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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 *July 6, 2005*

Volunteer Fire Fighter Suffers Heart Attack While Battling Structure Fire and Dies 6 Days Later – New York

SUMMARY

On August 27, 2003, a 52-year-old male volunteer fire fighter (FF) responded to a structure fire at a lumber yard. The FF performed physically demanding exterior and interior fire suppression activities for over 20 minutes in turnout gear before resting at the on-scene rehabilitation unit. While in rehabilitation, the FF did not initially complain of symptoms, although others noted that he was short of breath and diaphoretic (sweating). The FF initially refused cardiac (heart) monitoring and transport to the local hospital, but since his condition did not improve, he eventually consented to ambulance transport. En route to the hospital a cardiac monitor showed changes consistent with a heart attack and the FF's blood pressure began to fall. At the hospital an acute myocardial infarction was confirmed, and an emergent cardiac catheterization showed triple vessel coronary artery disease (CAD) including an acute 100% blockage in one of the main coronary arteries. Due to his critical condition (cardiogenic shock) the FF was not considered a surgical candidate and was given aggressive medical management which included endotracheal intubation, intravenous (IV) fluids, IV medications, and placement of an intra-aortic balloon pump for blood pressure support. Despite these aggressive supportive measures, his condition deteriorated, and he was transferred to a tertiary care facility for possible heart transplantation. On September 2, 2003, shortly after his arrival at the tertiary care center he died. The physical stress of fighting the fire and his underlying atherosclerotic CAD contributed to this FF's heart attack and subsequent death.

The following recommendations are preventive measures recommended by other fire service groups to reduce, among other things, the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. These recommendations are listed in order of priority as related to this investigation.

1) ***Incorporate exercise stress tests (EST) into the annual medical evaluations for fire fighters with multiple risk factors for CAD.***
2) ***Ensure that fire fighters are cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582, Standard on Comprehensive Occupational Medicine Program for Fire Departments.***
3) ***Ensure that FFs in Rehabilitation Units follow incident command orders.***
4) ***Expand the current annual medical evaluation requirement to include Driver/Operators.***
5) ***Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
6) ***Perform an autopsy on all on-duty fire fighter fatalities.***

Volunteer Fire Fighter Suffers Heart Attack While Battling Structure Fire and Dies 6 Days Later – New York

INTRODUCTION AND METHODS

On August 27, 2003, a 52-year-old male volunteer FF suffered a heart attack while battling a mutual aid structure fire. Despite Advanced Life Support (ALS) treatment at the scene and emergency transport to the hospital, the FF died 6 days later. The United States Fire Administration notified NIOSH of this fatality on September 4, 2003. NIOSH contacted the affected Fire Department (FD) on September 10, 2003, to obtain further information. On August 4, 2004, a physician assigned to the NIOSH Fire Fighter Fatality Investigation Team traveled to New York to conduct an on-site investigation of the incident.

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

- FD Chief, who was present at the fire scene
- FD crew members, who were present at the fire scene
- Ambulance personnel, who transported the FF to the hospital
- Family members of the deceased FF

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

- FD incident report
- Dispatch records
- Ambulance pre-hospital care report
- Emergency Department record
- Personal physician and other medical records
- Death certificate
- FD policies and operating procedures
- FD training records
- FD annual report for 2003

INVESTIGATIVE RESULTS

Incident. On August 27, 2003, at 1442 hours, the FD received a request for mutual aid to a working structure fire at a lumber yard in a neighboring district. The ambient temperature was 77° F with 95% humidity. The FD responded with an engine (801), a pumper/tanker (804), an ALS unit (832), a quint (841), a brush truck (842), and 37 FD personnel. The FF responded directly to the scene in his privately owned vehicle. FD resources began arriving on scene at 1452 hours.

The FF was first observed in full turnout gear including a self-contained breathing apparatus (SCBA) pulling a 4-inch hose line off the engine. It is unknown how many feet of hose he pulled or how long he was engaged in this activity. He was next reported to be doing an exterior attack with his son (also a fire fighter) using a 1¾-inch hose line for approximately 10–15 minutes. From here, they moved to an interior attack position and advanced approximately 10 feet into the structure before fire forced their retreat to an exterior position. At this point the FF informed his son that he had "burnt his knees" and needed to rest.

