2009
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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation *March 2010*

Lieutenant Suffers Fatal Heart Attack During Fire Operations – Pennsylvania

SUMMARY

On October 24, 2009, a 41-year-old male volunteer lieutenant (LT) responded to a reported residential fire with possible entrapment. At the scene, the LT assisted in stretching a 2-inch hoseline and participated in extinguishing the fire. After about 16 minutes, the water supply ran low, and crews took a break. The LT complained of a headache as he climbed into his engine's cab. The on-scene ambulance crew found the LT in the cab sweating heavily, complaining of tightness in his chest and shortness of breath. The LT became semiconscious and was helped to the ground and then carried to the ambulance. The cardiac monitor showed changes diagnostic of a heart attack. While en route to the hospital's emergency department (ED), the LT's condition worsened and, as the ambulance arrived at the ED, the LT suffered cardiac arrest. Cardiopulmonary resuscitation (CPR) and advanced life support were begun and continued in the ED for over an hour until the ED physician pronounced him dead. The death certificate and the autopsy listed "severe atherosclerotic coronary artery disease (CAD) and hypertensive cardiomyopathy" as the cause of death. Given the LT's severe underlying CAD, NIOSH investigators concluded that the physical exertion involved in responding to the call, stretching the fire hose, and extinguishing the fire triggered a heart attack and sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues.

- Provide preplacement and annual medical evaluations to all fire fighters.
- Perform a preplacement and an annual physical performance (physical ability) evaluation.
- Ensure 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 National Fire Protection Association (NFPA) 1582.
- Phase in a comprehensive wellness and fitness program for fire fighters.
- Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.
- Conduct annual respirator fit testing.

Lieutenant Suffers Fatal Heart Attack During Fire Operations – Pennsylvania

INTRODUCTION & METHODS

On October 24, 2009, a 41-year-old male volunteer LT died while fighting a structure fire. NIOSH was notified of this fatality on October 26, 2009, by the U.S. Fire Administration. NIOSH contacted the affected Fire Department (FD) on October 26, 2009, to gather additional information, and on December 1, 2009, to initiate the investigation. On December 7, 2009, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Pennsylvania to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Crew members
- LT's family

NIOSH personnel reviewed the following documents:

- FD training records
- FD annual report for 2008
- FD incident report
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Autopsy report
- Primary care provider medical records
- Employer medical records

INVESTIGATIVE RESULTS

Incident. On October 24, 2009, the FD was dispatched at 0013 hours to a residential structure fire with possible entrapment. The LT responded from his home to the fire station. One engine (staffed with a Driver/Operator, the Incident Commander, the LT, and a fire fighter) and an engine/tanker (staffed with three FD personnel) responded, arriving on the scene at 0022 hours. Upon arrival the crew realized that the residence on fire had been abandoned for many years. During size-up, the Incident Commander noted the roof and second floor had already collapsed into the basement and called for a "defensive attack." Three personnel, including the LT, deployed a 2-inch hose to the "D" side of the residence and began exterior fire suppression. Crew members initially wore full turnout gear and SCBA (not on air) but after a short time, they removed their SCBAs.

The Chief arrived at about 0025 hours, assumed command, and ordered a deck gun to replace the the hoseline. During this transition, the "B" side of the building collapsed into the basement. Additional FD personnel and mutual aid responded and arrived throughout the incident including an ambulance staffed with two emergency medical technicians (EMTs) and one paramedic.

After approximately 16 minutes on scene (0038 hours), both engines and the portable dump tank exhausted their water supplies. While the engine/tanker was en route to replenish its water, crew members began taking breaks. The LT informed a crew member that his head hurt

as he climbed into his engine's cab. The crew member asked nearby EMTs to evaluate the LT. The EMTs found the LT sitting in his cab, wearing bunker pants, boots, and a shirt. He was sweating heavily and complaining of lightheadedness with some tightness in his chest. As a stretcher was being retrieved, the LT became limp. The paramedic and nearby fire fighters assisted the LT to the ground where, although his eyes were closed, he was arousable and had a strong radial pulse. The EMT, paramedic, and two fire fighters carried the LT to the stretcher and loaded him into the ambulance.

Oxygen was administered as a cardiac monitor showed a heart rate of 110 beats per minute and significant ST-segment elevation (diagnostic of a heart attack). Two aspirin were given; two attempts at starting an intravenous (IV) line were unsuccessful. The LT became combative, not allowing measurement of his blood pressure or administration of nitroglycerin. However, the EMT was able to confirm a strong, regular radial pulse.

