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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 27, 2006*

Fire Fighter Dies After Performing Overhaul at a Fire in a Three-Story Dwelling – Pennsylvania

SUMMARY

On January 28, 2006, a 49-year-old male Fire Fighter (FF) responded to a fire in a three-story dwelling. While performing "wet down" overhaul inside the structure, the FF collapsed. Cardiopulmonary resuscitation (CPR) and advanced life support (ALS) were begun and the FF was transported to the hospital. Despite medical treatment for approximately 47 minutes on the scene and at the hospital, the FF died. The death certificate and the autopsy (completed by the City Medical Examiner) listed "arteriosclerotic cardiovascular disease (CVD)" as the immediate cause of death and "hypertensive cardiomyopathy" as a significant condition. The NIOSH investigator concluded that the physical stress of conducting fire suppression, coupled with the FF's underlying CVD, contributed to the FF's sudden cardiac death.

The NIOSH investigator offers the following recommendations to prevent similar incidents and to address general safety and health issues:

Provide mandatory annual medical evaluations to all fire fighters consistent with the National Fire Protection Association (NFPA) Standard 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.

Consider exercise stress tests for fire fighters at increased risk for coronary artery disease (CAD).

Develop a wellness/fitness program for fire fighters to reduce risk factors for CVD and improve cardiovascular capacity.

Ensure endotracheal tubes do not become dislodged during patient treatment, transfer, and transport.

Discontinue routine pre-employment/pre-placement exercise stress test for applicants, unless the applicants are at increased risk for CAD..

Discontinue routine screening chest x-rays for HazMat units unless medically indicated.

Ensure fire fighters wear self-contained breathing apparatus (SCBA) when working in a potentially hazardous atmosphere, including overhaul operations.

INTRODUCTION & METHODS

On January 28, 2006, a 49-year-old male FF lost consciousness while performing overhaul at a three-story dwelling fire. Despite CPR and ALS administered by crew members, fire department (FD) paramedics, and emergency room personnel, the FF died. NIOSH was notified of this fatality on January 30, 2006, by the United States Fire Administration. NIOSH contacted the affected FD on January 31, 2006 to obtain further information, and on April 17, 2006, to initiate the investigation. On May 10, 2006, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Pennsylvania to conduct an on-site investigation of the incident.

The **Fire Fighter Fatality Investigation and Prevention Program** is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Web site at **www.cdc.gov/niosh/fire** or call toll free **1-800-35-NIOSH**

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During the investigation, NIOSH personnel interviewed the following people:

- Deputy Fire Commissioner
- Fire Marshal
- Assistant Fire Marshals
- International Association of Fire Fighters (IAFF) Local Vice-President
- Crew members
- FF's spouse

During the site-visit, NIOSH personnel reviewed the following documents:

- FD investigative records, including the FD's Fire Fighter Fatality Investigation Report, incident reports, crew member statements, and dispatch records
- Emergency Medical Services ambulance report
- Hospital records of the resuscitation effort
- Death certificate
- Autopsy results
- Past Primary Care Physician's medical records of the FF
- FD policies and operating procedures
- FD training records
- The FD annual report for 2005

NIOSH personnel also visited the area where the structure fire occurred.

INVESTIGATIVE RESULTS

Incident Response. On January 27, 2006, the FF arrived for work at his fire station at approximately 1800 hours. He was assigned to Engine 54 (E54) as a fire fighter on the suppression crew for his 14-hour shift. He, along with his engine company were asleep when they were dispatched to the incident described below.

On January 28, 2006, at 0231 hours, E54, Engine 16 (E16), Engine 57 (E57), Engine 41 (E41), Ladder 24 (L24), Ladder 6 (L6), Battalion 11 (B11), Battalion 7 (B7), Rescue 1 (R1), and Medic 23 (M23) were dispatched and responded between 0231 hours and 0240 hours to a tactical box alarm for a fire in a three-story dwelling. The structure was an occupied, end of row, brick, single family dwelling with a three-story front and a two-story rear with a full basement. The dwelling measured 16' x 55' and was of ordinary construction (see Photograph 1). At the time of dispatch, the temperature was 30°Fahrenheit, relative humidity was 69%, and the wind direction was from the West at 8 miles per hour. A total of 41 FD personnel responded.