The FF was next observed at the on-scene rehabilitation unit where he had taken off his SCBA and unbuttoned his turnout coat. He was sitting next to the Fire Chief, drinking water with wet towels around his neck. While not complaining of any symptoms, he was noted to appear pale, diaphoretic (sweating), and winded. His appearance failed to improve despite the cooling measures mentioned above. With the help of an on-scene paramedic, the FF relocated to the air conditioned ambulance present at the scene. While walking unassisted 10–15 feet to the ambulance, he stated to fellow fire fighters, "I just don't feel well." At this time he was noted to have trouble walking and was described as pale, diaphoretic, short of breath, and unable to speak in full sentences.

Once inside the ambulance, he was reevaluated and found to be tachycardic (fast heart rate) with a systolic blood pressure of 100 to 120 mm Hg.

The paramedic advised transport to the nearby hospital, but the FF adamantly refused. At this time, the FF acknowledged having substernal chest tightness which he described as a muscle contraction, and that he had experienced this sensation in the past. After a protracted discussion, the FF allowed the administration of oxygen and continued oral rehydration with a combination of water and Gatorade but refused cardiac monitoring. After 30 minutes, he felt a little better and wanted to drive himself home. However, when he attempted to walk from the ambulance to his personal vehicle, he developed severe shortness of breath and ultimately consented to ambulance transport to the hospital.

En route to the hospital, 100% oxygen was administered via non-rebreather mask, an intravenous (IV) line was established, and cardiac monitoring was performed. Cardiac monitoring revealed significant ST elevation in leads I and aVL, suggesting an acute myocardial infarction (heart attack). A 12-lead electrocardiogram (EKG) could not be successfully performed secondary to diaphoresis. Three hundred twenty-four milligrams of aspirin was administered orally. At this point, the FF became hypotensive (low blood pressure) with a systolic blood pressure of 80 mm Hg. He was treated with an IV fluid bolus, which raised his blood pressure to 100 mm Hg. Due to his hypotension, sublingual nitroglycerin (treatment for angina) was not administered.

In the Emergency Department, a 12-lead EKG showed findings consistent with an acute anterolateral myocardial infarction. Subsequent blood tests revealed elevated cardiac enzymes thus confirming this diagnosis. The FF was taken emergently to the cardiac catheterization lab where triple vessel CAD was demonstrated with the following blockages:

- 100% occlusion of the left anterior descending (LAD) artery
- 95% occlusion of the left main artery
- 60%–70% occlusion of the circumflex artery
- 60% occlusion of his mid-right coronary artery

It was further determined that the FF had developed cardiogenic shock as a complication of the acute anterolateral myocardial infarction. Cardiothoracic surgeons were consulted for possible emergent bypass surgery. After reviewing his case, the surgeons felt his extremely critical condition (cardiogenic shock) would result in a low probability of surviving the surgery; therefore, he was not deemed to be a surgical candidate, and surgery was not performed.

Thus, the FF was managed medically with endotracheal intubation, placement of an intra-aortic balloon pump, and IV medications for blood pressure support. His carboxyhemoglobin level of 1.4% suggested that he had not been exposed to an excessive amount of carbon monoxide. Further work-up on day two included an echocardiogram that showed moderate left ventricular enlargement with mild left atrial enlargement, severely depressed left ventricular systolic dysfunction (ejection fraction of 25%) with regional wall motion abnormalities, moderate to severe mitral regurgitation, and moderate pulmonary hypertension. Despite aggressive evaluation and treatment, the FF's condition failed to improve, and he was flown to a tertiary care facility on September 1, 2002, for consideration of heart transplantation and/or bypass surgery. He died shortly after his arrival at this referral center in the early morning hours of September 2, 2004.

Medical Findings. The death certificate listed acute myocardial infarction as the immediate cause of death, and no autopsy was performed. The FF had a history of high blood pressure treated

with prescription medications and high blood cholesterol controlled by diet and exercise. In 1997 he had a non-cardiac related hospitalization, at which time a routine EKG showed possible left atrial enlargement. Prior to this incident he was not known to have CAD. The FF exercised regularly with his son and never reported any symptoms of angina (chest pain/discomfort). His most recent completed physical examination was two months prior to his death.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this FD manned four stations staffed by 350 to 400 volunteer fire fighters, but only about 100 of these are active members who respond to calls. The FD serves a population of 15–20,000 covering a 150–200 square mile area. According to the FD's Incident Type Report, in 2003, the FD responded to a total of 340 alarms.

Application Process. The FD requires that all new applicants be sponsored by a current FD member. The applicant must apply to one of the FD's five companies. The application is then reviewed by the company and a vote is taken. If the applicant is accepted, he/she must then complete a pre-placement physical examination, arson check, and new member training. Individuals can use their personal physicians to conduct these physical examinations and provide the medical clearance necessary to engage in unrestricted fire suppression activities. No physical ability test is required.

