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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 *February 2012*

Lieutenant Suffers Heart Attack During Physical Fitness Training and Dies Seven Days Later – Vermont

Executive Summary

On July 23, 2010, a 46-year-old male career lieutenant (LT) was working a 24-hour shift. During the day he responded to three non-fire emergency calls. At about 1800 hours, the LT prepared and ate dinner followed by physical fitness training on equipment in the fire station's basement. Shortly thereafter, a crew member found the LT unresponsive, sitting beside the treadmill. Although the LT appeared sweaty, it was unclear what stage of the workout he had completed. Crew members were summoned and cardiopulmonary resuscitation (CPR) and advanced life support were initiated. After approximately 45 minutes of resuscitation, the LT regained a heart beat in the emergency department (ED). A heart attack was diagnosed by electrocardiogram (EKG) and an emergent cardiac catheterization was performed. A thrombus was revealed and two coronary artery stents were placed in two occluded arteries. Although the LT's cardiac status was stabilized, he suffered hypoxic brain injury due to the extended resuscitation time. Over the next 7 days, his condition did not improve and, after consultation with the family, physicians removed life support and the LT died.

The death certificate listed "hypertensive and atherosclerotic cardiovascular disease" as the cause of death. No autopsy was performed. Given the LT's underlying cardiovascular disease, NIOSH investigators concluded that the physical stress of physical fitness training triggered a heart attack, resulting in cardiogenic shock and subsequent hypoxic brain injury.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear whether these recommendations could have prevented the LT's death, however his underlying cardiac disease may have been identified sooner, possibly allowing for further evaluation and treatment.

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

Ensure on-duty fire fighters exercise in pairs or within viewing/hearing distance of another crew member.

Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.

The following recommendations would not have prevented the LT's death, but they address safety and health issues that all fire departments should consider.

Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Perform an annual physical performance (physical ability) evaluation for all members.

Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

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Executive Summary (cont.)

Provide fire fighters with medical clearance to wear a self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

Perform an autopsy on all on-duty fire fighter fatalities.

Introduction & Methods

On July 23, 2010, a 46-year-old male career LT suffered a heart attack during physical fitness training and died 7 days later as a result of to hypoxic brain injury. NIOSH contacted the affected Fire Department (FD) on August 30, 2010, to gather information, and again on October 25, 2011, to initiate the investigation. On November 7, 2011, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Fire Chief
- Deputy Fire Chief
- IAFF Local Vice-President
- Crew members
- LT's spouse

NIOSH personnel reviewed the following documents:
- FD standard operating procedures
- FD annual report for 2010
- FD incident reports
- Emergency medical service (ambulance) report
- Hospital ED report
- Hospitalization reports
- Death certificate
- Primary care physician records

Investigative Results

Incident. On July 23, 2010, the LT reported for his 24-hour shift at 0730 hours. He was assigned as the officer of Engine 2. At 1000 hours, the crew of Engine 2 conducted a facility inspection at police headquarters which included climbing stairs and walking through the building. The first emergency call (1122 hours) was for a carbon monoxide detector activation. Arriving at the scene, the crew determined that no hazard existed and Engine 2 returned to service. The second emergency response (1329 hours) was a medical call for a person having chest pain. At the scene, the crew assisted with patient care; the person was transported to the hospital and Engine 2 returned to service.

The third call (1739 hours) was a good intent (mistaken citizen) call. Finding no hazard at the scene, Engine 2 returned to service. Back in the station, the LT prepared and ate dinner with the crew (1800 hours). After dinner, the LT suggested to several crew members that they join him in exercising, but the other crew members declined.

At about 1815 hours the LT went to the basement of the firehouse where the fitness equipment was set up. The LT's typical workout included a 5-7 mile jog on a treadmill followed by stretching exercises. At approximately 1845 hours, a crew member entered the fitness area and saw the LT sitting beside the treadmill with his head down. The LT appeared sweaty, but it was unclear what stage of the workout he had completed. The crew member spoke to the LT and proceeded to a weight machine. The LT was unresponsive and, upon additional assessment, it was discovered that the LT had no pulse or respirations. Crew members and dispatch were alerted of the medical emergency.