Photograph 1

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E54 arrived on the scene at 0235 hours. The Captain radioed Dispatch that there was heavy smoke showing at the rear of the structure and ordered the first engine and ladder to go into service. The FF and a crew member wore full bunker gear (weighing 25 pounds) with self-contained breathing apparatus (SCBA) (weighing 20 pounds) and were breathing air from their SCBAs (on-air). They stretched 200 feet of 1¾-inch hose line toward the rear of the structure, climbed onto a pickup truck (which was parked next to a 6-foot fence) (see Photograph 2), and jumped into the backyard (see Photograph 3) in order to reach the structure to begin fire extinguishment. E16 stretched 200 feet of 1¾-inch hose line into the first floor through the front and began fire extinguishment while L24 arrived and began ventilation operations. When B11 arrived, the second due engine and ladder companies were ordered to go into service. Then the third due engine company was ordered to go into service for the "D" side exposure; Division 1 (Deputy Chief) responded and placed the fire under control at 0304 hours. However, FFs were still encountering heavy smoke conditions as wet down and overhaul operations began. At 0411 hours, M23 became available and was released from the scene.

At approximately 0430 hours, while engaged in wet down and overhaul operations in the first floor rear of the structure, the FF collapsed. The E54 Captain notified Dispatch and requested an ambulance for "a fire fighter having a seizure;" M23 was dispatched. Crew members removed the FF onto the front porch to assess him. Oxygen equipment and a semi-automated external defibrillator (SAED) were obtained. However, due to the cramped conditions on the porch, crew members moved the FF into the yard and began CPR. The SAED was attached to the FF as M23 arrived on the scene (0434 hours). Paramedics found the FF unresponsive, pulseless, and not breathing, with CPR in progress. The FF was placed onto a backboard and a cot and transferred into the medic unit. The SAED was replaced with a cardiac monitor, which revealed ventricular fibrillation (Vfib); three defibrillation attempts (shocks) were administered without a positive change to the FF's heart rhythm.

Photograph 2

Photograph 3

The FF was intubated (breathing tube inserted into the trachea) and an intravenous (IV) line was placed. Intubation tube placement was verified by auscultation and end tidal CO_2. M23 departed for the hospital at 0438 hours. CPR and ALS continued en route, with no improvement in the FF's condition.

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M23 arrived at the emergency department at 0444 hours. Inside the emergency department, the FF was assessed and, due to the absence of breath sounds, was re-intubated. Cardiac pacing was attempted and ALS measures were continued with no improvement in patient status. The FF was pronounced dead at 0525 hours (55 minutes after his collapse) and resuscitation efforts were discontinued.

Medical Findings. The death certificate (completed by the City Medical Examiner) listed "arteriosclerotic CVD" as the immediate cause of death and "hypertensive cardiomyopathy" as a significant condition. Pertinent findings from the autopsy, performed by the Medical Examiner on January 28, 2006, included the following:

- Cardiomegaly (heart weighing 450 grams [g]; normal weight is ≤400 g)[1]
- Arteriosclerotic CAD
  - Near 100% occlusion of the right coronary artery
  - 60% occlusion of the left anterior descending coronary artery
  - 50% occlusion of the left main coronary artery
  - 50% occlusion of the left circumflex coronary artery
- Mild concentric left ventricular hypertrophy with wall thickness being 1.9 centimeters [cm]; normal thickness is 0.6-1.1 cm[2]
- A discrete 2 cm x 1 cm scar in the subendocardial and deep myocardium of the left ventricular wall (proximal medial posterior) suggesting a remote (old) heart attack (myocardial infarction [MI])
- No valvular disease
- No sign of a pulmonary embolus (blood clot in the lung)
- No evidence of smoke inhalation
- Carboxyhemoglobin (COHb) level (measure of carbon monoxide in the blood) of 3.7% (normal for smokers)

The FF saw his primary care physician episodically between 1983 and 2005. During those 22 years, relevant medical findings for CAD included:

1. Hypertension diagnosed in 2005. The first instance of high blood pressure (BP) occurred in 1991. He was not prescribed anti-hypertensive medication.
2. Smoking. He smoked approximately one-half pack of cigarettes per day.

