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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 *September, 2010*

Lieutenant Suffers Sudden Cardiac Death After Structure Fire – Florida

Executive Summary

On March 26, 2009, a 60-year-old male career Lieutenant (LT) responded to nine emergency calls. The last call was at 2012 hours for a structure fire. At the fire scene the LT forced entry into the structure and extinguished the fire with a portable fire extinguisher. He then performed overhaul with his crew. After returning to the station, the LT went to his bunkroom. Approximately 30 minutes later, he was found unresponsive in his bunkroom's chair. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) at the fire station, in the ambulance, and in the hospital's emergency department (ED), the LT died. The death certificate and the autopsy listed "coronary atherosclerosis with remote myocardial infarct" as the cause of death with "generalized atherosclerosis and pulmonary emphysema" as significant conditions. Given the LT's severe underlying coronary artery disease (CAD), NIOSH investigators concluded that the physical exertion involved in responding to nine calls and performing fire suppression and overhaul triggered his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear if these recommended programs would have prevented the LT's death.

Modify the FD's policy for conducting member exercise stress tests.

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

Ensure fire fighters are cleared for return to duty by a healthcare provider 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.

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

Discontinue lumbar spine x-rays as a screening test administered during the preplacement medical evaluation.

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Introduction & Methods

On March 26, 2009, a 60-year-old male career LT died shortly after performing fire suppression and overhaul at a small structure fire. NIOSH contacted the affected Fire Department (FD) on May 5, 2009, to gather additional information, and on July 29, 2010, to initiate the investigation. On August 10, 2010, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- FD Operations Chief
- FD Emergency Medical Services Chief
- IAFF Local Vice President
- Crew members

NIOSH personnel reviewed the following documents:

- FD training records
- FD annual report for 2009
- FD incident report
- Police report
- Witness statements
- FD medical records
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Autopsy report

Investigative Results

Incident. On March 26, 2009, at about 0730 hours, the LT arrived at his fire station for his 24-hour shift as the officer on Engine 74. While the LT completed paperwork and other duties, the crew cleaned the station and checked the equipment. Engine 74 spent the morning responding to three separate medical emergencies involving treatment and transport of three patients to local hospital EDs, and one rescue call for capsized boaters.

The afternoon started with Engine 74 responding to a small, smoldering grass fire at 1306 hours. The fire was quickly extinguished, and units cleared the scene at 1316 hours. Crew members described the smoke exposure as minimal. At 1347 hours, Engine 74 was dispatched to a medical call. On scene, crews provided treatment, and the patient was transported to the hospital.

At 1910 hours, Engine 74 was dispatched to a vehicle accident with injuries. Engine 74 arrived on scene, assisted with cleanup, and returned to the fire station about 10–15 minutes later. At 2012 hours, Engine 74 was dispatched to a structure fire along with Engine 75, Squad 74, District 70, Truck 74, and Engine 73. Units arrived on scene at 2015 hours to find a masonry structure with light smoke showing. Wearing full bunker gear and self-contained breathing apparatus (SCBA) on air, the LT and a crew member forced entry into the structure. The LT used a Halligan tool to pry the front door open. Both fire fighters completed a search of the structure to check for fire extension. The LT and the crew member exited the structure; the LT retrieved a portable water fire extinguisher and suppressed the fire, which was burning at the base of the exterior wall. The LT, still wearing SCBA and on air, then performed overhaul and pulled the soffit down to search for fire extension (approximately 5 minutes).

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Investigative Results (cont.)

After the smoke was ventilated, the crew finished operations and units returned to the fire station at 2107 hours.

Arriving at the station at approximately 2115 hours, the crew cleaned and serviced the equipment from Engine 74 and Truck 74. The LT completed incident paperwork and then entered his bunkroom. As the crew was cleaning the equipment, the Truck 74 lieutenant noted a problem with a chain saw. He went in search of the LT's opinion, knocking on the closed door of the LT's bunkroom at approximately 2130 hours. Receiving no response, he knocked again and entered the room. He found the LT slumped over the recliner, unresponsive, not breathing, and with no pulse. He summoned a crew member to retrieve resuscitation equipment, notified dispatch for an ambulance, and alerted the battalion chief (on duty in the fire station).

