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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 *March , 2010*

Lieutenant Suffers Sudden Cardiac Death at Scene of a Brush Fire - Missouri

Executive Summary

On March 14, 2009, a 49-year-old career Lieutenant (LT) responded to a brush fire as a "paid on-call" fire fighter. Once on-scene, he worked with hand tools for approximately 50 minutes to bring the fire under control. Approximately 10 minutes after the fire was reported under control the LT collapsed. Fellow firefighters began cardiopulmonary resuscitation (CPR) and moved the LT to the roadway where an automated external defibrillation (AED) was available. One shock was delivered without a change in the LT's clinical condition. An ambulance crew arrived on-scene approximately 15 minutes after the collapse, followed 5 minutes later by an air flight ambulance. The LT was intubated prior to transport and advanced life support (ALS) measures continued during the flight to the hospital's emergency department (ED). The LT arrived in the ED at 1534 hours, and ALS continued without change in the LT's condition. Approximately one hour after his collapse, the LT was pronounced dead and resuscitation efforts were discontinued. The death certificate listed "myocardial infarction [heart attack]" as the cause of death with "atherosclerotic coronary vascular disease" as a contributing condition. NIOSH investigators agree with this assessment and conclude that the heavy physical exertion associated with fighting the brush fire triggered the LT's sudden cardiac death.

Key Recommendations

NIOSH offers the following recommendations to reduce the risk of heart attacks and sudden cardiac arrest among fire fighters at this, and other FDs, across the country.

Provide mandatory pre-placement and periodic medical evaluations to all fire fighters consistent with the National Fire Protection Association (NFPA) 1582.

Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Develop a comprehensive wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease (CVD) and improve cardiovascular capacity.

Ensure that an automated external defibrillator (AED) is available at all emergency responses and planned training.

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

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

Lieutenant Suffers Sudden Cardiac Death at Scene of a Brush Fire - Missouri

Lieutenant Suffers Sudden Cardiac Death at Scene of a Brush Fire - Missouri

Introduction & Methods

On March 14, 2009, a 49-year-old LT, who worked as a full-time firefighter during the week and a paid on-call firefighter when not on duty, collapsed and died after battling a brush fire. NIOSH was notified of this fatality on March 16, 2009, by the U.S. Fire Administration. NIOSH contacted the affected FD shortly thereafter to obtain additional information, and again on January 7, 2010, to request further information and to schedule the investigation. On January 19th, 2010, a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) travelled to Missouri to conduct an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:
- Fire Chief
- Assistant Chief
- Crew members who were working with the LT
- Paramedics who responded to the LT
- LT's spouse
- LT's personal physician
- Medical examiner

The NIOSH investigator reviewed the following documents in preparing this report:
- FD incident report
- FD records
- Ambulance report
- Air flight ambulance report
- Death certificate
- Medical examiner's report
- Hospital records
- Personal physician medical records

Investigative Results

Incident Response. The LT was employed as a full-time fire fighter working the hours 0800 to 1700, Monday through Friday. During his off-duty hours he was allowed to respond to emergencies as a paid on-call fire fighter. On Saturday, March 14, 2009, he responded to two brush fires. At 1134 hours, the LT, responding as a paid on-call fire fighter, responded to the first call, wearing bunker gear but no self contained breathing apparatus (SCBA). He drove the FD's brush truck to the fire scene where a fellow firefighter used the booster line to extinguish the fire. The LT then worked with the firefighter for approximately 15 minutes of overhaul/mop-up using hand rakes. The crew was cleared from the scene at 1249 hours and returned to the station where the LT made some hose repairs and cleaned the truck.

At 1328 hours, while the LT was still at the station, firefighters were dispatched to a second brush fire. The temperature was 51 °F, relative humidity was 31%, and winds were out of the northeast at approximately 10 mph. The brush fire occurred on a hunting refuge that was covered with heavy vegetation. The LT and his crewmember were the second brush truck to arrive at 1341 hours. Due to wet/muddy ground conditions all brush trucks operating on-scene became stuck in the mud. The LT, wearing turnout gear without an SCBA, carried hand tools and an "Indian pack" that contained about 58 pounds of water when full to the fire line nearby their truck. This was the only water available to LT on the fire line.