Training. The FD first requires all new applicants to complete new member training prior to participation in any fire suppression activities. They are then assigned a mentor who supervises their in-house mandatory fire training. State certification is available but voluntary. Additional weekly training is offered every Tuesday evening. There is no mandatory annual refresher training.

The FF was a member of this Department for 34 years. He was certified as a Fire Fighter I and Driver/Operator. He was an active member who participated in interior fire suppression, and was named the FD's "Firefighter of the Year" with his sons in 2002. He also participated in "hose racing," and was a member of several championship hose teams.

Medical Clearance. As mentioned earlier, pre-placement physical examinations and medical clearance are required for all new applicants. Subsequent annual medical examinations and respirator clearance are only required for those involved in interior fire fighting activities with an EKG performed on those age 40 or greater. Both these physical exams and medical clearances (pre-placement and annual) can be performed by the applicant's/member's personal physician. At the time of this incident, the certifying physician determined the content of this evaluation.

Physical Fitness. The FD does not have a mandatory wellness/fitness program. However, cardiovascular and strength training equipment is available at the main fire station, and members are encouraged to utilize this equipment.

DISCUSSION

Coronary Artery Disease (CAD) and the Pathophysiology of Sudden Cardiac Death.

In the United States, atherosclerotic CAD leading to a myocardial infarction is the most common cause of cardiac arrest and subsequent sudden cardiac death.[1] Risk factors for CAD development include modifiable and non-modifiable risk factors. Modifiable risk factors include smoking, high blood pressure, high cholesterol, obesity, physical inactivity, and diabetes.[2] The FF had two modifiable risk factors (high blood pressure

and high cholesterol). Non-modifiable risk factors include increasing age, male gender, and family history.[2] The FF had all three of these non-modifiable risk factors.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[3] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[4] 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.[5] This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. Given the FF's EKG tracings, cardiac enzymes, and catheterization findings, he probably had a sudden blockage (thrombus) in his LAD coronary artery resulting in his anterolateral myocardial infarction and subsequent cardiogenic shock.

Angina is the most common presenting symptom of myocardial ischemia and underlying CAD, but in many persons the first evidence of CAD may be myocardial infarction or sudden death.[6] This FF's symptoms of shortness of breath and diaphoresis accompanied by chest tightness were his "anginal" symptoms. While the delays in being placed on a cardiac monitor and in transport to the hospital did not cause the heart attack, they did reduce his chances for survival.

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[7] 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 response to the initial alarm and persists throughout the course of fire suppression activities.[8-10] 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 insulating properties of the personal protective clothing.[11] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[12-15] This FF battled a structure fire in full turnout gear on a hot and humid August afternoon for over 20 minutes. This is considered a very heavy level of physical exertion.[16,17] The physical stress of fighting the fire and his underlying atherosclerotic CAD contributed to this fire fighter's heart attack and subsequent death.

Use of Exercise Stress Tests (EST) 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 guidelines entitled *Standard on Comprehensive Occupational Medicine Program for Fire Departments*, otherwise known as NFPA 1582.[18] In addition to screening for CAD risk factors, NFPA 1582 recommends an exercise stress test (EST) for some asymptomatic (i.e., no symptoms of angina) fire fighters. Conducting EST on asymptomatic individuals is somewhat controversial. NFPA Standard 1582 recommends, not as a part of the requirements but for informational purposes only, that all fire fighters with two or more risk factors for CAD be given an EST. The Standard lists the following criteria for CAD risk factors: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic greater than 140 mm Hg or diastolic greater than 90 mm Hg), smoking, diabetes, or family history of premature CAD (cardiac event in first degree relative less than 60 years old).[18]

The American College of Cardiology/American Heart Association (ACC/AHA) states that the evidence to conduct EST in asymptomatic individuals with diabetes mellitus is "Class IIa: there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy but the

weight of the evidence/opinion is in favor."[19] The ACC/AHA goes on to say the evidence is "less well established" (Class IIb) for the following groups:

1. Evaluation of persons with multiple risk factors as a guide to risk-reduction therapy with the risk factors essentially the same as the NFPA listed above.

2. Evaluation of asymptomatic men older than 45 years, and women older than 55 years who are sedentary and plan to start vigorous exercise.

3. Evaluation of asymptomatic men older than 45 years, and women older than 55 years who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters).

4. Evaluation of asymptomatic men older than 45 years, and women older than 55 years who are at high risk for CAD due to other diseases (e.g., peripheral vascular disease and chronic renal failure).

