changes. Additional findings from the autopsy are listed in Appendix A.

In February 2006 at age 15, the FF was diagnosed with hypertension that was treated with diet and exercise. In December 2007 his blood pressure was 146/98 millimeters of mercury (mmHg) and he was referred to a pediatric cardiologist. The blood pressure reading by the pediatric cardiologist using the FF's leg was within normal limits and no further treatment was prescribed. In 2009, the FF again began having periodic elevated blood pressure readings, and a diagnosis of "white coat hypertension" was considered. White coat hypertension is usually defined as an elevated clinic blood pressure in the presence of a normal daytime ambulatory blood pressure [Staessen et al. 2001; Franklin et al., in press]. The FF's most recent blood pressure reading in June 2012 was 150/72 mmHg, but he was not prescribed a blood pressure lowering medication.

The FF was 73 inches tall and weighed 222 pounds, giving him a body mass index of 29 kilograms per meter squared. A body mass index of 25.0–29.9 kilograms per meter squared is considered overweight [CDC 2011]. The FF never reported symptoms suggestive of coronary heart disease (CHD). He walked daily for exercise.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of one fire station with 36 volunteer uniformed personnel serving 10,000 residents in a geographic area of 25 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid state driver's license, have a high school diploma or a general equivalency diploma, pass a background check, pass a urine drug screen, pass an officer review, and be voted into the FD by members. Once an applicant becomes a new member, he/she is on probation for 1 year, and has 2 years to be trained to the Fire Fighter 2 level. The FF was certified as a Fire Fighter 1 and 2 and in Hazardous Materials Operations. He had 4 years of fire fighting experience.

Preplacement and Annual Medical Evaluations. Preplacement and annual medical evaluations are not required; however, apparatus operators are required to pass a commercial driver's license medical evaluation. The contents of the medical evaluation are:

- Health history
- Vital signs
- Vision
- Hearing
- Physical examination
- Urinalysis
- Drug screen

The evaluations are performed by an FD-contracted physician. Once this evaluation is completed, the physician makes a determination regarding medical clearance for apparatus operator duties and forwards this decision to the FD. Medical clearance to wear a respirator and an annual self-

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Description of the FD (cont.)

contained breathing apparatus facepiece fit test are not required. However, the FD plans to implement a respiratory protection program in the latter half of 2013.

Members injured on duty are evaluated by the attending ED physician or the workers' compensation physician, who makes the final determination regarding return to work. Members who suffer an illness that may result in harm to crew members and seek medical attention for that illness must be cleared by a physician prior to returning to duty. Members returning from a leave of absence of 6 months or more must be cleared by a physician and pass a drug screen. The member is then placed on probation for 6 months.

Physical Ability, Fitness, and Wellness. The FD does not require physical ability tests for candidates or members. It has no wellness/fitness program, although exercise equipment (strength) is available in the fire station.

Discussion

Atherosclerotic Coronary Heart Disease. Sudden cardiac death accounts for about half of all cardiac deaths [Kelesidis and Travin 2012]. 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 CHD include age older than 45, male gender, family history of CHD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [Greenland et al. 2010; Gray et al. 2011; NHLBI 2012; AHA 2013; Reis et al. 2013]. Although the FF had high blood pressure for 7 years, his autopsy showed no evidence of CHD. Given that the FF reported no angina (chest pain), his sudden death was probably due to a cardiac arrhythmia (i.e., ventricular tachycardia/fibrillation).

Primary Arrhythmia. Lethal ventricular arrhythmias account for most sudden cardiac deaths [Kelesidis and Travin 2012]. Risk factors for arrhythmias include cardiac disease, heart attack, sleep apnea, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [AHA 2012; Mayo Clinic 2013]. The FF's autopsy revealed cardiomegaly and left ventricular hypertrophy, two cardiac conditions that increase the risk for primary arrhythmia [Levy et al. 1990; AHA 2012; Tavora et al. 2012].

Among fire fighters, sudden cardiac events have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. Loading the water bottle-filled coolers into the FF's truck would have expended about 4 metabolic equivalents, which is considered light physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011]. In summary, NIOSH investigators conclude the FF's sudden cardiac death was probably due to an arrhythmia due to his underlying undiagnosed heart disease, possibly triggered by the physical exertion associated with loading the coolers into his truck and/or the stress of responding to the structure fire.

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the 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's previously undiagnosed heart disease was not known until autopsy, therefore there was no reason for work restrictions.

Recommendations

The following recommendations would not have prevented the FF's death. Nonetheless, NIOSH investigators offer the following recommendations to address general safety and health issues.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative (WFI) [IAFF, IAFC 2008; NFPA 2013]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. Although the FD is not legally required to follow the NFPA standard or the WFI, we recommend the FD follow these guidelines for the health and safety of its candidates and members.

Applying the NFPA standard or the WFI involves startup costs that may be particularly difficult for smaller fire departments to implement. To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians from the local ambulance service (vital signs, height, weight, visual acuity, and electrocardiogram). This information could then be provided to a community physician, perhaps volunteering his or her time, who could review the data and provide medical clearance or further evaluation, if needed. The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense, personal or through insurance, provided by a physician volunteer, or paid for by the FD, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

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

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008; NFPA 2013]. According to these guidelines, 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. The physician should review job descriptions and essential job tasks required for all FD positions and ranks to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. The FD currently uses the member's personal physician to clear fire fighters injured on duty or who miss work because of a lengthy illness. The extent of these physicians'

Recommendations (cont.)

knowledge of the fire fighting duties of their patients is unknown.

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, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; 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 [Chapman 2005; Mills et al. 2007; Pelletier 2009; Baicker et al. 2010]. Fire service health promotion programs have been shown to reduce CHD 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; Poston et al. 2013]. 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 from reduced medical costs [Kuehl 2013].

The FD currently does not offer a wellness/fitness program, and exercise equipment is not available in the fire station. Given the FD's structure, the NVFC program would be applicable [USFA 2004], but NIOSH would recommend a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #4: Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans. Michigan is a state-plan state [OSHA 2013]; therefore, the FD is required to ensure all members have been medically cleared to wear an SCBA.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored 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).

Appendix A

Autopsy Findings

- Heart disease
  - Cardiomegaly (enlarged heart; heart weighed 480 grams [g]; predicted normal weight is 391 g [ranges between 296 g and 516 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Left ventricular hypertrophy
    - Left ventricle and interventricular septum thickened (1.8 centimeter [cm] each)
      - Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]
      - Normal by echocardiographic measurement is 0.6–1.0 cm [Connolly and Oh 2012]
- No evidence of coronary artery atherosclerosis
- No evidence of a coronary artery thrombus (blood clot)
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative
- Microscopic examination of the AV node:
  - Distal AV node artery as it penetrates the summit of the ventricular septum has moderate narrowing by fibromuscular hyperplasia
  - Unremarkable His bundle, branching His bundle, working myocardium of the interventricular septum, and right and left bundle branches
  - No pathologic changes

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