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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation December, 2008

Career Fire Fighter Suffers Cardiac Arrest and Dies While Conducting Overhaul Operations at a Structure Fire – Missouri

SUMMARY

On March17, 2008, a 48-year old career Fire Fighter (FF) responded to a fire in a vacant single family dwelling. Dressed in full turnout gear and wearing his self-contained breathing apparatus (SCBA), the FF helped advance a charged hosed line to provide back-up to the front line fire suppression crew. After providing back-up fire suppression for about 10 minutes, the fire was declared under control and overhaul operations began. While performing overhaul activities with full respiratory protection the FF suddenly collapsed. The on-scene emergency medical service (EMS) unit provided advanced life support (ALS) care within 3 minutes, and this continued during transport to the nearest hospital Emergency Department. Despite arriving at the Emergency Department within 8 minutes of his collapse, efforts to revive the FF were unsuccessful. The death certificate and autopsy, completed by the Deputy Medical Examiner, listed "hypertensive and atherosclerotic cardiovascular disease" as the immediate cause of death. The FF's carboxyhemoglobin level was 3% suggesting that carbon monoxide poisoning was not responsible for his death. NIOSH investigators conclude the FF's sudden cardiac death was probably triggered by the FF responding to the fire alarm, the moderate to severe physical exertion associated with his fireground activities, and his underlying coronary and hypertensive heart disease.

It is unlikely the following recommendations could have prevented the FF's death at this time, but NIOSH investigators offer these recommendations to prevent sudden cardiac death in this, and other, Fire Departments across the country.

- ***Consider providing symptom limiting and diagnostic imaging exercise stress tests for fire fighters at increased risk for coronary artery disease and sudden cardiac death.***
- ***Work with the local union to phase-in an annual physical ability test.***

INTRODUCTION & METHODS

On March 17, 2008, a 48-year-old male career FF collapsed during overhaul activities in a vacant single family dwelling. Despite ALS at the fireground, during transport, and at the Emergency Department, the FF died. NIOSH was notified of this fatality on March 18, 2008, by the United States Fire Administration. NIOSH contacted the affected Fire Department shortly thereafter to obtain further information, and again on June 25, 2008, to schedule the investigation. On August 17, 2008, a contractor for

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the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, the NIOSH investigator met with the following individuals and groups:

- Fire Chief
- Principal Assistant to the Fire Chief
- Incident Commander of the fire incident
- Crew members working with the FF
- Representatives from the Fire Department Health and Safety Committee
- Representative from the local union

The NIOSH investigator reviewed the following documents during the preparation of this report:

- Incident report
- Dispatch records
- Ambulance report
- Death certificate
- Autopsy report
- Hospital Emergency Department records
- Fire Department medical evaluations
- Police report
- Crew members' statements
- FF training records
- Fire Department Standard Operating Procedures

INVESTIGATIVE RESULTS

Incident Response. On March 17, 2008, the FF reported for duty at 0700 hours. At 1020 hours his crew responded to a medical call, and was back in service in about 13 minutes. Shortly thereafter, the crew responded to a residential fire alarm at 1033 hours and was back in service at 1044 hours. A coworker reported that the FF was in a particularly good mood that day with no apparent discomfort.

At 1230 hours the FF and his crew were dispatched to a fire in a vacant single family dwelling. They were the second engine to arrive on scene, arriving at 1234 hours. When they arrived the structure was heavily involved in fire. The first engine to arrive had already advanced an 1 ¾" attack line and was performing fire suppression activities. Wearing full turnout gear and their SCBA (about 50 pounds), the FF and another crew member advanced a second attack line toward the fire. The FF and a crewmember who was on the nozzle stretched the charged line to the structure. They were not engaged directly in fire suppression activities, as the first engine company had extinguished visible fire. At approximately 1244 hours, when the fire was extinguished, the FF and his crew member were assigned to perform overhaul. The fire fighter was reported to be wearing his SCBA with the air on during overhaul.

While conducting overhaul activities the FF collapsed at approximately 1259 hours. Several firefighters working in the area immediately responded. They found the FF unresponsive

and carried him out of the structure. Once outside they removed his face piece and took his vital signs, finding shallow breathing and no pulse. Cardiopulmonary resuscitation (CPR) was initiated.

