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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 *September 2008*

Engineer Suffers Fatal Heart Attack at Scene of Residential Fire – Michigan

SUMMARY

On June 22, 2007, a 56-year-old male volunteer Engineer was paged to a residential fire. He responded to a nearby fire station and drove an engine to the scene. On-scene, he assisted crew members in pulling an uncharged 1¾-inch hoseline. The fire was extinguished shortly thereafter, and the Engineer notified the Fire Marshal that he did not feel well and that his chest hurt. Assessment provided in the rehabilitation (rehab) unit by the on-scene ambulance crew revealed the Engineer was suffering from a heart attack (myocardial infarction). Despite advanced life support treatment initiated in rehab, the Engineer became unresponsive with labored breathing. As the ambulance began transport to the hospital's Emergency Department, the Engineer lost his pulse and stopped breathing. Cardiopulmonary resuscitation (CPR) was begun and advanced life support treatment continued en route to the hospital. Approximately 55 minutes after his collapse, despite CPR and advanced life support administered on-scene and at the hospital, the Engineer died. The death certificate, completed by the medical examiner, listed "myocardial infarction" as the cause of death. No autopsy was conducted. The NIOSH investigator concludes the Engineer's response to the structure fire and his exertional activity at the fire, coupled with his underlying atherosclerotic coronary artery disease (CAD), triggered his heart attack and sudden cardiac death.

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the Engineer's collapse, perhaps his sudden cardiac death could have been prevented at this time.

- ***Provide annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.***
- ***Incorporate exercise stress tests following standard medical guidelines into the Fire Department's medical evaluation program.***
- ***Secure endotracheal tubes to prevent dislodgment during patient treatment, transfer, and transport.***

- ***Phase-in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***Perform an autopsy on all on-duty fire fighter fatalities.***

INTRODUCTION & METHODS

On June 22, 2007, a 56-year-old male volunteer Engineer suffered a heart attack while assisting with fire suppression efforts at a residential fire. Despite CPR and advanced life support administered by crew members, the Fire Department ambulance crew, and personnel in the hospital Emergency Department, the Engineer died. NIOSH was notified of this fatality on June 25, 2007 by the United States Fire Administration. NIOSH contacted the affected Fire Department to gather additional information on July 2, 2007, and on May 15, 2008 to initiate the investigation. On May 27, 2008, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Michigan to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Family members of the Engineer

NIOSH personnel reviewed the following documents:

- Fire Department policies and operating guidelines
- Fire Department training records
- Fire Department annual report for 2007
- Fire Department incident report
- Witness statements
- Emergency medical service (ambulance) incident report
- Fire Department physical examination protocols
- Hospital Emergency Department record
- Death certificate
- Primary care provider medical records

RESULTS OF INVESTIGATION

Incident. On June 22, 2007, the Engineer's Fire Department (Engines 2 and 3 and Rescue 3), along with a mutual aid fire department, an ambulance, and an incident commander, were dispatched to a residential fire at 1454 hours. The Engineer happened to be driving near one of the Department's fire stations, heard the dispatch and responded to the nearby station (not his assigned fire station). Other crew members had begun to pull Engine 3 out of the station, but when the Engineer arrived, he assumed driver/operator duties. At 1458 hours, Engine 3 left the station with the Engineer, a lieutenant, and two fire fighters.

The incident commander arrived on-scene at 1501 hours, advised dispatch of a working fire, and relayed assignments to incoming units.

The ambulance arrived at 1507 hours and set up the rehab unit. The weather conditions at this time included scattered clouds, a temperature of 73° Fahrenheit, 37% relative humidity, a falling barometric pressure of 30.11, and 8.1 mile per hour winds out of the north-northwest [NOAA 2008; Weather Underground 2008].