According to the FF's wife and crew members, he participated in regular exercise (bicycling and weight lifting) and had no complaints of angina (chest pain) or any other symptoms suggestive of acute heart-related problems.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the FD was comprised of 2,432 uniformed personnel and served a population of 1,480,000 residents, in a geographic area of 130 square miles. There are 60 fire stations where fire fighters work the following tour of duty: Day 1, 0800-1800 hours; Day 2, 0800-1800 hours; Day 3, 1800-0800 hours; Day 4, 1800-0800 hours; off-duty for 4 days. There are four platoons. Each shift of an engine company is staffed with an Officer and three Fire Fighters; each ladder company consists of an Officer and four Fire Fighters. The emergency medical service is a component of the FD. In 2005, the FD responded to 263,946 calls: 209,472 medical incidents and 54,474 fire incidents.

Training. The FD provides all new fire fighters with a basic 15-week recruit training course, conducted at the city's Fire Academy, to become certified Fire Fighters. All fire fighters are SAED- and Emergency Medical Technician (EMT)- certified. The FF was a certified FF/EMT and Hazmat First Responder and had almost 21 years of firefighting experience.

Pre-placement Medical Evaluation. The FD requires a pre-placement medical evaluation for all fire fighter candidates. Components of the evaluation are as follows:

- Complete medical history
- Height, weight, and vital signs
- Physical examination
- Vision test
- Hearing test
- Blood tests: complete blood count, cholesterol and triglycerides, SMA 12, cholinesterase level
- Urinalysis
- Urine drug test
- Pulmonary lung function tests
- Resting electrocardiogram (EKG)
- Exercise stress test
- Chest x-ray

These evaluations are performed by the Office of the City Medical Director, who makes a decision regarding medical clearance for firefighting duties. New hires are also required to complete a physical capacity test at the city's Fire Academy. This is a non-timed performance evaluation of typical firefighting duties.

Periodic Medical Evaluations. There are no routine annual/periodic medical evaluations required by this FD for **all** fire fighters. However, a medical evaluation is required when a fire fighter is promoted. If an employee is injured at work, he/she must be cleared for "return to work" by a physician in the city's Worker's Compensation Clinic. If an employee is away from work for a non-service-related illness/injury for more than 6 days, he/she must have a physical examination and be cleared for "return to work" by the City Medical Director. Fire fighters assigned to the hazardous materials unit are required to have medical evaluations (including exercise stress test) every 2 years. The contents of these evaluations are the same as for the pre-placement medical evaluation. There is no specific required medical clearance for SCBA use.

Health/Wellness. There are no annual/periodic physical capacity tests required by this FD. Some fire stations have exercise (strength and aerobic) equipment, typically purchased by the fire fighters themselves. There are voluntary smoking cessation and weight control programs; however, there is no required wellness/fitness program. There is no specific medical evaluation to obtain medical clearance for SCBA use.

DISCUSSION

CAD and the Pathophysiology of Sudden Cardiac Death. In the United States, CAD (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[3] Risk factors for CAD development include increasing age, male gender, family history of CAD, smoking, hypertension, high blood cholesterol, obesity/physical inactivity, and diabetes.[3] The FF had four of the American Heart Association risk factors for CAD: increasing age, male gender, smoking, and hypertension.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[4] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[5] 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.[6] This sudden blockage is primarily due to blood clots (thromboses) forming on the top of atherosclerotic plaques. On autopsy, the FF had evidence of atherosclerotic disease in his coronary arteries with near total occlusion of the right coronary artery and evidence of an "old" (several months to years previously) MI.