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Investigative Results (cont.)

CPR was started as other crew members responded to the basement with medical equipment. An AED was placed; a shock was advised and administered with no change in the LT's condition. An advanced airway (King airway) was placed and oxygen was administered via bag valve mask. The LT was placed onto a backboard, carried upstairs, and placed into the ambulance. At 1855 hours, the ambulance departed the station en route to the hospital ED. While en route, an intravenous line was placed and airway placement verified by breath sounds and chest rise, but not capnography [AHA 2000]. CPR continued and the cardiac monitor continued to show asystole as the ambulance arrived at the ED (1857 hours).

Inside the ED, resuscitation efforts continued including four defibrillation attempts. After 45 minutes of advanced life treatment, a pulse of 100 beats per minute returned. A subsequent electrocardiogram (EKG) revealed ST-segment elevation indicating a heart attack and the LT was taken for emergent cardiac catheterization. The catheterization revealed a 70% occluded right coronary artery, a 100% occluded left circumflex coronary artery, a 90% occluded left anterior descending coronary artery with thrombus, and a 100% occluded diagonal coronary artery. Angioplasty followed by stent placement occurred in the diagonal and the left anterior descending coronary arteries. An attempt to stent the left circumflex coronary artery was unsuccessful. Because of extremely low blood pressure (cardiogenic shock), an intra-aortic balloon pump was placed and the LT was given IV dobutamine. The LT was then packed in ice for cooling per hypothermia protocol.

The next day (July 24th) an echocardiogram revealed a reduced left ventricular ejection fraction of 40-45% (normal typically > 50%), severe hypokinesis to akinesis of the mid-distal anterior wall and apex, and a mild to moderately thickened left ventricular wall. The balloon pump was removed and the LT was weaned off dobutamine. That evening, cooling was slowly reversed and neuromuscular blocking was discontinued. On July 25, an electroencephalogram (EEG) revealed burst sequences and disorganized brain activity and an upper extremity evoked potential test showed no cortical (brain) activity. On July 30, after consulting with the family, life support was removed and he died.

Medical Findings. The death certificate, completed by the state medical examiner, listed "hypertensive and atherosclerotic cardiovascular disease (years)" as the cause of death. No autopsy was performed.

The LT was 71 inches tall and weighed 167 pounds, giving him a "normal" body mass index of 23.3 kilograms per meters squared [CDC 2011]. The LT's risk factors for CAD included hypercholesterolemia (high blood cholesterol) (diagnosed in 2005) and hypertension (high blood pressure) (diagnosed in 2007). He was prescribed diet modification and a blood pressure-lowering medication (beta blocker).

In 2008 the LT saw his primary care physician for heart palpitations that occurred while at rest. The examination, including EKG and laboratory blood tests, did not reveal a specific cause. No further symptoms occurred after this episode. Otherwise, the LT never complained about cardiac symptoms and jogged 5-7 miles per day.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of five fire stations with 79 career uniformed personnel serving 50,000 residents in a geographic area of 15.4 square miles. In 2010, the FD responded to 6,666 incidents. Engine 2 responded to 2,133 of these incidents.

Membership and Training. The FD requires new full-time fire fighter applicants to be 21 years of age; have a valid state driver's license; and pass a written exam, a candidate physical ability test, an oral interview board, a background check, and a preplacement medical evaluation. After receiving a job offer, the new hire is placed in the FD's 6-week fire academy for basic fire fighter training. During the 1-year probationary period, the new hire is trained to the Fire Fighter 1 and emergency medical technician level. During the year the new hire must pass several written and physical tests. At the end of the year, the new hire must pass one comprehensive test. The new hire works a 24 hours on-duty/48 hours off-duty, 0730-0730 hours schedule. The LT was certified as a Fire Fighter 2, Apparatus Operator, Emergency Medical Technician, Fire Officer II, Fire Service Instructor, Fire Inspector, and in Hazardous Materials Awareness. He had 26 years of fire fighting experience.

