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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* *March 3, 2003*

## Fire Fighter Suffers Fatal Heart Attack at Fire at his Residence - Florida

### SUMMARY

On September 26, 2001, a 32-year-old male fire fighter reported a fire at his own house and initially assisted the responding fire fighters by pulling and holding hose. Half an hour later, he had chest pain and sought help from emergency medical service personnel at the scene. After being evaluated, treated with oxygen (which relieved the pain), and observed, the pain returned and he had a seizure, developed a cardiac arrhythmia (abnormal heart beat), and stopped breathing. Despite cardiopulmonary resuscitation and advanced life support, which began immediately and continued on the way to the hospital and in the emergency department, the fire fighter died. Based on autopsy findings, the death certificate, listed "acute thrombosis of coronary artery" due to "arteriosclerotic cardiovascular disease" as the cause of death.

The following recommendations address some general health and safety issues identified during this investigation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. These selected recommendations have not been evaluated by NIOSH, but represent published research or consensus votes of technical committees of the National Fire Protection Association (NFPA) or fire service labor/management groups.

- **Institute preplacement and periodic medical evaluations. These should incorporate exercise stress testing, depending on the fire fighter's age and coronary artery disease risk factors.**
- **Fire fighters should be cleared for duty and for respirator use 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, the National Fire Protection Association's *Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians*.**
- **Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.**

### INTRODUCTION & METHODS

On September 26, 2001, a 32-year-old male fire fighter died after losing consciousness at the scene of a fire. On October 1, 2001, the United States Fire Administration notified NIOSH of the death. On October 7, 2001, NIOSH first tried to contact the affected Fire Department to initiate the

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investigation and eventually made contact on October 23, 2001. On May 6, 2002, a NIOSH contract physician traveled to Florida to conduct an on-site investigation of the incident.

People interviewed included the

- Current Fire Chief
- Fire Chief at the time of the incident
- Crew members on duty with the deceased fire fighter
- Deceased fire fighter's spouse
- Human resources director for the deceased fire fighter's oil platform employer
- Medical examiner who performed the autopsy

Documents reviewed included

- Fire Department policies and operating guidelines
- Fire Department run report and fire incident report
- Fire Department run log for 2001
- Deceased fire fighter's medical records maintained by his private physicians
- Ambulance response report
- Hospital emergency department record
- Autopsy report
- Death certificate

### INVESTIGATIVE RESULTS

*Incident*. On September 26, 2001, at 2126 hours, the affected fire fighter reported a fire in the bathroom of his house. He woke up his daughter and they went outside. At 2134 hours, the first engine, driven by the Chief, arrived and parked in back of the house. The affected fire fighter did not have his turnout gear at home, but he pulled hose and held hose for another fire fighter (who had arrived in his own vehicle). After about 15 minutes, the affected fire fighter went around front, and for the next half hour or so, he was seen walking about, leaning against a vehicle and going in and out of the house. (He also talked by cell phone to his wife, who was at the World Trade Center disaster site as part of a disaster medical assistance team.) It was after dark, warm but not hot. Although the fire fighter seemed distraught about the fire, other fire fighters did not observe him to be in physical distress or hear him mention any symptoms.

At 2225 hours, he went to the emergency medical service (EMS) ambulance (which routinely responds to structural fire calls) and reported chest pain, which he apparently attributed to smoke exposure. No other symptoms were recorded at this time. His pulse was 113 and his blood pressure was 160/102, but his physical examination was otherwise normal, his electrocardiogram (ECG) showed no significant abnormalities (normal sinus rhythm, one premature ventricular contraction), and his arterial oxygen saturation was 98% (normal). His pain was largely relieved with oxygen, but it returned after some minutes, more severe than before, and he became diaphoretic (sweating). As he was moved from the bench seat to the stretcher, he had a seizure. He stopped breathing and had no palpable pulse. His ECG first showed ventricular tachycardia (an abnormal heart rhythm) and then, as the defibrillator was being attached, ventricular fibrillation (a different abnormal rhythm). A series of three defibrillator shocks failed to restore his heart beat, cardiopulmonary resuscitation (CPR) and advanced life support (ALS) were initiated, and as these measures were in progress, the ambulance departed for the hospital at 2245 hours. The fire fighter's heart went into asystole (no heartbeat) at 2249 hours. ALS measures at the scene and en route included endotracheal intubation (placing a tube in the airway), intravenous medications, and two more defibrillator shocks when ventricular fibrillation returned for a few minutes (reverting again, at 2305 hours, to asystole). The ambulance arrived at the hospital at 2307 hours. CPR and ALS (including intravenous medications and external cardiac pacing) continued in the

emergency department, but the fire fighter did not respond. At 2332 hours he was pronounced dead.