An on-scene ambulance staffed with a paramedic received a call for a FF down at 1302 hours. At 1305 hours they made patient contact finding the FF in respiratory and cardiac arrest. The FF was on a backboard and CPR was in progress when the ambulance crew arrived. A cardiac monitor was attached to the FF revealing asystole. The FF was loaded into the ambulance. An oropharynegeal tube was inserted, CPR was continued and 100% oxygen was provided by bag-valve mask en route to the hospital.

The ambulance arrived at the Emergency Department at 1310 hours. Upon arrival, the FF was still unresponsive, and had no pulse or spontaneous breathing. An electrocardiogram indicated that he was still in asystole. ALS protocols including intubation were followed with no change in the FF's condition. At 1347 hours the firefighter was pronounced dead.

Medical Findings. The death certificate, completed by the Deputy Medical Examiner, listed "hypertensive and atherosclerotic cardiovascular disease" as the immediate cause of death. The autopsy, conducted by the Deputy Medical Examiner on March 18, 2008, revealed an enlarged heart with left ventricular hypertrophy and moderate to severe coronary artery disease (CAD) (Appendix A). The FF's blood had a carboxyhemoglobin level of 3% indicating the FF had not suffered carbon monoxide poisoning.

The FF had a history of hypertension first diagnosed in 2000. The FF was taking a blood pressure medication (Lisinoprol®) and his most recent blood pressure reading (130/80 millimeters of mercury (mmHg)) suggests that his blood pressure was well controlled. The FF also had elevated blood cholesterol with a total cholesterol level of 214 milligrams per deciliter (mg/dL) (normal < 200 mg/dL) and elevated low-density lipoproteins in the 145 mg/dL range (optimal < 100 mg/dL). The FF was not overweight (18.8% body fat as determined by skinfold thickness), and he exercised regularly. The FF was medically-cleared by the Fire Department physician in October 2007.

In February 2006, during his Fire Department medical evaluation, the FF was noted to have a new finding on his resting electrocardiogram (EKG). The FF had significant T-wave inversion in multiple leads which were new from his resting EKG in 2005. The FF was referred to a cardiologist. The cardiologist noted that he had previously seen the FF in May 2004 and in January 2005 and that his EKG was significant for very prominent voltage with bi-phasic T waves. He further noted that the FF had a history of hypertension which may increase the anterior voltage due to mild left ventricular hypertrophy. However, his hypertension was under excellent control and the FF had a normal exercise echocardiogram in May 2004. Therefore, the cardiologist considered the EKG finding consistent with a normal variant seen in young, black athletic males and

indicated that the FF could proceed with all activity, including vigorous activity, with low risk of a sudden cardiac event. With this information, the Fire Department physician cleared the FF for unrestricted full duty.

In 2007 the FF underwent a graded exercise stress test as part of his annual medical examination. He exercised for 7:27 minutes, achieving 10.2 metabolic equivalents (METs) with no symptoms of angina. The test was stopped when he reached 85% of his target heart rate. His post exercise blood pressure was 224/94 mmHg which may be considered a hypertensive response. The physician noted that there were no ST segment changes during the stress test and that there were only rare premature ventricular contractions (PVC) which were not considered significant. The physician also noted his EKG showed biphasic T-waves in the lateral leads. Given this finding was previously evaluated by a cardiologist a year ago, it was considered a normal variant.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the Fire Department consisted of more than 900 uniformed personnel and operated 34 fire stations. The department serves a population of approximately 440,000 residents. In 2007, the department responded to more than 55,000 calls, including over 1400 structure fires.

Hiring/Training. Recruit firefighters attend a 16-week training Academy. The first 8 weeks are devoted primarily to EMS training and preparing for the Candidate Physical Agility Test (CPAT). At 8 weeks recruits must pass the CPAT test to continue in the Academy. The final 8 weeks are devoted to firefighting training and emergency medical technician certification. Following graduation from the Academy, probationary firefighters have a 12-week field apprenticeship during which they rotate through several Engine companies before bidding for their first field assignment. In-service training for firefighting skills and EMS are provided every 6 weeks.

Pre-placement Medical Evaluations. Upon being offered conditional employment with the Fire Department, candidates must be medically cleared prior to training at the Academy. The medical evaluation is based on the National Fire Protection Association (NFPA) 1582: Standard on Comprehensive Occupational Medicine Program for Fire Departments. This medical evaluation is performed by an occupational medicine clinic under the supervision of a contracted Fire Department physician.