At approximately 1420 hours the fire was reported to be under control. At this point the LT and his crewmember returned to their brush truck for a rest. While in the truck, they noticed a small pile of smoldering grass a few yards in front of the

Lieutenant Suffers Sudden Cardiac Death at Scene of a Brush Fire - Missouri

Investigative Results (cont.)

truck. As the crewmember went to extinguish the fire, the LT radioed command and checked around the area for other areas of smoldering vegetation. The crew member saw the LT on the radio, stomped out the final smoldering, and turned around toward the LT. The crewmember could not see the LT. He scanned the area and noticed the LT's shirt on the ground. He ran to this position and found him laying face down, unresponsive, and with no pulse.

The crewmember began CPR as he used the LT's radio to call a "Mayday." Hearing the radio transmission, firefighters ran to the LT's position and assisted with CPR. At 1441 hours Command requested an ambulance as well as an air ambulance due to the remote location. Due to the wet conditions none of the brush trucks could reach the LT. A nearby tractor was used to transport the LT to the nearest paved road. A fire engine with an AED also mobilized to the paved road just as the LT arrived by the tractor (1455 hours). The AED was attached to the LT and one shock was delivered without a change in the LT's clinical condition.

The ambulance arrived with two paramedics at 1456 hours. The paramedics reassessed the LT and found him to be unresponsive with no pulse or respirations. A Combitube® airway was secured, oxygen was given by bag valve mask (BVM), and an intravenous (IV) line was established. At 1458 hours the AED advised another shock which was delivered with no change in the LT's condition. ALS medications were administered via the IV line and a manual defibrillation (shock) was given at 1509 hours, again with no change in the LT's condition.

At approximately 1500 hours the air ambulance arrived and began working with ground-based paramedics. At this time the cardiac monitor revealed pulseless electrical activity (PEA), however as they completed their assessment the LT's rhythm changed to ventricular fibrillation and he was shocked again. The LT's heart rhythm changed to asystole (no heart beat). The Combitube was replaced with an endotracheal tube (ET-T) and proper placement was confirmed by presence of fogging in the endotracheal tube and auscultation of bilateral breath sounds. The LT was loaded into the air ambulance which departed the fire scene at 1520 hours for the hospital's ED.

CPR continued enroute and an attempt was made to verify the ET-T placement with an end tidal carbon dioxide detector. This was unsuccessful because the paramedics could not disconnect the ET-T from the bag valve.

The air ambulance arrived at the ED at 1534 hours, approximately 55 minutes after the LT's collapse. He was given dextrose and Narcan but his rhythm remained in asystole. The ED physician examined the oropharynx with a videoscope and confirmed the proper placement of the ET-T. A bedside ultrasound did not show any signs of cardiac motion or activity. At 1547 hours the firefighter was pronounced dead and resuscitation efforts were discontinued.

Medical Findings. The death certificate, competed by the coroner, listed the immediate cause of death as "myocardial infarction [heart attack]" with "atherosclerotic coronary disease" listed as the underlying cause of death. The autopsy found significant atherosclerosis with blockages in all three coronary arteries and evidence of small,

Investigative Results (cont.)

healed myocardial infarcts. (See Appendix A for more complete autopsy findings).

The LT had a history of high blood pressure (hypertension) diagnosed in 1998 and treated with several antihypertensive medications over 10 years. In July 2007, the LT saw his personal physician to obtain medical clearance for firefighting. At that time, the LT's blood pressure was 147/83 millimeters of mercury (mmHg). Changes were made in his antihypertensive medications which resulted in better blood pressure control (116/61 and 112/64 mmHg in June 2008 and February 2009, respectively).

At the time of his firefighting medical examination in July 2007, a screening resting electrocardiogram (EKG) and echocardiogram were performed. The EKG revealed a normal sinus rhythm and no arrhythmias. The echocardiogram revealed a) normal left ventricular global systolic function with a normal left ventricular ejection fraction of 65%, and b) concentric left ventricular hypertrophy (grade I).