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It is possible the FF had an acute heart attack, which caused an arrhythmia and sudden cardiac death. The term "possible" is used because blood tests (cardiac isoenzymes), EKG findings, or thrombus formation are required to "confirm" a heart attack. The FF died prior to the cardiac isoenzymes becoming positive (typically at least four hours after onset) and he had no heart beat to show the characteristic findings of a heart attack on his EKG. Although the FF did not have evidence of a thrombus at autopsy, he did have near 100% occlusion of his right coronary artery. The FF did not report any episodes of chest pain (angina) during physical activity on or off-the-job, and did not complain of any angina during this episode. This lack of chest pain does not rule out a heart attack because in up to 20% of individuals, heart attacks can be asymptomatic.[4,7]

Firefighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[8] 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.[9-11] 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.[12] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[13-16] While at the fire scene, the FF wore full bunker gear and SCBA (weighing a total of 45 pounds) on-air. He helped stretch a 200-foot section of 1¾-inch hose line, climbed a 6-foot fence, and performed fire extinguishment and overhaul wet down. This is considered a heavy level of physical exertion.[8,17] The physical stress of responding to the alarm and performing a heavy level of physical exertion, coupled with his underlying arteriosclerotic CVD, probably contributed to the FF's possible "heart attack," subsequent cardiac arrest, and death.

Left Ventricular Hypertrophy. On autopsy, the FF had an enlarged heart and mild left ventricular hypertrophy. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing hypertension, a heart valve problem, or cardiac ischemia (reduced blood supply to the heart muscle).[1] The FF had no evidence of valvular disease on autopsy. Therefore, the most likely reason for his left ventricular hypertrophy was either his long-standing high blood pressure or chronic ischemia. As mentioned previously, left ventricular hypertrophy, chronic cardiac ischemia, and a possible acute MI all increase the risk of cardiac arrhythmia and sudden cardiac death.

Intubation. 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 CO_2 or esophageal detection device.[18,19] Both these procedures were followed by M23 paramedics. 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 pre-hospital setting or whenever transporting a patient.[19] After the FF was transferred from the ambulance to the hospital emergency department, no breath sounds were auscultated and he was re-intubated. It is unclear exactly when the tube became displaced. Therefore, it is unclear what role, if any, displacement played in this FF's death.

Carbon Monoxide (CO). Fire fighters' exposure to CO represents a relatively constant occupational hazard.[20,21] CO levels of up to 1,900 parts per million (ppm) have been found during the knockdown phase, and up to 82 ppm during overhaul.[21] Even wearing respiratory protection may not eliminate a fire fighter's exposure to CO. In fact, CO levels

from 1-105 ppm have been found inside fire fighters' SCBA masks.[21] Exertional levels and, therefore, ventilatory rates may be so great during firefighting that even in moderate or low levels of atmospheric CO, the COHb level in the blood can rise to dangerous levels within minutes.[20] This FF performed fire extinguishment activities while breathing air from an SCBA, but did not wear an SCBA while performing overhaul wet down. Despite the potential for CO exposure, the FF's blood measurement of COHb (one method to measure the amount of CO absorbed into the blood) was not above the expected value for a cigarette smoker. His blood COHb level at autopsy was consistent with his smoking habit (<5%) and not felt to be a contributing factor in his death.[22,23] Nonetheless, FFs should continue SCBA use during overhaul to reduce exposure to hazardous chemicals, including CO.

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.[24] NFPA 1582 recommends, for informational purposes only, asymptomatic fire fighters over the age of 45 with two or more risk factors for CAD be screened for obstructive CAD by an exercise stress test. The NFPA defines these CAD risk factors as family history of premature (first-degree relative <age 60) cardiac event, hypertension (diastolic BP >90 millimeters of mercury [mmHg]), diabetes mellitus, cigarette smoking, and hypercholesterolemia (total blood cholesterol level >240 milligrams [mg]/deciliter [dL]).[24] This guidance is similar to recommendations from the American College of Cardiology (ACC)/AHA and the Department of Transportation regarding exercise stress tests in asymptomatic individuals.[25,26] Since the FF was over the age of 45 and had two NFPA-recognized risk factors for CAD, the performance of an exercise stress test would have been recommended by NFPA 1582.[24,25] If an exercise stress test had been performed, the FF's CAD might have been detected, resulting in further evaluation and treatment. This may have prevented his sudden cardiac death at this time. Complying with NFPA 1582 could also have benefited his hypertension. With closer medical evaluation and treatment, perhaps his left ventricular hypertrophy (a complication from his hypertension) could have been avoided.

