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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 *December, 2010*

Captain Suffers Cardiac Death While Attending Training Drills – New York

Executive Summary

On April 12, 2010, a 65-year-old male Captain of a volunteer department suffered a fatal cardiac event after participating in a self-contained breathing apparatus (SCBA) drill. Approximately 20 minutes after completing the evolution the Captain complained of chest pains and on-site Emergency Medical Service (EMS) personnel were notified. En route to the ED the Captain went into cardiac arrest. The ambulance crew initiated Advanced Life Support (ALS) care. The cardiac monitor did not detect a shockable cardiac rhythm, so the ambulance crew provided cardiopulmonary resuscitation (CPR) and ALS care until arrival at the ED. Once inside the ED, advanced cardiac life support (ACLS) measures, including intubation, were performed. Despite these efforts, the Captain died. The death certificate listed the immediate cause of death as "acute myocardial infarction." NIOSH investigators agree with this assessment and that the Captain's relatively modest exertion may have been enough to trigger a heart attack due to his undiagnosed underlying coronary heart disease.

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

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

- ***Incorporate exercise stress tests following standard medical guidelines into the Fire Department's medical evaluation program.***

- ***Perform an annual physical performance (physical ability) evaluation.***

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Introduction & Methods

On April 12, 2010, a 65-year-old volunteer Captain complained of chest pain following SCBA training. During transport to the hospital ED, the captain suffered a cardiac arrest and subsequently died. NIOSH was notified of this fatality on April 13, 2010 by the U.S. Fire Administration. NIOSH contacted the affected fire district (FD) on April 23, 2010 to obtain additional information, and again on August 10, 2010, to request further information and schedule the investigation. On October 18, 2010 a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:
- Fire Chief
- Crew members working with the Captain
- Paramedics who treated the Captain
- Captain's spouse, son and daughter
- Captain's personal physician and FD physician

The NIOSH investigator reviewed the following documents in preparing this report:
- FD records
- FD general operating procedures
- FD incident report
- Witness statements taken shortly after the incident
- Ambulance report
- Death certificate
- Medical examiner's report
- Hospital records
- Personal physician medical records
- FD medical records

Investigative Results

Incident. On April 12, 2010, at approximately 1900 hours personnel from the FD met for training at a nearby facility. The focus of the evening's training was emergency evacuation procedures using escape ropes to descend out of a window. Not all firefighters could participate in the escape rope drill simultaneously; therefore a subgroup of five firefighters (including the Captain) took part in an SCBA drill designed to simulate wearing a SCBA under varying conditions.

The SCBA drill consisted of a fixed prop (maze) familiar to the Captain and used by this FD many times. The participants, in full bunker gear, donned their SCBA and facepieces (not on air) and maneuvered through the maze. One complete evolution through the maze took approximately 5 minutes. Throughout the drill the training officer in charge monitored the condition of the firefighters (including the Captain) and they all reported that they were doing fine. Following the drill the firefighters and the officer sat on a set of steps outside the prop to "catch their breath" and to review the drill. After spending approximately 5-10 minutes together on the steps the firefighters dispersed, with some firefighters rejoining the larger group to participate in the escape rope training. The Captain and several other firefighters returned their air packs to the rescue apparatus and then gathered around an engine parked by the escape rope training to observe the training exercises.

While watching the training exercises (an estimated 20-30 minutes after completing the SCBA drill), the Captain began having chest pain. Emergency medical technicians (EMTs)

Investigative Results (cont.)

from his FD immediately began evaluating the Captain and summoned the on-scene ALS ambulance.

At 2006 hours, a Chief at the training center indicated that the ALS ambulance crew on scene was providing care to the Captain. EMS personnel found the Captain dressed in bunker gear, alert and oriented, and complaining of non-radiating, substernal chest pain. The Captain was loaded onto a stretcher, placed in the ambulance, and provided with oxygen. ALS treatment was initiated in the ambulance

While being transported to the ED the Captain complained of dizziness and shortly thereafter lost consciousness. When the patient became unconscious and unresponsive, CPR was initiated. An oropharyngeal airway was established and ventilations were provided with bag-valve mask with supplemental oxygen. The captain's cardiac rhythm was checked and he was in sinus tachycardia (a non-shockable rhythm).

The ambulance arrived at the ED at 2018 hours. Initial evaluation found the Captain nonresponsive, pulseless, and in ventricular tachycardia. The Captain was intubated with an oral endotracheal tube (with placement confirmed by capnometry) and shocked two times after which the Captain's cardiac rhythm changed to asystole (no heart beat). The Captain received cardiac drugs (epinephrine, atropine, bicarbonate) per ACLS protocols and CPR continued for 14 minutes before he was pronounced dead and resuscitation efforts stopped (2032 hours.)