Periodic Medical Evaluations. The Fire Department requires annual medical evaluations for all fire fighters consistent with NFPA 1582. The Fire Department conducts exercise stress tests annually as part of the medical examination. Medical clearance for SCBA use is required and conducted during the annual medical evaluation. If a fire fighter suffers a serious injury or illness on or off the job, they must be cleared back to duty by the Fire Department physician.

Fitness/Wellness Programs. All firefighters receive a fitness evaluation and an individualized fitness prescription. The department houses exercise facilities, provides time on duty to exercise, employs a fitness trainer who consults with departmental peer-fitness trainers, and provides access to fitness centers for use off-duty. The department offers a comprehensive wellness program, including smoking cessation, weight control, blood pressure, diabetes, and cholesterol control programs.

DISCUSSION

Coronary Artery Disease (CAD) and the Pathophysiology of Heart Attacks. In the United States, CAD (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death. Risk factors for its development include age over 45, male gender, family history of coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2008]. The FF had three known CAD risk factors (male gender, over 45 years, high blood pressure), and high blood cholesterol (which was elevated but was not above 240 mg/dL. He was also an African American and this group is more likely to have hypertension and is at higher risk of heart disease [AHA 2008]. The FF was also found to have significant atherosclerotic disease at autopsy.

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 1992]. This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. The FF did not have definitive evidence of a thrombus at the time of autopsy.

Establishing the occurrence of an acute heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus/plaque rupture. In the FF's case, he never regained a heart rhythm on which an EKG could reveal characteristic changes, cardiac enzyme testing was not performed (but we would not expect the enzymes to become positive for at least 4 hours post-heart attack), and no coronary artery blood clot/plaque rupture was found at autopsy. However, occasionally (16-27% of the time) post-mortem examinations do not reveal the coronary artery blood clots/plaque rupture during acute heart attacks [Davies 1992; Farb 1995]. The clinical scenario of this FF's death could be consistent with a heart attack [Thaulow 1993; Libby 2005]. Another possible etiology for this FF's sudden death is a primary cardiac arrhythmia. Hypertension, left ventricular hypertrophy, and cardiomegaly all increase the risk of an arrhythmia causing sudden cardiac death [Bigger 1994; Haider 1998; Verdecchia 1998].

Hypertension and Left Ventricular Hypertrophy. On autopsy, the FF had left ventricular hypertrophy which was probably responsible for his enlarged heart. 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, chronic cardiac ischemia due to CAD, or, less commonly, hypertrophic cardiomyopathy. On autopsy, the FF had normal heart valves, moderate to severe CAD, and hypertrophy of both the left ventricular wall and interventricular septum. The right ventricle wall was not enlarged. These findings suggest that hypertension was probably responsible for his left ventricular hypertrophy [Hughes 2004; Maron 2005]. Left ventricular hypertrophy increases the risk for CAD, ventricular arrhythmias, and sudden cardiac death [Siegel 1997; Phillips and Diamond, 2005].

The FF had annual resting EKGs as part of his annual medical evaluation, yet none of his tracings met the voltage criteria for left ventricular hypertrophy. A variety of criteria are available to diagnose left ventricular hypertrophy by EKG, but they only have sensitivities of about 5 to 10%. The sensitivities are particularly low in men younger than 50 and African Americans [Levy 1990; Verdecchia 1998; Okin 2002; Basavarajaiah 2008].

In 2006 the FF had a new finding on his resting EKG: an inverted T wave. While this finding could be due to a number of cardiac and non-cardiac conditions, it is most commonly associated with left ventricular hypertrophy [Huzar 2002, Franz 2004]. To further evaluate this new finding, the FF was referred to a cardiologist who noted that the FF's hypertension was under excellent control and that the FF had a normal exercise echocardiogram in May 2004. In light of the FF's overall health and high fitness level, the cardiologist considered the abnormal EKG finding consistent with a normal variant seen in young, black athletic males. With this information, the Fire Department physician cleared the FF for unrestricted full duty.

The NIOSH Fire Fighter Fatality Investigation and Prevention Program notes that many fire fighters suffering sudden cardiac death have left ventricular hypertrophy at autopsy yet their resting EKGs have not detected this condition. Additional research is needed to assess whether the voltage criteria for left ventricular hypertrophy needs to be revised, or whether echocardiograms are a more appropriate screening test for left ventricular hypertrophy in fire fighters with long-standing hypertension.