The LT had several risk factors for coronary artery disease including age, gender, hypertension, family history, and cigarette smoking [AHA 2010b]. The LT's blood cholesterol levels were normal. LT reportedly exercised on the station's treadmill, but the frequency of his workouts was unknown. The LT also had a body mass index of 30.5, which is considered borderline for obesity [AHA 2010a].

Description of the Fire District (FD)

The FD consists of nearly 30 uniformed personnel in a single fire station serving a population of approximately 14,000, in an area of approximately 100 square miles.

Employment and Training. The FD requires new applicants to be at least 16 years of age (for a junior firefighter) and to have a valid driver's license. After approximately 6 months as a probationary firefighter, members must take a hands-on examination with an officer to demonstrate proficiency in basic firefighting skills, familiarity with tools and equipment, and the proper use of personal protective equipment. Members must then receive 6 hours of in-house training every 3 months.

The LT was hired by the FD in 2004 as a paid on-call firefighter. In 2008 he was hired as a full-time firefighter with a 40 hour shift (Monday thru Friday, 0800-1700 hours). He also responded to calls as a paid on-call firefighter when he was not on duty. He was promoted to the rank of LT less than a month before the incident.

Pre-placement and Period Medical Evaluations. Pre-placement and period medical evaluations are not required by the FD. However, in 2007 the FD paid for a one-time medical evaluation. As noted earlier, the LT took advantage of this voluntary program.

Fitness/Wellness Programs. The FD does not offer a health and wellness program but the fire station has aerobic exercise equipment and weight machines. All members are encouraged to use the equipment.

Lieutenant Suffers Sudden Cardiac Death at Scene of a Brush Fire - Missouri

Discussion

CAD and the Pathophysiology of Sudden Cardiac Death. This LT suffered sudden cardiac death after performing strenuous fire suppression activities at a brush fire. The most common risk factor for cardiac arrest and sudden cardiac death is coronary artery disease (CAD), defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2010b]. The LT had several CAD risk factors and had CAD confirmed at autopsy. Furthermore, the autopsy revealed heart muscle scarring consistent with a few small, old heart attacks. Given that the LT never reported a history of chest pain, these old heart attacks were probably "silent" (e.g., without angina) heart attacks.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2005]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Most heart attacks occur when a vulnerable plaque ruptures, causing a blood clot to form which occludes a coronary artery.

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic 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, 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]. Based on the clinical scenario and autopsy findings of significant CAD and scarring consistent with prior heart attacks, the LT's death was probably caused by a heart attack. However, a primary heart arrhythmia (e.g., ventricular tachycardia or ventricular fibrillation) cannot be ruled out.

Physiological Stress of Firefighting. Firefighting is widely acknowledged to be physically demanding. Firefighting activities require fire fighters to work at near maximal heart rates for long periods. An increase in heart rate typically occurs in response to the initial alarm and persists throughout the course of fire suppression activities [Barnard and Duncan 1975; Lemon and Hermiston 1977; Manning and Griggs 1983; Smith et al. 2001]. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be over 170 beats per minute due to the insulative properties of the personal protective clothing [Smith et al. 1995].

Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death [Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Epidemiologic studies among fire fighters have shown that fire suppression, training, alarm response, or strenuous physical activity on the job in the preceding 12 hours, increases the risk for a sudden cardiac event [Kales et al. 2003; Hales et al. 2007; Kales et al. 2007]. The LT collapsed shortly after completing nearly 50 minutes of strenuous fire suppression activities, including working with hand tools and carrying an "Indian Pack" that weighted about 58 lbs when fully filled with water. Based on the findings discussed above, the NIOSH investigators concluded that the LT died from a probable heart attack triggered by the heavy physical exertion associated with fighting the brush fire.

Discussion (cont.)

Occupational Medical Standards for Structural Firefighting. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA has developed NFPA 1582 [NFPA 2007a]. NFPA 1582 recommends that all fire fighters receive annual medical evaluations. NFPA 1582 also recommends diagnostic screening for CAD via an exercise stress test for asymptomatic fire fighters over age 45 (55 for women) with two or more risk factors for CAD (family history of premature cardiac event, hypertension, diabetes mellitus, cigarette smoking, and hypercholesterolemia). This recommendation is similar to recommendations from the American Heart Association and American College of Cardiology (AHA/ACC) and the Department of Transportation (DOT) regarding exercise stress tests in asymptomatic persons [Gibbons et al. 2002; Blumenthal et al. 2007].