The ambulance departed the scene at 0047 hours en route to the local hospital's emergency department (ED). During the transport, the LT sat upright and attempted to remove the oxygen mask, stating that he was having difficulty breathing. The crew calmed the LT and replaced the mask. He attempted again to remove the oxygen mask, and the paramedic replaced the mask with a nasopharyngeal airway. Upon nearing the hospital, the LT's heart rate dropped to 38 beats per minute, and cardiac pacing was initiated at a rate of 70 beats per minute with capture.

As the ambulance arrived at the ED (0057 hours), the LT became unresponsive, stopped breathing, and was pulseless. The LT was transferred to the ED staff who began CPR, intubated the LT, and placed an IV line. Cardiac resuscitation medications were administered, and the LT was shocked (defibrillated) two times with no change in his heart rhythm. Advanced life support continued without change in the LT's condition until 0206 hours, when the attending physician pronounced the LT dead, and resuscitation efforts stopped.

Medical Findings. The death certificate, completed by the coroner, and the autopsy, completed by the forensic pathologist, listed "severe atherosclerotic coronary artery disease and hypertensive cardiomyopathy" as the cause of death. Specific findings from the autopsy are listed in Appendix A.

The LT was 69 inches tall and weighed 220 pounds, giving him a body mass index (BMI) of 32.5 kilograms per meters squared (kg/m2). A BMI > 30.0 kilograms per meter squared is considered obese [CDC 2010]. The LT's risk factors for coronary artery disease (CAD) included hypertension (high blood pressure), smoking, family history of CAD, and obesity/lack of exercise. He had been prescribed two antihypertensive medications but had not refilled the prescriptions for over a year. The LT had gone hunting the day before his death. He had no medical complaints. He had walked over somewhat hilly terrain for approximately 2 miles, expending about 9 metabolic equivalents (METs), which is considered moderate physical activity [Ainsworth et al. 1993; Peterson et al. 1999].

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the volunteer FD consisted of one fire station with 25 uniformed personnel that served 2,000 residents in a geographic area of 30 square miles. In 2008, the FD responded to 55 calls including 17 structure fires, 2 brush fires, 2 vehicle fires, 7 motor vehicle crashes, and 27 other calls.

Membership and Training. The FD requires new fire fighter applicants to be recommended by three currently active FD members, complete an application, be 18 years of age (21 years to drive fire apparatus), and have a valid State driver's license. The applicant is voted on at the next general meeting. The member must complete the Fire Fighter Essentials course to fight interior structure fires. The FD also has a Junior Fire Fighter Program that allows the junior fire fighter to train and perform support activities until reaching the age of 18. Pennsylvania does not require minimum training levels for fire fighters. The LT was certified as a Fire Fighter, Driver/Operator, Wildland Fire Fighter, and in water rescue. He had 28 years of fire fighting experience.

Preplacement and Periodic Medical Evaluations. The FD does not require preplacement or periodic (annual) medical evaluations for members. No annual SCBA medical clearance or annual SCBA facepiece fit test are required. Members injured on duty must be evaluated by their primary care physician, who makes the final determination regarding return to duty.

Health and Wellness Programs. The FD does not have a formal wellness/fitness program, and no exercise equipment is available in the fire station. No annual physical ability test is required.

DISCUSSION

Atherosclerotic Coronary Artery Disease. In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2010; NHLBI 2010]. The LT had five CAD risk factors (male gender, family history of CAD, smoking, hypertension, and obesity/lack of exercise); the autopsy revealed severe CAD.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Heart attacks typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques.

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. In the LT's case, his symptoms (chest tightness, lightheadedness, shortness of breath after exertion, and sweating) were typical of a heart attack. In addition, the ambulance's cardiac monitor revealed significant ST-segment elevation, a finding that confirms an acute heart attack.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Siscovick et al. 1984; Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks in fire fighters 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]. The LT had responded to the alarm, stretched a hoseline, and performed fire suppression. These activities expended about 8 METs, which is considered moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Given the LT's underlying CAD, the stress of performing fire fighting duties probably triggered his acute heart attack, resulting in sudden cardiac death.

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the LT was found to have left ventricular hypertrophy (LVH) and an enlarged heart. Both LVH and cardiomegaly increase the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure (hypertension), a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The LT had a history of hypertension and CAD consistent with chronic cardiac ischemia.

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 2007a]. This voluntary industry standard provides (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria. The LT had a history of hypertension but had not taken his prescription antihypertensive medication for over a year.

Exercise stress tests screen people at risk for CAD and sudden cardiac death. NFPA 1582 recommends performing an exercise stress test "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Diagnostic stress tests (maximal or symptom-limiting stress tests) with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease
- two or more risk factors for CAD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter [mg/dL]), hypertension (diastolic blood pressure greater than 90 millimeters of mercury [mmHg]), smoking, diabetes mellitus, or family history of premature coronary artery disease (heart attack or sudden cardiac death in a first-degree relative less than 60 years old). This exercise stress test recommendation is similar to that recommended by the American College of Cardiology/American Heart Association (ACC/AHA) and the U.S. Department of Transportation [Gibbons et al. 2002; Blumenthal et al. 2007].

Although the LT had three of the five risk factors listed above for conducting an exercise stress test for CAD, he was younger than the guidelines indicate and therefore would not have been tested.

RECOMMENDATIONS

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.

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 [NFPA 2007a; IAFF, IAFC 2008]. 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. However, the FD is not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer 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 (EMTs) from the local EMS (vital signs, height, weight, visual acuity, and EKG). 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 be-

tween 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: Perform a preplacement and an annual physical performance (physical ability) evaluation.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b].

Recommendation #3: 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 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008]. 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. This recommendation is based on review of the FD health and medical programs. The LT's primary care physician had treated the LT for hypertension and back pain since 2003. Whether the LT's physician was aware that his patient was a fire fighter is unclear, and neither his medical nor his FD records mentioned medical clearance for duty.

Recommendation #4: Phase in a 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 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 [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].

Given the FD's structure, the NVFC program might be the most appropriate model [USFA 2004]. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #5: 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 [OSHA 2009]. Pennsylvania does not operate an OSHA-approved State plan nor other State-regulated workplace safety and health program. However, we recommend voluntary compliance with this standard to ensure all members have been medically cleared to wear an SCBA.

Recommendation #6: Conduct annual respirator fit testing.

The OSHA respiratory protection standard requires employers whose employees are required to use a respirator (e.g., an SCBA) to have a formal respiratory protection program, including annual fit testing [29 CFR 1910.134]. As mentioned previously, Pennsylvania is not an OSHA-approved State plan; therefore, the FD is not required to follow OSHA standards [OSHA 2010].

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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 Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

APPENDIX A - Autopsy Findings

- Severe atherosclerotic cardiovascular disease
  - Severe (80%) focal narrowing of the left anterior descending coronary artery
  - Moderate (70%) focal narrowing of the left circumflex coronary artery
  - Moderate (50%) focal narrowing of the right coronary artery
  - No evidence of recent thrombus (blood clot in the coronary arteries)
- Hypertensive cardiomyopathy
  - Cardiomegaly (enlarged heart) (heart weighed 520 grams [g]; predicted normal weight i between 296 g and 516 g as a function of sex, age, and body weight) [Silver and Silver 2001]
  - Left ventricular hypertrophy (LVH)
    Left ventricular wall and interventricular septum thickened (2.0 centimeters [cm] and 1. cm respectively;
    - normal by autopsy 0.76–0.88 cm [Colucci and Braunwald 1997];
    - normal by echocardiography 0.6–1.1 cm [Armstrong and Feigenbaum 2001]

    Microscopic evidence of myocyte hypertrophy, myocyte disarray, and interstitial fibros
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Carboxyhemoglobin (blood test for carbon monoxide exposure) 4.6% (normal for smokers; toxic level is 15% – 35% saturation [Winek 1976])
- Negative blood tests for drugs and alcohol

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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 fiscal year 1998, the Congress appropriated funds to NIOSH to conduct a fire fighter initiative. NIOSH initiated the Fire Fighter Fatality Investigation and Prevention Program to examine deaths of fire fighters in the line of duty so that fire departments, fire fighters, fire service organizations, safety experts and researchers could learn from these incidents. The primary goal of these investigations is for NIOSH to make recommendations to prevent similar occurrences. These NIOSH investigations are intended to reduce or prevent future fire fighter deaths and are completely separate from the rulemaking, enforcement and inspection activities of any other federal or state agency. Under its program, NIOSH investigators interview persons with knowledge of the incident and review available records to develop a description of the conditions and circumstances leading to the deaths in order to provide a context for the agency's recommendations. The NIOSH summary of these conditions and circumstances in its reports is not intended as a legal statement of facts. This summary, as well as the conclusions and recommendations made by NIOSH, should not be used for the purpose of litigation or the adjudication of any claim. 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)