Physiological Stress of Firefighting. Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death [Tofler 1992; Mittleman 1993; Willich 1993; Albert 2000]. Fire fighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and persist through the course of response activities [Barnard 1975; Lemon 1977; Hurley 1980; Kuorinka 1981; Manning 1983; Guidotti 1992; Smith 2001]. Therefore, it should not be surprising that recent epidemiologic studies found fire suppression, training, alarm response, and strenuous physical activity on the job in the preceding 12 hours independently increase the risk for a sudden cardiac event [Kales 2003, Kales 2007, Hales 2007]. The FF was engaged in overhaul activity at the time of

his collapse. He had pulled an 1 ¾ " back-up line during the suppression efforts while wearing personal protection equipment weighing at least 50 pounds and provided fire suppression assistance for approximately 10 minutes. The FF had been performing overhaul activities in full personal protective equipment for approximately 12 minutes prior to his collapse.

NIOSH investigators conclude the FF's sudden cardiac death was probably triggered by the FF responding to the fire alarm, the moderate to severe physical exertion associated with his fireground activities, and his underlying coronary and hypertensive heart disease.

Occupational Medical Standards for Structural Firefighting and the Use of the Exercise Stress Test to Screen for CAD. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the National Fire Protection Association (NFPA) has developed NFPA 1582 [NFPA 2007]. 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. Exercise stress tests are an appropriate screening test for CAD, however testing asymptomatic individuals is controversial. 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 used 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 Fire Department has adopted the guidelines in NFPA 1582 and an exercise stress test was performed on this FF at his most recent medical exam. The FF passed the stress test. This FF was a male over the age of 45 and he had a history of hypertension which was controlled by medication. He also had elevated cholesterol levels. However, his cholesterol level was below the 240 mg/dL cut off identified in the 1582 standard, thus a symptom limited diagnostic imaging exercise test was not warranted based on guidelines outlined in the standard.

RECOMMENDATIONS

It is unlikely the following recommendations could have prevented the FF's death at this time. NIOSH investigators, however, offer these recommendations to prevent sudden cardiac death in this, and other, Fire Departments across the country.

Recommendation #1: Consider providing symptom limiting and diagnostic imaging exercise stress tests for fire fighters at increased risk for coronary artery disease and sudden cardiac death.

We applaud the occupational health clinic for implementing a comprehensive medical evaluation program, and for conducting sub-maximal exercise stress tests on an annual basis. However, for male FFs over the age of 45 with two or more CAD risk factors, consider symptom-limiting imaging stress tests [NFPA 2007]. Although following this recommendation would not have prevented this fatality, its adoption could prevent future cardiac fatalities.

Recommendation #2. Work with the local union to phase-in an annual physical ability test.

NFPA 1500 requires fire departments to develop physical performance requirements for fire fighter candidates and fire department members. "Members who engage in emergency operations shall be annually qualified as meeting the physical performance requirements established by the fire department" [NFPA 2007b].

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INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by:

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Appendix A: Pertinent Autopsy Findings

- ardiomegaly (590 grams) with mild biventricular dilation
- Left ventricular hypertrophy
- Moderate to focally severe coronary artery atherosclerosis
  - — Up to 80% stenosis, distal left circumflex coronary artery
  - — 60% luminal stenosis, proximal left anterior descending coronary artery
  - — 60% luminal stenosis, right coronary artery
- Pulmonary congestion/edema in the lungs
- Mild to moderate aortic atherosclerosis
- Arteriolonephrosclerosis
- Negative blood testing for alcohol or drugs
- Postmortem carboxyhemoglobin levels of 3%

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The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In fiscal year 1998, the Congress appropriated funds to NIOSH to conduct a fire fighter initiative. NIOSH initiated the Fire Fighter Fatality Investigation and Prevention Program to examine deaths of fire fighters in the line of duty so that fire departments, fire fighters, fire service organizations, safety experts and researchers could learn from these incidents. The primary goal of these investigations is for NIOSH to make recommendations to prevent similar occurrences. These NIOSH investigations are intended to reduce or prevent future fire fighter deaths and are completely separate from the rulemaking, enforcement and inspection activities of any other federal or state agency. Under its program, NIOSH investigators interview persons with knowledge of the incident and review available records to develop a description of the conditions and circumstances leading to the deaths in order to provide a context for the agency's recommendations. The NIOSH summary of these conditions and circumstances in its reports is not intended as a legal statement of facts. This summary, as well as the conclusions and recommendations made by NIOSH, should not be used for the purpose of litigation or the adjudication of any claim. For further information, visit the program website at

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