The LT was 49 years-old and had at least three CAD risk factors (family history, hypertension, smoking). Therefore, an exercise stress test was indicated. Had an exercise stress test been performed, his CAD may have been identified, and he would have been referred for further evaluation and treatment. This may have prevented his premature death.

Recommendations

NIOSH offers the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac death among fire fighters in this FD and other FDs across the country.

Recommendation #1: Provide mandatory annual medical evaluations to all fire fighters consistent with NFPA 1582.

Guidance regarding the content and frequency of periodic medical evaluations for fire fighters can be found in NFPA 1582 and in the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF/IAFC 2007; NFPA 2007a]. FDs are not legally required to follow this standard or this initiative. However, these guidelines help determine a fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

Applying this recommendation involves economic repercussions and may be difficult for small volunteer/combination FDs such as this one, to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [USFA 2004; NFPA 2007]. 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 emergency medical service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided

Recommendations (cont.)

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. Finally, medical evaluations should occur prior to performing fire suppression duties and/or other physically demanding duties including training.

Recommendation #2: Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.
According to NFPA 1582 and the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, the FD should officially designate a physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty. [NFPA 2007, 2007a, IAFF/IAFC 2007]. The physician should review job descriptions and essential job tasks required for all FD positions to understand the physiological and psychological demands of firefighting and the environmental conditions under which firefighters perform, as well as the personal protective equipment they must wear during various types of emergency operations.

Recommendation #3: Develop a comprehensive wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.
Guidance for FD wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the NVFC's Health and Wellness Guide [IAFF/IAFC 2007; USFA 2004; NFPA 2008]. These guidelines provide information to reduce risk factors for cardiovascular disease and improve cardiovascular capacity. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, reducing the number of work-related injuries, and reducing the number of work-related 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; Elliott et al. 2007]. A study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large FDs implementing the IAFF/IAFC wellness/fitness program compared to four large FDs not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future non-occupational healthcare costs [Kuehl 2007].

Recommendation #4: Ensure that automated external defibrillators (AED) are available at emergency responses and planned training.
A major determinant of survival after a sudden cardiac arrest is rapid defibrillation [Bayes de

Recommendations (cont.)

Luna et al.1989; Page et al. 2000; Capucci et al. 2002]. Firefighters initiated CPR immediately upon discovering the LT's body (estimated at less than 1 minute). However, no AEDs were available from the on-scene brush trucks and it took approximately 14 minutes for an AED to arrive. Given the improvement in survival rates with the prompt use of an AED, it is recommended that an AED be readily available at all emergency responses and all planned training drills.

Additional Recommendations

The following recommendations could not have prevented the FF's death, but are offered to address general safety and health issues.

Recommendation #5: 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 2007a]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007a].

Recommendation #6: Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's medical evaluation program.

The 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. Missouri does not operate an OSHA-approved State plan, therefore the FD is not required to follow this OSHA directive. Nonetheless, this recommendation is offered for safety and health considerations. 1Code of Federal Regulations. See CFR in references.

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Lieutenant Suffers Sudden Cardiac Death at Scene of a Brush Fire - Missouri

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Denise L. Smith, Ph.D, led the investigation and coauthored the report. Dr. Smith is professor of Health and Exercise Sciences, and holds the Class of 1961 Chair at Skidmore College. She was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component during this investigation. Thomas Hales, MD, MPH, provided medical consultation and coauthored 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

Pertinent Autopsy Findings

Atherosclerotic coronary vascular disease

Myocardial infarcts, healed, multifocal

Coronary Arteries

- left main coronary artery/ left anterior descending coronary artery - 80% stenosis
- left circumflex coronary artery - 85% stenosis
- right coronary artery – 90% stenosis
- a large atheromatous plaque markedly narrowed the ostia of the right coronary artery
- aorta – moderate, focally marked

Cardiomegaly (510 g)

Upper and lower airways were patent with no signs of soot deposition

Carboxyhemoglobin reported as less than 10%

Blood tests were negative for alcohol and other illicit drugs