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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 *April , 2010*

Corporal Suffers Sudden Cardiac Death at Structure Fire - Oklahoma

Executive Summary

On March 4, 2009, a 43-year-old career fire fighter (Corporal) responded to a structural fire in a two-story apartment complex. The Corporal was initially assigned to the rapid intervention team (RIT) and, after the fire was brought under control, assigned to overhaul for about 24 minutes. After loading equipment on the apparatus and while preparing to leave the fire scene, the Corporal complained of severe back pain and then collapsed. Despite advanced life support (ALS) and cardiopulmonary resuscitation (CPR) delivered immediately by crew members, continued by the ambulance crew, and by physicians at the hospital's emergency department (ED), the Corporal could not be revived. The death certificate completed by the pathologist from the office of the Chief Medical Examiner, listed "coronary artery disease" as the cause of death. NIOSH investigators agree with this assessment and concluded that the Corporal probably had a fatal heart attack triggered by his fire fighting duties.

Key Recommendations

NIOSH offers the following recommendation to reduce the risk of heart attacks and sudden cardiac arrest among fire fighters at this, and other fire departments (FD) across the country. It is unlikely, however, that the following recommendation could have prevented the Corporal's death.

Provide medical evaluations consistent with NFPA 1582.

Introduction & Methods

On March 4, 2009, a 43-year-old Corporal collapsed and died after working a two-story apartment building fire. NIOSH was notified of this fatality on March 5, 2009 by the U.S. Fire Administration. NIOSH contacted the affected fire department (FD) shortly thereafter to obtain additional information and again in February 2010 to request further information and to schedule the investigation. On March 9, a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) travelled to Oklahoma to conduct an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:
- Fire Chief
- FD Safety Officer
- Crew members working with the Corporal
- FD Safety Investigation Team
- Fire Fighter's Local Union President
- Corporal's spouse

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

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Investigative Results

Incident Response. On March 4, 2009 at about 0630 hours the Corporal arrived at his fire station for his 24-hour shift. The Corporal was one of four FD members assigned to Engine 25 (E-25) (Sergeant, Captain, Corporal, Fire Fighter). Prior to the afternoon apartment fire, E-25 responded to two emergency calls, a minor vehicle accident at 0832 hours and an emergency medical system (EMS) incident at 1336 hours.

At 1417 hours, the FD responded to a two-alarm apartment fire. The ambient temperature was 71 degrees Fahrenheit (°F) with a heat index of 77 °F and a southern wind at approximately 24 mph. Upon arrival a FD Chief reported a two-story apartment complex with heavy smoke. At 1428 hours the Chief requested a third alarm. As part of the third alarm, E-25 arrived on-scene at 1435 hours.

Upon arrival E-25 was assigned to the RIT. The crew staged in front of the apartment building wearing full personal protective equipment (including self contained breathing apparatus (SCBA)). At approximately 1442 hours the fire was reported under control and E-25 was re-assigned to overhaul. The crew began overhaul operations in a breezeway at about 1449 hours still wearing their bunker gear, but they had doffed their SCBA. After approximately 16 minutes of overhaul, the crew took a break. They removed their helmets, gloves and coats, and drank water retrieved from the incident rehabilitation station. After resting about 10 minutes, the crew continued overhaul using a 1 3/4" charged hose line to wet down hot spots. The crew completed overhaul at about 1526 hours and began to help reload hose.

At 1558 hours, crewmembers of E-25 were the only remaining FD personnel at the fire scene. The crew was loading their gear into the apparatus and preparing to leave the fire scene when the Corporal complained of back pain. While sitting on the curb the Corporal tried lying down and pulling his knees to chest. He then sat up and complained of more severe back pain and added that he was losing his vision. An ambulance was called, and shortly thereafter the Corporal lost consciousness (about 1601 hours).

All members of E-25 were paramedics and ALS measures were initiated immediately. An oropharyngeal airway was placed and ventilations were provided via bag-valve mask and high flow oxygen. A cardiac monitor was attached to the Corporal showing ventricular fibrillation (VFib). The first shock was administered at 1603 hours without change in the Corporal's heart rhythm. CPR was begun. The first round of epinephrine was administered followed by a second shock at 1605 hours. Vasopressor administration included epinephrine at 3-5 minute intervals in addition to antiarrhytmic administration of aminodarone.