Engine 3 arrived at 1510 hours and was tasked to enter through the garage, search the structure with a thermal imaging camera for hot spots, and turn off circuit breakers. The Engineer and crew members pulled an uncharged 1¾-inch crosslay hoseline to the front door. The mutual aid fire department arrived at 1511 hours and began interior fire suppression operations. The Engineer operated the Engine's pump panel while his crew members performed their assigned tasks. Engine 2 arrived and was staged behind Engine 3, while Rescue 3 arrived and was tasked with refilling self-contained breathing apparatus (SCBA) bottles. Fire fighters on-scene either passed by or spoke with the Engineer and, according to witness statements, he did not complain of any chest pain, shortness of breath, or other cardiac problems. The fire was declared under control at 1521 hours.

A few minutes later, the Engineer told the engineer of Engine 2 that he didn't feel well. When asked to clarify the comment, the Engineer said, "I don't feel good from the waist up, my chest hurts" and that he should go to rehab. Both walked to rehab, and the Engineer related that he had felt ill since he arrived at the fire scene.

At 1525 hours, the Engineer entered the ambulance stationed at the rehab unit, where a paramedic began an evaluation. Initial assessment revealed a blood pressure of 123/75 millimeters of mercury (mmHg), a pulse rate of 68 beats per minute (bpm), and a respiration rate of 20 breaths per minute. The Engineer was pale, diaphoretic (sweaty), and complained of chest pain. He was placed on oxygen and a cardiac monitor, which revealed a normal sinus rhythm with ST segment elevation (finding consistent with a heart attack). An intravenous (IV) line was placed (1535 hours), and he was given a nitroglycerin tablet under his tongue which reduced his chest pain, but also lowered his blood pressure (88/53 mmHg). The ambulance departed the scene at 1543 hours en route to the hospital's Emergency Department.

During transport, a cardiac monitor showed the Engineer developed a heart arrhythmia (nonspecific intraventricular block). Shortly thereafter, the Engineer suffered seizure-like activity, began ineffective breathing, and his heart rate and blood pressure dropped. At 1545 hours, the Engineer became unresponsive. He was intubated at 1550 hours with proper tube placement determined by condensation in the tube and bilateral breath sounds. Secondary technology tests recommended by the American Heart Association were not performed. Despite being intubated, the Engineer's heart beat stopped (cardiac arrest) and CPR was begun. The ambulance drove over a bump and the intubation tube became dislodged. The Engineer was re-intubated with proper tube placement again being determined by bilateral breath sounds and condensation in the tube.

At the entrance of the hospital, the intubation tube became dislodged again. The ambulance arrived at the hospital at 1608 hours.

Inside the Emergency Department, the Engineer was re-intubated. The cardiac monitor revealed asystole/ventricular fibrillation (VF) and a shock was delivered with no positive change in the Engineer's heart rhythm. Cardiac resuscitation medications consistent with advanced life support were given and CPR continued until 1620 hours, when the Engineer was pronounced dead by the attending physician.

Medical Findings. The death certificate, completed by the Medical Examiner, listed "myocardial infarction" as the cause of death. No autopsy was performed.

The Engineer was 74 inches tall and weighed 235 pounds, giving him a body mass index (BMI) of 30.16. A BMI >30.0 kilograms per meters squared (kg/m2) is considered obese [CDC 2008]. The Engineer's risk factors for CAD included: family history, male gender, and borderline obesity. In 2003 the Engineer was evaluated by his primary care physician for episodic chest pressure/ discomfort and referred to a cardiologist for an imaging stress test. The Engineer exercised to 9 metabolic equivalents (METS) and stopped due to fatigue. He had a good blood pressure response, no angina, no arrhythmias, and no electrocardiogram (EKG) changes suggestive of ischemia. The imaging study showed a normal left ventricular ejection fraction (61%), however there was a small reversible defect in one area of the heart. The Engineer and his physicians opted for medical management, rather than a cardiac catheterization, and one baby aspirin per day was prescribed.

About 10 months later (August 2004), the Engineer suffered another episode of chest discomfort and a resting EKG showed show non-specific changes. He was referred to his cardiologist who repeated the imaging stress test. The Engineer exercised to 11.5 METS with a good blood pressure response, no symptoms, no arrhythmias, and a normal left ventricular ejection fraction (55%). Again, the imaging study showed a non-life threatening reversible defect in the inferior region of the heart, but this time the defect was a little larger. The cardiologist recommended a cardiac catheterization, however the procedure was not covered by insurance. The physician recommended continued medical management which now included aspirin, a beta-blocker, and a statin (high blood cholesterol pill despite not having elevated blood cholesterol levels).

