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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 *August, 2012*

Fire Fighter Suffers Heart Attack and Dies After Fighting a Structure Fire – Louisiana

Executive Summary

On December 3, 2011, a 45-year-old male volunteer fire fighter ("the FF") was dispatched to a structure fire. Wearing turnout gear and self-contained breathing apparatus (SCBA) off-air, the FF assisted in exterior fire suppression operations followed by interior overhaul (SCBA on-air) for a total of 30 minutes. After 10 minutes of self-rehabilitation, the FF assisted in breaking down hoselines when he commented that he "felt funny." He walked to the rescue unit and suddenly collapsed (0541 hours). Crew members notified dispatch to request an ambulance while cardiopulmonary resuscitation (CPR) was begun and an automated external defibrillator (AED) was placed; three shocks were administered. Advanced life support was provided by the ambulance personnel at the scene and during transport to the local hospital emergency department (ED). Inside the ED, the FF's pulse returned, but he never regained consciousness. An acute heart attack was diagnosed and emergency cardiac catheterization was performed with stent placement. The FF, however, suffered recurring bouts of ventricular fibrillation in the catheterization lab and in the intensive care unit over a period of 4 hours. At 1120 hours the FF was declared dead and resuscitation efforts were discontinued.

The death certificate and the autopsy report listed "myocardial infarction" as the cause of death. Given the FF's underlying coronary artery disease (CAD), NIOSH investigators concluded that the physical stress of fire suppression activities triggered his heart attack which resulted in sudden cardiac death.

NIOSH investigators offer the following recommendations to prevent future similar incidents and to address general safety and health issues.

Monitor fire fighters' vital signs in rehabilitation during strenuous fire operations.

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.

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

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

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Introduction & Methods

On December 3, 2011, a 45-year-old male volunteer fire fighter suffered a heart attack and cardiac arrest shortly after fighting a structure fire. After being revived in the hospital, emergent cardiac catheterization with stent placement was performed but he died approximately 4 hours later. NIOSH contacted the affected fire department (FD) on December 5, 2011, to gather additional information, and on March 30, 2012, to initiate the investigation. On April 9, 2012, 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
- Fire Fighter's family

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD annual report for 2011
- FD incident report
- Emergency medical service (ambulance) report
- Hospital ED records
- Death certificate
- Autopsy report

Investigative Results

Incident. On December 3, 2011, the FD was dispatched to a structure fire at 0419 hours. Engine 415, Engine 475, Rescue 41, Tanker 476, Quint 417, Chief 403, Chief 401, Tanker 466, and an ambulance responded with a total of fourteen FD personnel. Engine 415 arrived on scene at 0423 hours to find a single-wide mobile home fully involved in fire. The FF and a crewmember removed the occupants from the front porch to a safe area. Ladder 417 arrived on scene, connected to the nearby hydrant, and connected the 4-inch supply line to Engine 415. Engine 415's deck gun was placed into service as the FF and another crewmember pulled 1½-inch handlines. The deck gun was shut down and handline streams were applied through the windows of the structure until other units arrived.

Additional personnel arrived at approximately 0430 hours; an interior attack/overhaul was performed. The FF and a crewmember entered the structure in full turnout gear and SCBA (on-air) to extinguish hot spots (overhaul) for approximately 8 minutes. The fire was declared under control at 0443 hours and the FF and his crewmember exited the structure. They then "self-rehabbed" by doffing their SCBA, removing/opening their turnout gear, hydrating, and resting for about 10 minutes.

Because the fire was under control, the ambulance was released from the fire scene. As crewmembers began breaking down hoselines and the fire investigation was begun, the FF and a crewmember shut down a nearby hydrant. While walking back, the FF commented that he felt dizzy; he sat down on the tailboard of the rescue truck. He said that his arms felt funny and that something was not right; he then collapsed. Dispatch was notified (0541 hours) and the ambulance was alerted. Other crewmembers retrieved the medical bag and AED from Rescue 41.

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Investigative Results (cont.)

Their initial assessment found the FF unresponsive, pulseless, and not breathing. CPR was begun, the AED was applied, and three shocks were administered with no change in his clinical status.