Medical Findings. The death certificate, completed by the Chief Medical Examiner (CME) for the County, listed the immediate cause of death as "acute myocardial infarct" due to or as a consequence of "atherosclerotic cardiovascular disease." The autopsy, also conducted by the CME, revealed a dilated left ventricle, evidence of coronary artery disease, and a previous (old) heart attack. See Appendix A for a more complete listing of pertinent autopsy findings.

The Captain had a history of high cholesterol managed by his primary care physician (PCP). This included a modified diet and a cholesterol lowering medication (Lipitor) since 1999. His last lipid profile conducted in August 2009 revealed a total cholesterol of 243 milligrams per deciliter (mg/dL) (desirable < 200 mg/dL; borderline high 200-239 mg/dL; high ≥ 240 mg/dL) [National Cholesterol Education Program 2001], a high density lipoprotein (HDL cholesterol) of 45 mg/dL (normal 40-59 mg/dL), and a low density lipoprotein (LDL-cholesterol) of 165 mg/dL (optimal < 100 mg/dL; near optimal 100-129 mg/dL; borderline high 130-159 ml/dL) [National Cholesterol Education Program 2001]. In 2002, he was advised to take low-dose aspirin daily.

In May 2009 the Captain had his last FD medical evaluation. At that time, his blood pressure was 130/76 millimeters of mercury (mmHg) and his resting electrocardiogram (EKG) was normal. At the time of this medical evaluation, a local cardiology medical practice was offering free coronary artery calcium (CAC) scans to all firefighters. The Captain had a scan performed with a resulting CAC score

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Investigative Results (cont.)

of 263 suggesting the Captain was at high risk (> 20 % risk for a cardiac event in 10 years based on equivalent CAD risk factors from the Framingham study) [Hecht 2006]. Based on his CAC score, the PCP referred the Captain to a cardiologist.

The Captain owned his own business as an auto finisher doing upholstery work to restore antique cars. As part of this work, he engaged in moderate manual labor. He also routinely performed yard work and engaged in physical exercise on an irregular basis. He had no established family history of premature cardiovascular mortality (< 55 years for males, < 65 years for females). The Captain had a body mass index (BMI) of 30.4, placing him in the borderline obese range [AHA 2010]. He was a nonsmoker.

Description of the Fire Department

The FD has approximately 120 members, organized into 3 fire companies operating from three fire stations. The FD serves a population of approximately 11,000 in an area of approximately 30 square miles. The FD responded to over 1,000 calls in 2009 (fire and EMS).

Membership. Potential members must complete an application package which is reviewed by a membership committee. If the membership committee approves the application, the applicant must get a medical evaluation (the FD pays for this medical evaluation). Once medical clearance is obtained, an arson background check is performed. Membership applications must first be favorably voted by the membership of one of the fire companies. Following these steps the Board of Fire Commissioners votes on the membership application.

Training. The FD requires members to attend a minimum of 18 hours of education per year, which must include at least 9 hours of hands-on training. The FD routinely offers hands-on training for its members, including the drill performed on the night of the captain's death. The Captain was certified as an Interior Firefighter and had taken numerous training classes.

Pre-placement Medical Evaluations. The FD requires that new members receive a medical examination. This evaluation includes a health history, blood pressure check, physical examination, urinalysis, urine drug screen, spirometry, resting EKG, and hearing and vision test.

Periodic Medical Evaluations. The FD requires and provides for periodic medical evaluations. Members less than 50 years old are required to

Description of the FD (cont.)

have a medical evaluation every other year; members 50 or more years old must have an annual medical evaluation. The medical evaluation consists of the same components as the preplacment medical evaluation except that a urine drug screen is not performed. The medical evaluation may be performed by a PCP or the FD contracted physician. An evaluation conducted by a PCP must use the FD approved paperwork and address the required elements of the FD evaluation.

Medical clearance for SCBA use is required yearly through approval by the FD physician. Fire fighters must be cleared by a physician (PCP or Fire District physician) before returning to work after a serious injury or a serious illness. The District reserves the right to require any firefighter to be cleared by the FD physician before returning to work.

Fitness/Wellness Programs. The FD has a voluntary program that pays half the cost of monthly membership to a local fitness center provided the member uses the facility a minimum of 6 times per month.

Discussion

Coronary Artery Disease and the Pathophysiology of Sudden Cardiac Death. The Captain suffered cardiac arrest after participating in a FD training drill. 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 2009]. Although the Captain had a history of high cholesterol and was borderline obese, he was not known to have CAD prior to his death. However, at autopsy, the Captain was found to have CAD and evidence of a prior (old) myocardial infarction (heart attack).

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 Captain did not have a heartbeat on which to conduct an EKG, his 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 CAD and a previous heart attack, the Captain's death was probably caused by a heart attack.

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Discussion (cont.)