He followed-up with his primary care physician and his cardiologist on an annual basis. Since 2004 he did not report heart-related symptoms (chest pain, chest pressure, angina, shortness of breath on exertion, etc.) to his physicians, his family, or the Fire Department.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the volunteer Fire Department consisted of 53

uniformed personnel and served a population of 7,900 residents in a geographic area of 103 square miles. There are 5 fire stations.

In 2007, the Fire Department responded to 295 calls: 190 emergency medical calls, 86 fires, and 19 mutual aid calls.

Membership and Training. The Fire Department requires all new fire fighter applicants to be 18 years of age, have a valid state driver's license, pass a background check, a pre-placement medical evaluation (described below), a physical agility test, and an oral interview. The candidate's application package is then reviewed by the Fire Chief and Fire Department Officers prior to being selected for membership. New members must become State-certified to the Fire Fighter I and II levels within 2 years. The State requires fire fighters to take 24-hours of training each year. The Engineer was certified as a Fire Fighter II, Driver/Operator, HazMat Operations, Wildland, and had 4 years of firefighting experience.

Pre-placement Medical Evaluation. The Fire Department currently requires a pre-placement medical evaluation for all new members, regardless of age. Components of this evaluation include the following:

- A complete medical history and OSHA respirator medical evaluation questionnaire
- Physical examination (including vital signs)
- Complete blood count with lipid panel
- Pulmonary function test
- Hearing test (whisper at 5-feet)
- Audiogram
- Vision screen
- Urinalysis
- Resting EKG
- Lumbar X-ray
- Chest X-ray (baseline)

These evaluations are performed by a City-contracted physician, who makes a determination regarding medical clearance for firefighting duties.

Periodic Medical Evaluation. Periodic (annual) medical evaluations are not currently required by the Fire Department. However, the Fire Department plans to begin a periodic medical evaluation program in 2008.

An annual SCBA facepiece fit test and a pulmonary function test are required for interior structural fire fighters. If a member is injured on duty, the member must be evaluated by their primary care physician and the Worker's Compensation physician, who makes the final determination regarding "return to duty."

Health and Wellness Programs. The Fire Department does not have a wellness/fitness program, and exercise (strength and aerobic) equipment is not available in the fire stations. However, a local gym offers reduced membership to fire fighters. Health maintenance pro-

grams are not available from the City. The Fire Department plans to begin an annual physical ability test in 2008. Components include a one-person ladder carry and raise, high-rise pack carry, victim drag, and hose pull. If a member does not pass this test, he/she will be placed on restricted duty until they can pass the test.

DISCUSSION

In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age over 45, male gender, family history of CAD, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2008]. The Engineer had four of these risk factors (age over 45, male gender, family history of CAD, and borderline obesity).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Heart attacks typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques.

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In the Engineer's case, the EKG confirmed the occurrence of an acute (abrupt onset) heart attack.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks [Willich et al. 1993; Mittleman et al. 1993; Siscovick et al. 1984; Tofler et al. 1992]. The Engineer had responded to the structure fire and assisted in stretching a hose line. This activity expended about 9 METs, which is considered moderate to heavy physical activity [Gledhill and Jamnik 1992]. Heart attacks in fire fighters have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. Given the Engineer's underlying CAD, the physical stress of responding to the call and performing firefighting duties probably triggered his heart attack, resulting in his subsequent cardiac arrest, and 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 minimum medical requirements for candidates and current fire fighters.