The ambulance arrived at the scene at 0548 hours with CPR in progress. Reassessment by the ambulance paramedic found the FF unresponsive, pulseless, and not breathing. The FF was placed onto a backboard and into the ambulance. A cardiac monitor was attached, an oro-pharyngeal airway and intravenous line were placed, and cardiac resuscitation medications were administered. The cardiac monitor revealed ventricular fibrillation and a shock was administered with no change in the FF's heart rhythm. The ambulance departed the scene at 0557 hours en route to the hospital's ED. Three additional defibrillations were administered en route to the ED.

The ambulance arrived at the ED at 0608 hours. Inside the ED, the oro-pharyngeal airway was removed and the FF was intubated. Two additional intravenous lines were placed and additional cardiac resuscitation medications were administered. Over the next 20 minutes, five defibrillations were administered.

At 0631 hours, a pulse and heart rhythm returned. An electrocardiogram (EKG) revealed an anterior ST segment elevation consistent with an acute myocardial infarction (heart attack). The FF's blood pressure was 90/62 millimeters of mercury (mmHg), indicating cardiogenic shock. Blood testing in the ED revealed elevated levels of troponin (0.08 nanograms per milliliter [ng/mL] (normal is 0.00 ng/mL–0.07 ng/mL)) and creatine kinase (602 units per liter [U/L] (normal is 20 U/L–200 U/L)). His carboxyhemoglobin blood level was slightly elevated at 2.2% (normal is < 1%), but not at a level associated with significant carbon monoxide exposure or carbon monoxide poisoning [Ernst and Zibrak 1998].

At 0720 hours, the FF was taken for emergent cardiac catheterization and angiography.
Cardiac catheterization revealed 100% occlusions in the left anterior descending (LAD) and diagonal coronary arteries. Both coronary lesions were opened via angioplasty and a stent was placed in the left anterior descending artery. His left ventricular ejection fraction was measured at 30% and his wall motion was severely hypokinetic in the anterolateral and apical walls. During the procedure, the FF had recurrent bouts of ventricular fibrillation requiring CPR and multiple shocks. An intra-aortic balloon pump was placed to assist in maintaining blood pressure. The FF was admitted to the intensive care unit for critical care management but his recurrent ventricular fibrillation persisted. Despite continued CPR and advanced life support, the FF was pronounced dead at 1120 hours and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy report listed "myocardial infarction" as the cause of death. The autopsy showed moderate to severe CAD with evidence of an acute heart attack. More complete findings from the autopsy are listed in Appendix A.

The FF was 68 inches tall and weighed 249 pounds, giving him a body mass index of 37.9 kilograms per meters squared. A body mass index > 30.0 kilograms per meter squared is considered obese [CDC 2011]. According to family members, the FF was rarely sick and had not visited a primary care physician for several years. His primary care physician had retired several years ago and the FF's medical records could not be located. The FF was not taking any prescription medications at the time of his death and had never complained of cardiac symptoms.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of 10 fire stations with 5 full-time career, 35 part-time, and 85 volunteer uniformed personnel. The FD served 40,000 residents in a geographic area of 225 square miles. In 2011, the FD responded to 3,292 incidents: 460 fire calls, 91 hazardous condition calls, 623 good intent calls, 106 service calls, 88 false alarm calls, 1,918 rescue/medical calls, and 6 other calls.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid state driver's license, pass an interview, and pass a background check prior to being accepted as a member. The new member begins a 24-hour basic firefighting course and is assigned to a fire station. Additional training occurs at the member's fire station. The new member is placed on probation for 6 months. The member may attend the State training academy for Fire Fighter 1 and 2, emergency medical technician, hazardous materials, driver/operator training but certification is not required. The FF was not a State certified fire fighter, but had received training in fire fighter standards, hazardous materials awareness, live fire training, and motor vehicle crashes. He had 2 months of fire fighting experience and had devoted 70 hours to training, meetings, and emergency calls as a volunteer.