At 1608 hours the ambulance arrived on scene. The Corporal's heart rhythm remained in VFib and a third shock was administered. The Corporal was intubated at 1609 hours with proper placement determined by visualization of the tube passing through the vocal cords, bilateral breath sounds, absence of epigastric sounds, and confirmed by end-tidal carbon dioxide testing [AHA 2000]. The Corporal remained in VFib and a forth shock was administered at 1610 hours followed by another round of IV medications. At this time a ResQ-Pod® was attached to the endotracheal tube.

The Corporal was placed onto a cot and loaded into the ambulance which departed for the hospital ED at 1617 hours. ALS and CPR continued enroute. The ambulance arrived at the ED at 1619 hours. The ED staff continued resuscitation efforts for 24 minutes without a change in the Corporal's clinical condition. At 1643 hours, the Corporal was pronounced dead by the attending physician and resuscitation efforts were discontinued.

Investigative Results (cont.)

Medical Findings. The death certificate, completed by a pathologist from the office of the Chief Medical Examiner, listed the cause of death as coronary artery disease. The autopsy revealed almost total occlusion of the distal left circumflex coronary artery, no significant blockages of the other coronary arteries, left ventricular hypertrophy (LVH), and a carboxyhemoglobin level of <5%, suggesting minimal carbon monoxide (CO) exposure during fire fighting activities. See Appendix A for more complete autopsy findings. The Corporal was an apparently healthy individual who rarely saw his physician. His most recent medical evaluation in April 2008 showed a borderline high total cholesterol of 235 milligrams per deciliter (mg/dL) (desirable < 200 mg/dL; borderline high 200-239 mg/dL; high ≥ 240 mg/dL), a low HDL cholesterol of 34 mg/dl (normal 40-59), and a borderline high LDL cholesterol of 138 mg/dl (optimal < 100 mg/dL; near optimal 100-129 mg/dL; borderline high 130-159 ml/dL) [National Cholesterol Education Program, 2001]. His body mass index (BMI) of 30.1 suggested borderline obesity [AHA 2010a]. The Corporal did not have any other CAD risk factors (diabetes, hypertension, smoking, or family history). The Corporal exercised intermittently on the station's exercise equipment, but the frequency and duration of his workouts is unknown.

Description of the Fire District (FD)

The FD consists of over 900 uniformed personnel working out of 35 fire stations and serving a population of over 500,000 residents, in an area of over 600 square miles.

Post-Offer/Pre-placement Medical Evaluations. New hires receive a complete medical evaluation which includes a health history, physical examination, complete blood cell count, blood chemistry (occupational panel of 20 variables), cholesterol testing, urinalysis, urine drug screen, spirometry, vision testing, hearing testing, resting EKG, stress EKG test, and chest X-ray.

Periodic Medical Evaluations. Members receive periodic medical evaluations with the frequency based on age; fire fighters in their 20's receive evaluations every 3 years, fire fighters in their 30's receive evaluations every 2 years, and fire fighters over 40 years receive evaluations every year. The content of the periodic medical evaluation is the same at the post-offer/pre-placement evaluation except that chest X-ray, urine drug test, and stress EKG tests (unless indicated by the physical examination or history) are omitted.

Fitness/Wellness Programs. The FD has a mandatory health and wellness program for firefighters. The program is designed to be positive and non-punitive by not setting fitness standards. However, all uniformed personnel must have an annual fitness assessment and are expected to participate in their personalized exercise programs. The program allows for on-duty participation (up to 90 minutes) and the fire stations are equipped with aerobic and weight lifting equipment.

Discussion

CAD and the Pathophysiology of Sudden Cardiac Death. This Corporal suffered sudden cardiac death after performing fire fighting activities. 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 Corporal had one CAD risk factor (high blood cholesterol), one borderline CAD risk factor (obesity), and had CAD confirmed at autopsy.

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 Corporal 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, the Corporal'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. The 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 Corporal collapsed shortly after serving as a member of the RIT during a 3rd alarm fire, and performing moderately heavy physical work during overhaul operations. Given the Corporal's underlying severe single vessel CAD, NIOSH investigators concluded that the Corporal died from a probable heart attack triggered by his fire fighting duties.

Discussion (cont.)

Left Ventricular Hypertrophy. On autopsy, the Corporal was found to have LVH which increases 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 (CAD) [Siegel 1997]. The Corporal was not known to be hypertensive, and the autopsy did not reveal a heart valve problem. Therefore, the Corporal's CAD was the most likely cause of the LVH.