The U. S. Department of Transportation (DOT) also addresses the issue of EST. To obtain medical certification for a commercial drivers license, DOT recommends EST for drivers over the age of 45 with more than two CAD risk factors.[20] The U.S. Preventive Services Task Force (USPSTF), however does not recommend EST for asymptomatic individuals, even those with risk factors for CAD; rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes).[21] The USPSTF indicates that there is insufficient evidence to recommend screening middle age and older men or women in the general population but notes that "screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety."

Had an EST been performed on this FF, it is possible his CAD would have been identified, thereby leading to further evaluation and treatment, and possibly the prevention of his sudden cardiac death at this time.

RECOMMENDATIONS

The following recommendations are preventive measures recommended by other fire service groups to reduce, among other things, the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. These recommendations are listed in order of as related to this investigation.

Recommendation #1: Incorporate exercise stress tests (EST) into the annual medical evaluations for fire fighters with multiple risk factors for CAD.

As mentioned earlier, NFPA 1582 recommends EST for male FFs above the age of 45 with two or more risk factors for CAD. This recommendation involves economic repercussions and may be particularly difficult for volunteer fire departments, such as the one involved in this incident, to implement.

Recommendation #2: Ensure that fire fighters are cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582, Standard on Comprehensive Occupational Medicine Program for Fire Departments.

Physicians providing input regarding medical clearance for fire-fighting duties should be knowledgeable about the physical demands of fire fighting and should recognize that fire fighters frequently respond to incidents in environments that are immediately dangerous to life and health (IDLH). They should also be familiar with a FF's personal protective equipment and the consensus

guidelines published in NFPA 1582, *Standard on Comprehensive Occupational Medicine Program for Fire Departments*.[18] To ensure physicians are aware of these guidelines, we recommend that the FD, or the FF, provide the personal physicians with a copy of NFPA 1582.

We also recommend the FD retain a "Fire Department Physician" to critically review all medical clearances. This decision requires knowledge not only of the medical condition, but also of the fire fighter's job duties. Personal physicians may not be familiar with an employee's job duties, or guidance documents, such as NFPA 1582. In addition, they may consider themselves patient advocates and dismiss the potential public health impact of public safety officials who may be suddenly incapacitated.

Recommendation #3: Ensure that FFs in Rehabilitation Units follow incident command orders.

Being hot, sweaty, and short of breath on a hot humid day is normal during fire suppression. However, the Rehabilitation Officer astutely recognized that the FF did not look well and provided sound advice for cardiac monitoring and transport. The incident commander (IC) has the authority and responsibility to ensure that personnel who become ill or injured on the fire ground receive appropriate medical evaluation and treatment.[22] In most medical cases, the IC passes this authority and responsibility to the Rehabilitation Officer or the Rehabilitation Team Leader as part of the incident command system. In this case, the FF disagreed with the Rehabilitation Officer's recommendations. Therefore, the Rehabilitation Officer should have contacted the IC for guidance. Presumably, the IC would have required an immediate medical evaluation as recommended by the Rehabilitation Team Leader (i.e. cardiac monitoring and/or transport).

Recommendation #4: Expand the current annual medical evaluation requirement to include Driver/Operators.

The FD currently requires an annual medical evaluation for fire fighters participating in interior fire suppression. Given the potential risk to the public and other FFs if a Driver/Operator becomes suddenly incapacitated, the NIOSH investigator believes the FD should include Driver/Operators in this required evaluation.

Recommendation #5: Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

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.[23] The International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) joined in 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 to create a practical fire service program. They produced a manual and a video detailing elements of such a program.[24] The *Wellness/Fitness Initiative* provides guidance regarding wellness program content to include physical examination and evaluation, fitness, and behavioral health. Wellness programs have been shown to be cost-effective, typically by reducing the number of work-related injuries and lost work days.[25, 26] An unpublished analysis by the Phoenix, Arizona city auditor found a reduction in disability pension costs following

a 12-year commitment to the wellness program at the Fire Department. Small FDs, such as the one involved in this incident, should review the programs mentioned above and determine which components are practical.

Recommendation #6: Perform an autopsy on all on-duty fire fighter fatalities.

In 1995, the United States Fire Administration (USFA) published the Firefighter Autopsy Protocol,[27] which includes a recommendation for autopsies on all on-duty fire fighter fatalities. The USFA recommendation is designed 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 Lisa Anderson, MD, an Emergency Room Physician and an Occupational Medicine Resident assigned to the NIOSH Fire Fighter Fatality Investigation Team located in Cincinnati, OH.

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