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 high (over 170 beats per minute) owing 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 Captain took part in a training evolution (lasting about 5 minutes) while wearing full bunker gear and carrying his SCBA. He reported the onset of chest pains approximately 20 minutes after completing these drills and went into cardiac arrest a few minutes later. This relatively modest exertion may have been enough to trigger a heart attack because of the Captain's undiagnosed heart disease.

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 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/American College of Cardiology (AHA/ACC) and the Department of Transportation regarding exercise stress tests in asymptomatic persons [Gibbons et al. 2002; Blumenthal et al. 2007]. The Captain had diagnosed hypercholesterolemia. However, he had no other major risk factor for CAD and therefore a stress test was not indicated based on the 2007 edition of NFPA 1582.

However, the AHA/ACC also recommends that patients with a Framingham Risk Score >10% have a stress test [Gibbons el al. 2002]. The Captain had a Framingham Risk Score of 15% [NHBLI 2010]. Therefore, using this criterion, a stress test was indicated. Finally, the Captain did have a CAC score indicating he was at increased risk for heart disease. It appears that the Captain never followed-up on his PCP's recommendation to be evaluated by a cardiologist.

Recommendations

NIOSH investigators offer the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters.

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

Although the FD has a medical evaluation program designed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others, it could be strengthened by adopting additional elements as recommended by various fire service organizations [IAFF/IAFC 2007; NFPA 2007a]. The current program does not include blood tests for cholesterol. High blood cholesterol is an important risk factor for CAD and should be checked on an annual basis. Additionally, exercise stress tests for fire fighters with CAD risk factors (discussed in detail below) should be part of the medical evaluation program.

Recommendations #2: Incorporate exercise stress tests following standard medical guidelines into the Fire District's medical evaluation program.

While age is one of the strongest predictors for a coronary heart disease event, it is not the only risk factor. The FD should take other risk factors (such as cholesterol levels, blood pressure, smoking) into account when determining who should receive exercise stress tests. One approach would be to calculate a Framingham Risk Score [http://hp2010.nhlbihin.net/atpiii/calculator.asp]. For fire fighters with a >20% risk of a cardiac event in the next 10 years, an exercise stress test should be conducted on a periodic basis. The following paragraphs provide recommendations by NFPA, ACC/AHA, U.S. Department of Transportation (USDOT), and the U.S. Preventative Services Task Force (USPSTF) for conducting stress tests in asymptomatic people.

The National Fire Protection Association (NFPA) 1582 states, "Stress EKG with or without echocardiogram or radionuclide scanning shall be performed as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007]. Items in the Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends that sub-maximal (85% of predicted heart rate) stress tests be used as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (e.g., symptom limiting) stress tests with imaging should be use for fire fighters with:

- abnormal screening sub-maximal tests
- cardiac symptoms
- known coronary artery disease
- Males over the age of 45 and females over the age of 55 with two or more risk factors for coronary artery disease. Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (diastolic blood pressure greater than 90 mm Hg), 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).

The ACC/AHA has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA states that the evidence to conduct stress tests in asymptomatic individuals with diabetes mellitus

Recommendations (cont.)

is "Class IIa" which is defined as "conflicting evidence and/or a divergence of opinion about the usefulness/efficacy but the weight of the evidence/ opinion is in favor." The ACC/AHA goes on to say the evidence is "less well established" (Class IIb) for the following groups:

1. Evaluation of persons with multiple risk factors as a guide to risk-reduction therapy with the risk factors essentially the same as the NFPA listed above.
2. Evaluation of asymptomatic men older than 45 years, and women older than 55 years:
    - Who are sedentary and plan to start vigorous exercise
    - Who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters)
    - Who are at high risk for coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The USDOT has also provided guidance for those seeking medical certification for a commercial drivers license. Their expert medical panel recommended exercise tolerance tests for asymptomatic "high risk" drivers [Blumenthal et al. 2007]. They define high risk drivers as those with any of the following:

- Diabetes mellitus
- Peripheral vascular disease
- Person above the age of 45 with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

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

Recommendation #3: Perform an annual physical performance (physical ability) evaluation.

NFPA 1500 recommends that the FD annually evaluate and certify FD members who engage in emergency operations as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007]. This is recommended to ensure that fire fighters are physically capable of performing the essential job tasks of structural fire fighting. The physical ability test could be performed as part of the FD's training program.

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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

Heart Size/Structure

- Left ventricle was symmetrically dilated and 1.0 cm in thickness
- Heart weighs 420 grams
- 0.3 cm focus of scarring in interventricular septum consistent with an old myocardial infarction

Coronary Arteries

- Right dominant distribution of coronary arteries
- Diffuse calcific artherosclerotic narrowing with no greater than 50% luminal narrowing
- No thrombi in epicardial arteries

Microscopic Evaluation

- Myocyte hypertrophy
- Patchy interstitial fibrosis
- Focal acute ischemic changes