RECOMMENDATIONS

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

Recommendation #1: Provide mandatory annual medical evaluations to all fire fighters consistent with NFPA 1582 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 periodic medical evaluations and examinations for fire fighters can be found in NFPA 1582[24] and in the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) *Fire Service Joint Labor Management Wellness/Fitness Initiative*.[27] The FD, however, is not legally required to follow this standard or this initiative.

In addition to providing guidance on the frequency and content of the medical evaluation, NFPA 1582 provides guidance on medical requirements for people performing firefighting tasks. Applying NFPA 1582 involves legal issues, so it should be carried out in a **confidential**, **nondiscriminatory** manner. Appendix B of NFPA 1582 provides guidance for FD administrators regarding legal considerations in applying the Standard.

Applying NFPA 1582 also involves economic issues. These economic concerns go beyond the costs of administering the medical program; they involve the personal and economic costs of dealing with the medical evaluation results. NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, addresses these issues in Chapter 8-7.1 and 8-7.2.[28]

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The success of medical programs hinges on protecting the affected fire fighter. The Department must: **1)** keep the medical records confidential, **2)** provide alternate duty positions for fire fighters in rehabilitation programs, and **3)** provide permanent alternate duty positions or other supportive and/or compensated alternatives if the fire fighter is not medically qualified to return to active firefighting duties.

Recommendation #2: Consider exercise stress tests for fire fighters at increased risk for CAD.

The 2003 Edition of NFPA 1582, the 1997 IAFF/IAFC *Fire Service Joint Labor Management Wellness/Fitness Initiative*, and the ACC/AHA recommend an exercise stress test for fire fighters with two or more CAD risk factors.[24,25,27] 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: Develop a wellness/fitness program for fire fighters to reduce risk factors for CVD 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 risk factors: obesity and diabetes.[29] NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[28] Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[30-32] A similar cost savings has been reported by the wellness program at the Phoenix FD, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.[33] Guidance for implementation and components of a wellness/fitness program may be found in NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters*,[34] and in the IAFF/IAFC, *Fire Service Joint Labor Management Wellness/Fitness Initiative*.[27]

The FD should work with the local union to develop and implement any type wellness/fitness program.

Recommendation #4: Ensure endotracheal tubes do not become dislodged during patient treatment, transfer, and transport.

After the endotracheal tube is inserted into the trachea and positive breath sounds are confirmed by auscultation and end-tidal CO_2, the tube should be secured in place by a specific, validated technique or device to prevent dislodgement.[20] These include taping and strapping. It is unclear what role, if any, the tube displacement played in the FF's death.

Recommendation #5: Discontinue routine pre-employment/pre-placement exercise stress test, unless the applicants are at increased risk for CAD.

Currently the FD is conducting exercise stress test on all FFs during their pre-placement medical evaluations, regardless of whether they have CAD risk factors. This testing represents an unnecessary medical expense for the FD. As mentioned earlier, NFPA 1582 recommends exercise stress test only for FFs at increased risk for CAD. NFPA defines increased risk as male FFs over the age of 45 and female FFs over the age of 55, with two or more CAD risk factors.[24]

Recommendation #6: Discontinue routine screening chest x-rays for HazMat units unless medically indicated.

According to NFPA 1582, "chest x-rays shall include an initial baseline and shall be repeated every 5 years or as medically indicated."[24] Chest x-rays are currently being conducted every year during the FD's annual medical evaluation. These x-rays expose members to unnecessary

radiation and represent an unnecessary expense for the FD. In addition, these x-rays and are not recommended by the OSHA Hazmat Standard unless clinically indicated (e.g., respiratory symptoms).[35,36]

Recommendation #7: Ensure fire fighters wear SCBA when working in a potentially hazardous atmosphere, including overhaul operations.

NFPA 1500 states, "When engaged in any operation where they could encounter atmospheres that are immediately dangerous to life or health or where the atmosphere is unknown, the fire department shall provide and require all members to use SCBA that has been certified as being compliant with NFPA 1981.[28,37] Such operations would include overhaul and other areas subject to smoke and gases.

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