Crew members began CPR and ALS using an AutoPulse® (a noninvasive cardiac life support pump). An intravenous line was placed, and cardiac resuscitation medications were administered. Intubation was attempted two times without success. However, a Combitube® was placed successfully with placement verified by positive lung sounds and capnography. A cardiac monitor revealed asystole (no heart beat). The LT was positioned onto a backboard/cot and placed into the ambulance, which departed the scene at 2201 hours en route to the hospital ED across the street.

The ambulance arrived at the ED (2203 hours) where ALS continued. In the ED the Combitube® was replaced with an endotracheal tube with placement verified by capnography. The LT's heart rhythm remained in asystole with no cardiac activity. At 2230 hours the LT was pronounced dead by the attending physician, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy listed "coronary atherosclerosis with remote myocardial infarct" as the cause of death with "generalized atherosclerosis and pulmonary emphysema" as significant conditions. No blood carboxyhemoglobin was detected, suggesting the LT had not inhaled significant amounts of carbon monoxide. The blood test for cyanide was also negative. Specific findings from the autopsy are listed in Appendix A.

The LT was 71 inches tall and weighed 183 pounds, giving him a borderline normal body mass index of 25.5 kilograms per meters squared [CDC 2010]. The LT's only risk factor for coronary artery disease (CAD) was hypercholesterolemia (high blood cholesterol). According to FD medical records, he had not been prescribed cholesterol-lowering medications since 2004. The LT underwent annual FD medical evaluations, the last being 7 days prior to his death. His electrocardiogram (EKG) was normal. An exercise stress test also was performed. The LT exercised for 8 minutes, 3 seconds on an expedited (2 minutes between stages) Bruce protocol, expending 12.5 metabolic equivalents. He reached a maximum heart rate of 140 beats per minute, 88% of his age-predicted maximum before stopping due to fatigue. He reported no angina and his blood pressure response was normal. The EKG revealed frequent premature ventricular ectopy (singlets with rare couplets), which decreased in frequency with continued exercise, and no significant ST-T wave changes. Overall, the test was interpreted as negative for ischemia with good exercise capacity.

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Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of eight fire stations with 134 career uniformed personnel that served 80,000 residents in a geographic area of 41 square miles. In 2009, the FD responded to 13,526 incidents: 221 fire calls, 11,585 emergency medical calls, 1,004 hazardous condition calls, service, and/or good intent calls, 553 false alarms, and 163 mutual aid incidents.

Membership and Training. The FD requires new full-time fire fighter applicants to be 18 years of age (21 years old to drive fire apparatus); have a valid State driver's license; be a State-certified Fire Fighter/Emergency Medical Technician; pass a written test and physical agility test; perform a "mega-code" (cardiac arrest resuscitation); and complete an oral interview, a preplacement medical evaluation (described below), and a background check prior to being hired. The new hire then receives 2 weeks of preassignment training and is on probation for 6 months. The new hire is placed on a shift working 24-hours on duty (0730 hours to 0730 hours) and 48 hours off-duty. The LT was certified as a Fire Fighter 2, Fire Officer, Driver/Operator, Paramedic, Hazardous Materials Technician, and Fire Inspector. He had 29 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:

- A complete medical history
- Physical examination (including vital signs)
- Complete blood count with lipid panel
- Pulmonary function test
- Resting EKG for candidates age 50 and older
- Chest x-ray (baseline)
- Spine x-ray
- Urinalysis
- Urine drug screen
- Audiogram
- Vision screen

The evaluation is performed by a physician contracted with the City. Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for wearing a respirator and firefighting duties and forwards this decision to the FD. The LT joined this FD in 1979. It is unclear if a medical evaluation was conducted 30 years ago.

Periodic Medical Evaluations. The FD requires periodic (annual) medical evaluations for all members. The components of this medical evaluation are the same as for the preplacement evaluation except resting EKG is conducted for those 30 years old and older, and stress tests are conducted for those 50 years and older. The evaluations are performed by a physician contracted with the City. Once complete, the contracted physician determines medical clearance for wearing a respirator and for fire fighting duties and forwards this decision to the FD. An annual SCBA medical clearance and an annual SCBA facepiece fit test are required. Members injured on duty must be evaluated by their primary care physician who forwards their determination for return to duty to the City Nurse. The City Nurse reviews the documentation and makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program, and exercise equipment is available in the fire stations. Exercise time is not protected time (i.e., the employee is not taken out of service). An annual physical ability test is not required.