Preplacement Medical Evaluations. The FD requires preplacement medical evaluations for all applicants. Components of the medical evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)
- Comprehensive metabolic profile
- General health panel
- Urinalysis
- Urine drug screen
- Spirometry
- Resting EKG
- Hearing (audiometric) test
- Vision screen
- Twinrix vaccine (if indicated)
- Hepatitis B surface antibody vaccine (if indicated)

The evaluations are performed by a City-contracted physician. Once this evaluation is completed, the contract physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD.

Periodic Medical Evaluations. The FD does not require periodic (annual) medical evaluations or medical clearance to wear a respirator. An annual SCBA facepiece fit test is required. Members injured on duty who miss two or more shifts are evaluated by the attending ED physician or their primary care physician, who forwards their medical clearance opinion to the City physician. The City physician makes the final determination regarding return to work. Members who are ill and miss three or more shifts must provide a medical clearance statement from their personal physician, which is reviewed by the City physician. The City physician makes the final determination regarding return to work.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program, and exercise equipment is available in the fire stations. No annual physical ability test is required. Additionally, the city has wellness/fitness facilities available to FD members at any time. The LT jogged 5-7 miles every day whether on- or off-duty.

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 2011; NHLBI 2011]. The LT had four CAD risk factors (age older than 45, male gender, high blood pressure, and high blood cholesterol).

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 a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, an EKG indicated an acute heart attack (myocardial infarction), the LT's cardiac enzymes were elevated, and cardiac catheterization revealed a thrombus.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [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 three alarms and performed a building inspection. Later, he began physical fitness training by running on the treadmill for an undetermined time. Jogging on the treadmill at about 7 miles per hour expends 11 METs, which is considered moderate-heavy physical activity [AIHA 1971; Ainsworth et al. 2011]. NIOSH investigators conclude that the LT's heart attack was probably triggered by his physical activity and his underlying CAD.

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 the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The LT had two factors related to medical clearance: CAD (unknown to the LT and his physicians) and use of a beta blocker medication for hypertension.

Beta Blocker Medication. In 2007 the LT was found to have hypertension and was prescribed a beta blocker. The NFPA considers use of beta blockers potentially to preclude safely wearing the fire protective ensemble and safely climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces, and operating near electrical power lines and/or other hazards. The concern about betablockers focuses on their potential to exacerbate heat stress and dehydration, and their blocking an increase in heart rate during emergency responses [NFPA 2007a].

Discussion (cont.)

Coronary Heart Disease (CHD) and Exercise Stress Tests. The LT had four risk factors for CHD and, despite being asymptomatic, should have been considered for an exercise stress test to screen for CHD. Recommendations for conducting exercise stress tests on asymptomatic individuals without known heart disease are varied. The following paragraphs summarize the positions of widely recognized organizations on this topic.

National Fire Protection Association (NFPA) 1582, a voluntary industry standard, recommends an exercise stress test be performed "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. Maximal (e.g., 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), hypertension (diastolic blood pressure greater than 90 mm of mercury), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The American College of Cardiology/American Heart Association (ACC/AHA) has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA guideline states that the evidence to conduct stress tests in asymptomatic individuals with diabetes mellitus is "Class IIa," which is defined as "conflicting evidence and/or a divergence of opinion about the usefulness/efficacy but the weight of the evidence/opinion is in favor." The ACC/AHA guideline states the evidence is "less well established" (Class IIb) for the following groups:

- persons with multiple risk factors (defined similarly to those listed by the NFPA)
- asymptomatic men older than 45 years and women older than 55 years:
    - o who are sedentary and plan to start vigorous exercise
    - o who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters)
    - o who are at high risk for coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation provides guidance for those seeking medical certification for a commercial driver's license. An expert medical panel recommended exercise tolerance tests (stress tests) for asymptomatic high risk drivers [Blumenthal 2007]. The panel defines high risk drivers as those with any of the following:

- diabetes mellitus
- peripheral vascular disease
- age 45 and above with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

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Discussion (cont.)