Carbon Monoxide, Carboxyhemoglobin Levels, and Carbon Monoxide Poisoning. Carbon monoxide is a component of fire smoke. When inhaled, CO crosses the alveolar (lung) membrane and binds to hemoglobin, forming carboxyhemoglobin (COHb). The COHb reduces the availability of oxygen to other tissues and disrupts the intercellular use of oxygen, which can lead to hypoxia (inadequate oxygen supply) [Alonso et al. 2003]. The brain and the heart are the organs most vulnerable to hypoxia. Symptoms/signs associated with CO poisoning include headache, dizziness, weakness, nausea, confusion, fast heart rate, and shortness of breath [Ernst and Zibrak 1998]. The Corporal did not report any of these symptoms prior to his collapse.

COHb levels in the blood are used to assess CO exposure and CO poisoning. At autopsy, the Corporal's COHb level was <5.0%, a level not considered clinically important [Piantadosi 2002]. Because additional laboratory testing was not done, it is unclear if the Corporal's COHB level was actually <3% the level typical for a nonsmoker [Ernst and Zibrak 1998]. Resuscitation efforts (intubation and administration of 100% oxygen for 34 minutes) would be expected to accelerate the elimination of COHb and lower COHb levels [Ernst and Zibrak 1998; Alonso et al. 2003]. However, the Corporal never regained a heartbeat; therefore, these resuscitation measures probably had minimal impact on lowering his COHb level.

In summary, the Corporal may have had a slightly elevated COHb level due to carbon monoxide exposure during overhaul. Nonetheless, it is unlikely this CO exposure triggered his probable heart attack or his sudden cardiac death.

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 2007]. This voluntary industry standard provides medical requirements for candidates and current fire fighters. The Corporal had no known medical conditions that would have precluded his work as a fire fighter.

NFPA 1582 also provides guidance on screening fire fighters for CAD and sudden cardiac death. One such screening test is the exercise stress EKG test. NFPA 1582 recommends an exercise stress EKG test be performed "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007]. 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:

Discussion (cont.)

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

A maximal stress test was not indicated based on the Corporal's age of 43 years and only one CAD risk factor. Therefore, even if the FD had been following all aspects of NFPA 1582, it is unlikely his sudden cardiac death could have been prevented.

Recommendations

NIOSH offers the following recommendation to reduce the risk of heart attacks and sudden cardiac arrest among fire fighters at this, and other fire departments across the country. It is unlikely, however, that the following recommendation could have prevented the Corporal's death.

Recommendation #1: Provide medical evaluations consistent with NFPA 1582.

Guidance regarding the content and frequency of periodic medical evaluations and examinations 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 2007]. These documents aid physicians in determining a fire fighter's medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.
The FD's medical evaluation program differs from NFPA 1582 in a few areas. The first involves the frequency of medical evaluations for members. NFPA 1582 recommends annual evaluations rather than periodic evaluations based on the fire fighter's age.

The second area of discrepancy involves the content of the evaluation for both candidates and members. Currently, the FD conducts stress EKG tests on all candidates, regardless of the candidate's age or CAD risk factors. NFPA recommends that stress EKG tests be performed on candidates and members only if indicated by history or physical examination (see discussion section of this report). Given that many of the candidates are younger than the recommended age for stress testing (45 years for men), eliminating

Recommendations (cont.)

this testing represents a potential cost saving for the FD. Finally, the FD is not performing annual resting EKGs for members as stated in the text of NFPA 1582. However, the appendix of NFPA 1582 states, "(Periodic resting electrocardiograms [EKGs] have not been shown to be useful but can be reasonable as a member's age increase.)" Therefore, the FD should consider, but not necessarily require, annual resting EKGs for its members.

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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
• Near total occlusion of the left circumflex coronary artery
• No significant occlusion of the other coronary arteries

Left Ventricular Hypertrophy (LVH)
Left ventricle and septal wall 1.5 and 1.7 centimeters (cm) respectively
(normal by autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997];
(normal by echocardiographic measurement is 0.6–1.1 cm) [Armstrong and Feigenbaum 2001]

Abdominal obesity

No soot present in the airways

Carboxyhemoglobin is less than 5% suggesting the Corporal was not exposed to toxic levels of carbon monoxide.

Blood tests were negative for alcohol and other illicit drugs

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