NFPA 1582 considers CAD, including angina pectoris (chest pain), to be a Category A condition for candidates, that is, "a medical condition that will preclude a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the member or others" [NFPA 2007]. For members, the standard states that CAD compromises a member's ability to safely perform many of the essential job tasks of structural firefighting, specifically wearing SCBA and advancing water-filled hoselines [NFPA 2007]. The Standard states that the physician shall report the applicable job limitations to the fire department if any one of the following is present:

1. Current angina pectoris even if relieved by medication
2. Persistent significant stenosis in any coronary artery (greater than 70 percent lumen diameter narrowing) following treatment
3. Lower than normal left ventricular ejection fraction as measured by radionuclide scan, contrast ventriculography, or echocardiography
4. Maximal exercise tolerance of less than 42 milliliters of oxygen per minute per kilogram or less than 12 metabolic equivalents (METS)
5. Exercise-induced ischemia or ventricular arrhythmias observed by radionuclide stress test during an evaluation reaching at least a 12-METS workload
6. History of myocardial infarction, angina, or coronary artery disease with persistence of modifiable risk factor(s) for acute coronary plaque rupture (e.g., tobacco use, hypertension despite treatment or hypercholesterolemia with cholesterol greater than or equal to 180, or low density lipoproteins greater than or equal to 100 despite treatment, or glycosylated hemoglobin greater than 7 despite exercise and/or weight reduction) [NFPA 2007]

The consulting cardiologist presumed the Engineer had CAD, and his chest pressure probably represented stable angina. With the Engineer's imaging exercise stress test showing reversible ischemia he probably did not meet NFPA 1582 requirements. If his condition were presented as life threatening and the Engineer were precluded from working as a fire fighter, perhaps he would have consented to cardiac catheterization with potential to be diagnosed and surgically treated (angioplasty or by-pass surgery) for his CAD.

RECOMMENDATIONS

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the Engineer's collapse, perhaps his sudden cardiac death could have been prevented at this time.

Recommendation #1: Provide annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007; IAFF, IAFC 2000]. However, the Fire Department is not legally required to follow this standard or this initiative. Nonetheless, we recommend the Fire Department and the City work together to establish an annual medical evaluation consistent with the above guidelines.

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

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters over the age of 45 with two or more CAD risk factors [NFPA 2007; IAFF, IAFC 2000; Gibbons et al. 2002]. The exercise stress test could be conducted by the fire fighter's personal physician or the City contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the City physician, who should be responsible for decisions regarding medical clearance for firefighting duties.

Recommendation #3: Secure endotracheal tubes to prevent dislodgment during patient treatment, transfer, and transport.

Immediately after insertion of the tracheal tube, tube placement should be confirmed by auscultating over the epigastrium, the midaxillary, and the anterior chest line on the right and left sides of the chest. Even when the tracheal tube is seen to pass through the vocal cords and is verified in the trachea by auscultation, secondary confirmation of placement should be made with an end-tidal CO2 or esophageal detection device [AHA 2000a; AHA 2000b]. After the endotracheal tube is inserted into the trachea and positive breath sounds are confirmed by auscultation and end-tidal CO2, the tube should be secured in place by a specific, validated technique or device to prevent dislodgment [AHA 2000b]. Once the tube is placed, especially out of hospital, the location of the tracheal tube must be monitored closely. A specific, validated technique (taping or strapping) or device to prevent dislodgement should be used, especially in the prehospital setting or whenever transporting a patient. Condensation in the endotracheal tube is not an AHA secondary confimatory test of proper placement.

Recommendation #4: Phase-in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, and the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2008; IAFF, IAFC 2000]. 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 [Aldana 2001; Stein 2000]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005]. A recent study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future non-occupational healthcare costs [Kuehl 2007].

Recommendation #5: Perform an autopsy on all on-duty fire fighter fatalities.

In 2008, the USFA published the Firefighter Autopsy Protocol [USFA 2008]. With this publication, the USFA hopes to provide "a more thorough documentation of the causes of firefighter deaths for three purposes:

1. to advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;

2. to help determine eligibility for death benefits under the Federal government's Public Safety Officer Benefits Program, as well as state and local programs; and

3. to address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

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INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by:

Tommy N. Baldwin, MS
Safety and Occupational Health Specialist

Mr. Baldwin, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, a Kentucky Certified Fire Fighter and Emergency Medical Technician (EMT), and a former Fire Chief, is with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio.