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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 *August 10, 2005*

Fire Equipment Operator Suffers a Heart Attack at the Scene of a Medical Call and Dies in the Hospital Thirteen Days Later – South Carolina

SUMMARY

On January 7, 2005, a 41-year-old male career Fire Equipment Operator (FEO) responded to a medical call for an unconscious person. Arriving on the scene, he entered the dwelling and found a person who had been deceased for quite some time. Shortly after exiting the dwelling, he lost consciousness. He regained consciousness when the ambulance arrived and was transported to the hospital's emergency department (ED). In the ED, he was noted to have an acute heart attack and emergent cardiac catheterization and angioplasty were performed. Despite these procedures and other advanced life support (ALS) measures, the FEO died 13 days later. The death certificate, completed by the attending physician, listed "myocardial infarction" due to "renal failure" due to "stroke" as the cause of death. No autopsy was performed. The NIOSH investigator concluded that the physical stress of responding to the alarm and his underlying atherosclerotic coronary artery disease (CAD) probably contributed to this FEO's heart attack and death.

NIOSH investigators offer the following recommendations to prevent similar incidents or to address general safety and health issues:

Consider conducting maximal (symptom-limiting) exercise stress tests (EST) for fire fighters with two or more risk factors for CAD.

Phase in a <u>MANDATORY</u> wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.

Perform an autopsy on all on-duty fire fighter fatalities.

Staff fire stations with a minimum of two fire fighters.

INTRODUCTION & METHODS

On January 7, 2005, a 41-year-old male FEO suffered a heart attack during a medical call. Despite ALS performed by crew members and EMS personnel, and cardiac catheterization and angioplasty by hospital personnel, the FEO died 13 days later. NIOSH was notified of this fatality on January 24, 2005, by the United States Fire Administration. NIOSH contacted the affected Fire Department (FD) on January 25, 2005, to

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obtain further information, and on February 4, 2005, to initiate the investigation. On February 14, 2005, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to South Carolina to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met and/or interviewed the following persons:

- Fire Chief
- Assistant Chief for Operations
- FD Safety Officer
- City Risk Manager
- FEO's wife

NIOSH personnel reviewed the following documents:

- FD incident report
- FD training records
- FD annual response report for 2004
- FEO's annual FD medical evaluation records
- Ambulance report
- Hospital records
- Death certificate

INVESTIGATIVE RESULTS

On January 7, 2005, the FEO arrived for duty at his fire station (Engine 30) at 0745 hours. At his fire station, a career FEO is the only person on duty. FD volunteers responding to emergency calls go directly to the scene via their personal vehicles. Additional FD apparatus staffed with career personnel respond from other stations as necessary.

Throughout the day the FEO checked the fire apparatus and equipment. At 0836 hours, Engine 30 was dispatched for an activated fire alarm (pull station) at a nursing care facility. No hazard was found and fire units became available at 0846 hours. Back in the fire station, the FEO spent the remainder of the day studying fire fighting training manuals.

At 1712 hours, the FD was dispatched to a medical call for an unconscious person. The FEO, driving Engine 30, the volunteer District Chief (DC), an ambulance, and a Deputy Sheriff responded. After arriving on the scene at 1725 hours, wearing his station uniform, the FEO entered the dwelling and found the person to have been deceased for some time. As the FEO was exiting the structure, the DC arrived and asked the FEO if the person was deceased. The FEO grunted affirmatively and continued past the DC. The DC entered the dwelling and confirmed the death. As he exited the dwelling, he saw the FEO leaning over the trunk of a car parked in the driveway. Thinking the FEO was having an emotional response to the decaying body, the DC asked the FEO several times what was wrong; the FEO stated that he did not feel well. The DC and a Deputy Sheriff assisted the FEO to sit on the ground. Once on the ground, the FEO had a brief syncopal (unconscious) episode. The DC radioed Dispatch and requested the ambulance to upgrade their response.

The ambulance arrived on the scene at 1731 hours. At this time, the DC notified the ambulance personnel of the situation with the FEO. Initial assessment by the ambulance paramedics revealed the FEO was responsive, with a pulse of 56 beats per minute (normal 60-100) and a systolic blood pressure (BP) of 60 millimeters of mercury (mmHg) (normal 100-140) by palpation. At this time, the FEO began complaining of chest pain and shortness of breath. His skin was cold, wet, and pale, and he was agitated and restless. A cardiac monitor revealed sinus bradycardia (slow heart rate) with a bundle branch block (a type of conduction abnormality) and an elevated T wave. Oxygen was administered via non-rebreather

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mask, an intravenous (IV) line was placed and fluids given, and an aspirin was administered. In response to this, the FEO's BP rose to 88 mmHg systolic and his chest pain began to lessen. He was placed into the ambulance, which departed the scene at 1738 hours en route to the hospital.

The ambulance arrived at the hospital ED at 1801 hours. Initial evaluation in the ED found the FEO to be alert, diaphoretic (sweating excessively), and complaining of chest pain and shortness of breath. His blood pressure was hypotensive (88/60 mmHg). An EKG showed clear signs of an acute heart attack (myocardial infarction [MI]) in the "posterior lateral" portion of his heart. The MI resulted in pulmonary edema and cardiogenic shock; the FEO was immediately transferred to a cardiologist's care for an emergency cardiac catheterization.

During the catheterization, an intra-aortic balloon pump was inserted to assist circulation to vital organs. The catheterization revealed 99% stenosis (blockage) of the left main coronary artery with a thrombus (blood clot), extending into the left anterior descending coronary artery and the left circumflex coronary artery. Two stents were successfully placed, one in the left main/lower anterior descending coronary artery and one in the left circumflex coronary artery. A subsequent echocardiogram revealed normal left ventricular chamber size and wall thickness, but a severely reduced left ventricular function (ejection fraction [EF] of 15%). It also revealed a severe left ventricle wall motion abnormality where the heart attack was occurring. On Doppler examination, there was trace tricuspid regurgitation with an estimated pulmonary artery (PA) systolic pressure of 40 mmHg (normal).

The FEO's hospital course was remarkable for the successful stenting of his coronary arteries and subsequent improvement of his left ventricular function (EF increasing from 15% to 35-45%). However, he had the following complications:

1) Thrombus due to a central line thrombus in the right upper extremity venous system traveling to the lungs (pulmonary embolus) and subsequent marked pulmonary hypertension and tricuspid valve insufficiency.
2) Thrombus due to heart arrhythmias (atrial fibrillation) probably in the left atrium traveling to the brain (thromboembolic stroke) resulting in altered mental status.
3) Reduced platelets (thrombocytopenia) due to heparin.
4) Acute renal (kidney) failure due to persistent hypotension.
5) Sepsis (infection in the blood) probably due to a pneumonia.
6) Recurrent heart arrhythmias associated with the heart attack.

On January 20, the FEO suffered another type of heart arrhythmia (pulseless electrical activity which is incompatible with life) and resuscitation measures were not successful. The FEO was pronounced dead at 1415 hours.

Medical Findings. The death certificate, completed by the attending physician, listed "myocardial infarction" due to "renal failure" due to "stroke" as the cause of death. No autopsy was performed.

FD medical evaluations from 1984 to 2004 revealed the following CAD risk factors:

Hypercholesterolemia. The first elevated total cholesterol reading was in 1998 (209 milligrams per deciliter [mg/dL]) (normal 143-200 mg/dL).

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His first elevated low density lipoprotein (LDL) reading was also in 1998 (154 mg/dL) (normal 70-130 mg/dL). His high density lipoprotein (HDL) levels remained normal. His first elevated total cholesterol/ high density lipoprotein (Chol/HDL) ratio was in 1999 (5.8) (normal 0.0-5.0). The physician recommended a low cholesterol, low fat diet, and an exercise program. The FEO's last lipid measurements in February 2004 showed persistently elevated total cholesterol, LDL cholesterol, and cholesterol/HDL ratio.

Smoking. The FEO smoked about one pack per day since about 1988.

Hypertension (HTN). The first elevated blood presssure reading was in 2004 (132/104 mmHg). The physician recommended a followup with the FEO's primary care physician. A diagnosis of HTN requires three instances of elevated readings, and the reading above was the only documented elevated reading and was also the most recent reading.

Obesity. At his last FD physical evaluation in 2004, the FEO weighed 191 pounds. Being 67 inches tall, he would have a body mass index (BMI) of 30.0, which is considered borderline obese.[1] Recommendations to exercise began in 1998.

During his last FD annual physical evaluation in February 2004, the FEO performed a fitness test/ exercise stress test (EST) on a cycle ergometer. He exercised for 6 minutes, stopping because he had achieved 85% of his maximum predicted heart rate (154 beats per minute). His estimated aerobic capacity was 33.9 milliliters per kilogram per minute (ml/kg/min). He had an exaggerated BP response (systolic BP of 238 mmHg at 6 minutes which returned to his baseline after 4 minutes of recovery). Although his resting EKG showed inverted T waves in leads II, III, and aVF, these findings were unchanged from previous resting EKGs. His EKG showed no other signs of ischemia.

According to the FEO's wife, the day before his collapse was spent at home performing yard work. The next day, he arose at approximately 0530 hours to prepare for work and left for work at 0700 hours. He expressed no symptoms of cardiac-related problems.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this combination FD consisted of 355 uniformed career personnel and 93 volunteers, served a population of 321,000 in a 680 square mile area, and had 29 fire stations.

In 2004, the FD responded to 21,473 calls including: 580 structure fires, 599 wildland fires, 421 vehicle fires, 187 refuse fires, 41 other fires, 2 explosions, 11,584 rescue/medical calls, 990 hazardous condition calls, 30 overpressure/rupture calls, 4,876 false calls, 961 good intent calls, 603 service calls, and 599 other calls.

Training. The FD requires all career fire fighter applicants to complete an application, possess a valid state driver's license, pass a background check, and pass a combat challenge (candidate physical agility test [described below]) and a physical examination prior to being selected for the 10-week recruit school (trained to the Fire Fighter II [FFII] level). During recruit school, the candidate must pass every segment. After successful completion of recruit school, the can-

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didate is hired and placed on shift. The member is on probation for 6 months. Career fire fighters work 24 hours on-duty, 0745 hours to 0745 hours, and are off-duty for 48 hours.

The physical agility test consists of five timed tasks. The candidate wears a helmet, gloves, and a 45-pound weighted vest. The clock begins when the applicant first touches the high-rise pack and ends when the applicant carries the victim across the finish line. The test consists of the following tasks:

1. Stair climb with high rise pack. The applicant must climb four flights of interior stairs at the drill tower while carrying 100 feet of 1½-inch fire hose on their shoulder. The clock will continue to run.

2. Hose hoist. From the 4th floor window of the drill tower and utilizing a hose roller and a hand-over-hand motion, the applicant must pull a ¾-inch rope to hoist a 50-foot rolled length of 2½-inch fire hose to the window edge on the 4th floor. The clock will continue to run.

3. Forcible entry. The applicant descends the drill tower, reaching the ground. The applicant will then walk to the "slammer" machine, take the 9-pound dead blow sledge hammer and, while straddling the 170-pound slide, will strike it with the sledge hammer until the slide crosses the 5-foot line. The clock will continue to run.

4. Hose advance. The applicant will walk 140-feet and pick up a nozzle attached to a charged 1¾-inch fire hose. The applicant will move the hose and nozzle 75-feet in a straight line to a point between two cones, and place the nozzle onto the ground. The clock will continue to run.

5. Victim rescue. The applicant will walk to the 150-pound victim (dummy), take hold of it, and drag it a distance of 100-feet across the finish line. The method used to move the victim will be at the discretion of the applicant.

Volunteer fire fighter candidates must complete an application, pass a background check, pass a physical examination, and obtain a bloodborne pathogen clearance prior to being accepted. The member receives turnout gear and is allowed to perform duties based on his/her current level of training. The member must complete FFII training within 18 months of being accepted by the FD. Hazardous materials operations level and First Responder training is also included in the FFII training.

State fire fighter certification is voluntary. There is no state mandatory annual refresher training. State fire training that is conducted is in accordance with OSHA requirements for fire departments. The Fire Academy is accredited by the International Fire Service Accreditation Congress (IFSAC). EMTs and Paramedics recertify every 3 years. The FEO was certified as a Fire Fighter, Fire Equipment Operator, First Responder, and in hazardous materials operations. He had 20 years of fire fighting experience.

Pre-placement Physical Examination. A pre-placement physical examination is required by this FD for all applicants. The contents of the examination are as follows:

- A complete medical history
- Physical examination
- Vital signs
- Complete blood count
- SMA-20 blood chemistry test
- Vision screening

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- Audio test (tuning fork)
- Urine drug screen
- Urinalysis
- Spirometry
- Resting EKG
- Submaximal cycle ergometer test (CET) (test stops when fire fighter reaches 80%-90% of maximal heart rate) with a 12-lead EKG with blood pressure monitoring
- Chest x-ray

A City-contracted physician performs the medical examinations for career candidates and a County-contracted physician performs the medical examinations for volunteer candidates.

Periodic Evaluations. Annual medical evaluations are required by this FD for all members. The contents of the examination are the same as the pre-placement with the following exceptions:

- Urine drug screen is conducted only for holders of commercial driver's license (CDL)
- Prostate specific antigen (PSA) test for males over age 40 for positive family history, African-American, or if otherwise clinically indicated; after age 50 for all male members
- Mammography for each female member over age 40
- Screening colonoscopy for all members over age 50 or earlier if clinically indicated

Chest x-rays are repeated every 5 years or as clinically indicated. Maximal (symptom-limiting) ESTs are conducted as clinically indicated by history or symptoms. As with the pre-placement examinations, a City-contracted physician is used for career candidates and a County-contracted physician is used for volunteer candidates.

An annual physical agility test is not required for members. Exercise equipment (strength and aerobic) is available in the fire stations and all members have access to the City gym. A return-to-duty medical clearance is required from the City-contracted physician for duty-related injuries. A return-to-duty medical clearance is required from the fire fighter's primary care physician (PCP) for illnesses (depending on the type and length of illness) that prevent fire fighters from performing their duty. The clearance is provided to the FD and the City Occupational Health Clinic. The Clinic reviews the clearance and makes a final determination to the FD. Annual SCBA clearance and fit test are conducted.

DISCUSSION

Coronary Artery Disease (CAD) and the Pathophysiology of Sudden Cardiac Death. In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[2] Risk factors for its development include age over 45, male gender, family history of coronary artery disease, smoking, high blood pressure (systolic >140 mmHg or diastolic > 90 mmHg), high blood cholesterol (total cholesterol > 240 mg/dL, obesity/physical inactivity, and diabetes.[3,4] The FEO had at least three of these risk factors (male gender, smoking, high cholesterol). Additionally, he was borderline obese.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[5] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[6] 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.[7]

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This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. The FEO had a thrombus in his left main coronary artery and EKGs revealed changes consistent with an acute heart attack.

Firefighting 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 fire suppression activities.[8-10] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[11-14] The physical stress of responding to the alarm and his underlying atherosclerotic CAD probably contributed to this FEO's heart attack and eventual 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 National Fire Protection Association (NFPA) developed NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments*.[15] NFPA 1582 recommends that, as part of its annex for informational purposes only, asymptomatic fire fighters with two or more risk factors for CAD be screened for obstructive CAD by an EST. NFPA defines these CAD risk factors as: family history of premature (first degree relative less than age 60) cardiac event, hypertension (diastolic blood pressure greater than 90 mmHg), diabetes mellitus, cigarette smoking, and hypercholesterolemia (total cholesterol greater than 240 mg/dL).[15] This guidance is similar to recommendations from the American College of Cardiology/American Heart Association (ACC/AHA) and the Department of Transportation (DOT) regarding EST in asymptomatic individuals.[16,17] Since the FEO had two "NFPA" CAD risk factors (smoking and hypercholesterolemia), an EST would have been consistent with NFPA 1582 guidance. In the NFPA 1582 annex, submaximal EST using a treadmill, bicycle, or stair climber is approved.[15] On this point, NFPA 1582 is not consistent with recommendations from the ACC/AHA. The ACC/AHA recommends other exercise end points rather than an arbitrary percentage of predicted maximum heart rate.[16]

As mentioned earlier, in February 2004, the FEO had a submaximal CET/EST which showed no signs of ischemia. His test, however, did show a rise in systolic blood pressure from 132 mmHg at rest to 238 mmHg at peak exercise (6 minutes). This exaggerated BP response has been associated with future hypertension, CAD, and mortality from an MI.[18-22] With this finding, the FD physician could have considered additional non-invasive diagnostic options including: 1) repeating the submaximal CET at a later date, 2) performing a maximal symptom-limiting EST, 3) repeating the EST with an imaging component (e.g. thallium), or 4) conducting an echocardiogram EST.[23] With this additional diagnostic information, the FEO's CAD may have been identified and possibly led to further evaluation and treatment. With intervention, his acute MI may have been prevented.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to prevent similar incidents or to address general safety and health issues:

Recommendation #1: Consider conducting maximal (symptom-limiting) exercise stress tests for fire fighters with two or more risk factors for CAD.

As mentioned earlier, this FEO had a submaximal CET. Although the fire fighter had no signs of ischemia on EKG, the fact that a submaximal test lead to an exaggerated systolic BP response could have lead to additional diagnostic tests. It is possible these additional tests may have identified his underlying CAD and led to therapeutic CAD procedures.

Recommendation #2: Phase in a MANDATORY wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Physical inactivity, or lack of exercise, is associated with other CAD risk factors: obesity and diabetes.[24] NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[25] NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters*, provides the minimum requirements for a health-related fitness program.[26] In 1997, the International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) published a comprehensive *Fire Service Joint Labor Management Wellness/Fitness Initiative* to improve fire fighter quality of life and maintain physical and mental capabilities of fire fighters. Ten fire departments across the United States joined this effort to pool information about their physical fitness programs and create a practical fire service program. They produced a manual and a video detailing elements of such a program.[27] Large-city negotiated programs can also be reviewed as potential models. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[28-30] A similar cost savings has been reported by the wellness program at the Phoenix Fire Department, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.[31]

Recommendation #3: Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.

NFPA 1500 requires fire department members who engage in emergency operations to be annually evaluated and certified by the fire department as meeting the physical performance requirements identified in paragraph 8-2.1.[25] At his last FD physical evaluation in February 2004, the FEO's aerobic capacity (myocardial ventilation oxygen [MVO_2]) was 33.9 ml/kg/min, below the 38 ml/kg/min minimum suggested for structural fire fighting.[32]

Recommendation #4: Perform an autopsy on all on-duty fire fighter fatalities.

In 1995, the United States Fire Administration (USFA) published the Firefighter Autopsy Protocol.[33] This publication promotes the use of autopsy to provide "a more thorough documentation of the causes of firefighter deaths for the following three purposes:

1. advance analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;
2. 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. address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

Recommendation #5: Staff fire stations with a minimum of two fire fighters.

In this incident, an extra person on duty would probably not have changed the outcome. However, the fire station involved in this incident is staffed with only one career person, the FEO position. At least one additional engine staffed with four career personnel and volunteers in their personal vehicles responding from the community respond to all structure fires. While there are specific requirements for fire station facility safety,[25,34] there is currently no specific requirement to staff a fire station with a minimum of two personnel to be on duty during a shift. NFPA 1710 requires that "on-duty personnel assigned to fire suppression shall be organized into company units and shall have appropriate apparatus and equipment assigned to such companies."[35] Those companies may respond with two apparatus, depending on the seating configuration of the apparatus to ensure four personnel arrive on scene.[35] Personnel assigned to the initial arriving company shall have the capability to implement an initial rapid intervention crew (IRIC),[35] which requires four personnel (two to enter the structure and two standing by outside). NFPA 1500 recommends that "members operating in hazardous areas at emergency incidents shall operate in teams of two or more."[25] Understaffing causes those members on-scene to work harder and for longer periods of time. Additionally, it requires the use of extra fire companies in order to meet the demand for manpower. Responding engine companies should be staffed with four personnel at a minimum. While the Fire Department is an emergency response agency, and paid members staff the station part of the time, the fire station should be staffed with two persons per shift for safety considerations.

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