Discussion

Atherosclerotic Coronary Artery Disease (CAD). 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 three CAD risk factors (age over 45, male gender, and hypercholesterolemia) and severe CAD on autopsy.

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. The LT did not have a heartbeat on which to conduct an EKG, cardiac enzymes were not tested, and no thrombus was identified at autopsy. However, occasionally (16%–27% of the time) postmortem examinations do not reveal the coronary artery thrombus/plaque rupture during acute heart attacks [Davies 1992; Farb et al. 1995]. The LT suffered either sudden cardiac death due to an acute heart attack without a thrombus being present at autopsy, or a primary heart arrhythmia (discussed below). The autopsy revealed evidence of an old (years ago) 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 nine calls, including a structure fire where he performed forcible entry, fire suppression with a portable fire extinguisher, and overhaul. These activities expended about 10 metabolic equivalents, which is considered heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Given the LT's severe underlying CAD, NIOSH investigators concluded that the physical exertion involved in performing fire suppression duties triggered either a heart attack or a heart arrhythmia resulting in sudden cardiac death.

Primary Arrhythmia. A primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation) could have also been responsible for the LT's sudden cardiac death. Risk factors for arrhythmias include heart disease, heart attack, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [AHA 2010; Mayo Clinic 2009]. The LT's underlying CAD and prior heart attack were risk factors for a primary arrhythmia.

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Discussion (cont.)

Exercise Stress Tests. The LT had an exercise stress test performed by the FD contract physician 7 days prior to his death. As noted previously, the findings of this test were interpreted as negative for ischemia. Frequent premature ventricular contractions were noted prior to exercise, but these decreased with exercise. Given the LT's sudden death shortly after the test, it is likely that the test results were falsely negative. Exercise stress tests without imaging tests are known to have sensitivities of about 80%; that is, produce false negative results about 20% of the time. Including imaging tests (e.g., thallium) with the exercise stress test as recommended by NFPA 1582, can reduce the false negative rate from 20% to 5% [Gibbons et al. 2002; Grundy 2003; NFPA 2007a].

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear if these recommended programs would have prevented the LT's death.

Recommendation #1: Modify the FD's policy for conducting member exercise stress tests.

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), hypertension (diastolic blood pressure greater than 90 millimeters 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). 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].

Recommendations (cont.)

Rather than using age as the sole criterion to initiate exercise stress tests, consider using the member's age and the number and severity of CAD risk factors. When an exercise stress test is indicated, consider including imaging studies to improve the test's sensitivity as recommended in NFPA 1582. The FD requires exercise stress tests. However, if this LT had an imaging exercise stress test, perhaps his underlying CAD could have been identified, leading to further evaluation and treatment.

Recommendation #2: 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 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 has a voluntary wellness/fitness program. However, NIOSH recommends a formal, structured 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 member participation.

Recommendation #3: Ensure that fire fighters are cleared for return to duty by a healthcare provider knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Currently, the City Nurse reviews all return-to-duty medical clearances. NFPA 1582 recommends that physicians knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582 be the final reviewing health care provider regarding return to work issues [NFPA 2007a]. The City should ensure the City Nurse has had training to perform this function.

Recommendation #4: Perform 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

Recommendations (cont.)

fighters [NFPA 2007b]. This evaluation could be performed as part of the FD annual training program.

Recommendation #5: Discontinue lumbar spine x-rays as a screening test administered during the preplacement medical evaluation.

The FD currently performs preplacement physical evaluations, which include routine lumbar spine x-rays. While these x-rays may be useful in evaluating individuals with existing problems, the American College of Radiology, American College of Occupational and Environmental Medicine, and NIOSH have concluded that lumbar spine x-rays have no value as a routine screening measure to determine risk for back injuries [Present 1974; ACOEM 1979; Gibson 1998]. This procedure involves both an unnecessary radiation exposure for the applicant and an unnecessary expense for the FD.

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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

- Atherosclerotic cardiovascular disease
  - Severe (70%–80%) focal narrowing of the left anterior descending coronary artery
  - Severe (70%–80%) focal narrowing of the right coronary artery
  - Severe (70%–80%) focal narrowing of the left circumflex artery
  - Fibrotic infarction at the left posterior wall (remote)
- Normal heart weight of 410 grams (g); predicted normal weight is 358 g (between 271 g and 473 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative
- Blood tests for carboxyhemoglobin were negative
- Blood tests for cyanide were negative

Refernce

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