Preplacement and Periodic Medical Evaluations. The FD does not require preplacement or periodic (annual) medical evaluations. Medical clearance to wear a respirator is not required. Members injured on duty must be evaluated by the member's primary care physician who forwards his or her determination for return-to-duty to the FD. Members who become ill on- or off-duty are not required to be cleared for return-to-work.

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

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 [NHLBI 2011; AHA 2012]. The FF had two modifiable CAD risk factors (obesity and physical inactivity) and one potential risk factor (high blood pressure, as discussed below).

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, the FF's cardiac enzymes were elevated, the EKG revealed characteristic changes of a heart attack, and the cardiac catheterization showed 100% occlusion (presumably due to a thrombus) of his left anterior descending and diagonal coronary arteries.

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Discussion (cont.)

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 FF had responded to the alarm and performed interior and exterior fire suppression activities. These activities expended about 9-12 METs, which is considered moderate – heavy physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

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. It is unclear if any of these recommended medical evaluations would have detected this fire fighter's underlying CAD.

Cardiomegaly/Left Ventricular Hypertrophy. The autopsy report identified an enlarged heart and left ventricular hypertrophy. Both conditions 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]. Because no heart valve problem was identified at autopsy, the most likely cause for the FF's cardiomegaly and left ventricular hypertrophy was either undiagnosed hypertension or undiagnosed chronic cardiac ischemia.

Recommendations

NIOSH investigators offer the following recommendations to prevent similar incidents in the future and to address general safety and health issues.

Recommendation #1: Monitor fire fighters' vital signs in rehabilitation during strenuous fire operations.

The Incident Commander considers the circumstances of each incident in determining the need for rehabilitation [NFPA 2007b]. As recommended in NFPA 1584, members performing intense work for 40 minutes without SCBA should receive at least 10 minutes of self-rehab [NFPA 2008a]. Members entering rehab should receive medical monitoring including rating of perceived exertion, heart rate, blood pressure, and temperature [NFPA 2008a]. The fire at this incident was a mobile home fire where fire fighters performed fire suppression and overhaul activities, which required moderate–heavy physical exertion. The FF performed self-rehab. A more structured rehab including measuring the FF's vital signs should have been considered, but given the rapid onset of the FF's symptoms and collapse, it is unclear if this could have detected his impending heart attack.

Recommendation #2: 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 [NFPA 2007a;

Recommendations (cont.)

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, particularly the section addressing stress tests to screen for coronary heart disease. Applying this recommendation involves economic repercussions and may be particularly difficult for smaller fire departments to implement. The FD is not legally required to follow the NFPA standard or the IAFF/IAFC initiative.

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 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 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 #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 and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; 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. The FD currently utilizes the member's personal physician to clear fire fighters injured on duty or who miss two or more shifts due to illness. The extent of these physicians' knowledge of the fire fighting duties of their patients is unknown.

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/

Recommendations (cont.)

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 2008b; 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 for career and volunteer personnel. Given the FD's structure, the NVFC program would be applicable [USFA 2004]. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

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

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]. This could be incorporated into the annual task-level training program.

Recommendation #6: 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. Because Federal OSHA rules apply in Louisiana [OSHA 2012], the FD is not required to ensure all members have been medically cleared to wear an SCBA. However, we recommend voluntary compliance with this recommendation to improve fire fighter health and safety.

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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

- Cardiomegaly (enlarged heart; heart weighed 510 grams [g]; predicted normal weight is 416 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Left ventricular hypertrophy
  - Left ventricle thickened (1.2 centimeter [cm])
    - 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]
- Coronary artery atherosclerosis
  - Moderate to severe (80%) focal narrowing of the left anterior descending coronary artery
  - Mild focal narrowing (30%) of the circumflex coronary artery
  - Minimal focal narrowing (10%) of the right coronary artery and the left main coronary artery
  - Recent transmural hemorrhagic infarct of the anterolateral aspect of the left ventricular myocardium (recent heart attack)
  - Recent stent placed in the left anterior descending coronary artery
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood level of carbon monoxide < 10% (performed by the medical examiner's laboratory)
- Drug and alcohol blood levels negative

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