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart disease events. For individuals at increased risk for coronary heart disease events, the USPSTF found "insufficient evidence to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning…." Rather, the USPSTF recommends the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [USPSTF 2004]. The USPSTF does note that "For people in certain occupations, such as pilots, and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than the health benefit to the individual patient may influence the decision to screen for coronary heart disease."

Given the LT's age and CAD risk profile, the NFPA, the ACC/AHA, and the DOT would have recommended a symptom-limiting exercise stress test.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear whether these recommendations could have prevented the LT's death, however his underlying cardiac disease may have been identified sooner, possibly allowing for further evaluation and treatment.

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

Recommendations (cont.)

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. To ensure improved health and safety of candidates and members, and to ensure continuity of medical evaluations, it is recommended the FD comply with this recommendation. However, the FD is not legally required to follow the NFPA standard or the IAFF/IAFC initiative.

Recommendation #2: Ensure on-duty fire fighters exercise in pairs or within viewing/hearing distance of another crew member.

Members should exercise in pairs or at least within viewing/hearing distance of another crew member. If a medical emergency occurs, the other crew member can alert EMS or dispatch promptly. Other, but less desirable, options include use of a PASS device and/or portable radio or remote cameras. PASS devices are portable, lightweight units that, when activated, emit a 95-decibel alarm. The devices, which can be manually activated, automatically activate if no motion is detected for approximately 30 seconds [NFPA 2007b]. Portable radios have the advantage of allowing affected members to specify the problem and their exact location. Even if no one is present in the station, the member could alert Dispatch. Radios, however, are larger and heavier than PASS devices and do not automatically alert anyone if the member suddenly collapses. Remote cameras mounted in

Recommendations (cont.)

the fitness room and monitored in the fire station radio room may be helpful, although when the crew is dispatched, the radio room is unattended.

Recommendation #3: Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters older than 45 with two or more CAD risk factors [IAFF, IAFC 2008; Gibbons et al. 2002; NFPA 2007a]. The LT was over the age of 45 and had two of the risk factors for CAD (high blood pressure and high blood cholesterol) listed by these organizations.

The exercise stress test could be conducted by the fire fighter's personal physician or the FD contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the FD physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

The following recommendations would not have prevented the LT's death, but they address safety and health issues that all fire departments should consider.

Recommendation #4: 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 CAD 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.

Recommendation #5: Perform an annual physical performance (physical ability) evaluation for all members.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD develop physical performance requirements for candidates and members who engage in emer-

Recommendations (cont.)

gency operations [NFPA 2007c]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007c]. This could be incorporated into the annual task-level training program.

Recommendation #6: Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

To reduce the risk of improper intubation, the AHA and the International Liaison Committee on Resuscitation published recommendations in the "Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care" [AHA 2011]. These guidelines recommend confirming tube placement by primary and secondary methods. Primary confirmation is the five-point auscultation: left and right anterior chest, left and right midaxillary, and over the stomach. Secondary confirmation requires a technology test, either an end-tidal carbon dioxide detector or an esophageal detector device. In this incident, tube placement was verified by good breath sounds and chest rise; however, secondary confirmation was not performed until after the LT was reintubated in the ED. This issue did not contribute to the LT's death. We make this recommendation to ensure that future advanced life support resuscitation efforts follow AHA guidelines.

Recommendation #7: 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 CFR1 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans. Vermont operates an OSHA-approved state plan; therefore the FD is required to ensure all members have been medically cleared to wear an SCBA.

Recommendation #8: Perform an autopsy on all on-duty fire fighter fatalities.

In 2008, the USFA published the Firefighter Autopsy Protocol [USFA 2008]. With this publication, the USFA hoped to provide "a more thorough documentation of the causes of firefighter deaths for three purposes:

1. to advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;

2. to help determine eligibility for death benefits under the Federal government's Public Safety Officer Benefits Program, as well as state and local programs; and

3. to address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

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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).