*Medical Findings*. Pertinent findings from the autopsy, performed by the Medical Examiner, are listed below:

Atherosclerotic cardiovascular disease to include

A. Cardiomegaly (445 grams) with left and right ventricular hypertrophy
B. Mild to severe calcific atherosclerosis of the coronary arteries
C. Acute thrombosis of the left anterior descending coronary artery

There was no sign of previous myocardial infarction. The carboxyhemoglobin (COHb) concentration (a measure of carbon monoxide exposure) in blood obtained at autopsy was 1.4% (a medically insignificant level). There was no soot in the lungs. Although both right and left ventricular hypertrophy were noted, the right ventricular hypertrophy was slight. [The finding of ventricular hypertrophy in a young man with no history of hypertension and no valvular abnormality could indicate a primary cardiomyopathy (a disorder of the heart muscle), but the Medical Examiner did not think that the autopsy findings were suggestive of cardiomyopathy, and there were unequivocal findings of coronary artery disease and acute thrombosis.] On the death certificate, the Medical Examiner recorded "acute thrombosis of coronary artery" as the immediate cause of death and "arteriosclerotic cardiovascular disease" as the underlying cause.

At the time of his death, the fire fighter had three jobs: safety officer on an offshore oil platform, emergency medical technician (EMT), and 911 dispatcher. He worked (and lived) on the oil platform for a week, then he had a week off. The other two jobs were part-time during the off week. He had previously worked as a sheriff's deputy and before that as a professional fire fighter. He had been a volunteer fire fighter with his current department for 4 years. He completed Fire Fighter I training and had additional training in apparatus driving/operation, hazardous materials (HAZMAT) operations, wildland fire fighting, and search and rescue. He was the Department's training officer for the last year before his death and held the rank of Captain for the last 6 months.

Except for one episode of self-limited chest pain (for which he did not seek medical attention), he never reported symptoms of CAD to his family or crew members. He had no known chronic health problems and took no prescription medications. His father had coronary artery bypass surgery at age 56. The fire fighter smoked cigarettes (a pack a day since he was a 14 or 15 years old). Except for home and yard work, he did not engage in regular physical exercise. (EMT work can include episodic strenuous physical activity, but the fire fighter's other jobs did not.) In addition to his apparent emotional stress resulting from the fire at his house, and his concern (unfounded) that he might have caused it, he was under further stress because of a pending legal matter. The deceased fire fighter's last physical examination was in July 2000 for EMT school. At that time, his blood pressure was 140/70 mm Hg (normal). He weighed 226 pounds and was 70 inches tall, giving him a body mass index (BMI) of 32 $kg/m^2$. (A BMI above 30 $kg/m^2$ indicates obesity.[1]) A blood cholesterol level in 1987 was 157 mg/dL (normal). He never had an electrocardiogram (ECG) or an exercise stress test (EST).

## DESCRIPTION OF THE FIRE DEPARTMENT

The Fire Department consists of 15 volunteer fire fighters. It serves a rural area of 126 square miles with a population of 1,260. There is one fire station. In 2001, the Department responded to 78 calls; these

included calls for medical assistance, for which the Department has first responder responsibility until the county EMS arrives.

*Training*. Fire fighters who were members of the Department when it was established in 1995 have had Fire Fighter I training, but there are no formal training requirements for new members. One current member, who is also a professional fire fighter in another department, provides regular training for the other volunteers. All members are certified in first aid and CPR and trained in the use of an automatic external defibrillator.

*Medical Evaluations*. The Department has no preplacement or periodic medical evaluations or physical agility tests. Medical clearance is not required for respirator use or for returning to duty after an injury or illness. Members who are unable to perform a full range of duties due to health problems or age, however, are accommodated by limiting their tasks to those they are able to do. The department has no health promotion programs or exercise/fitness equipment.

## DISCUSSION

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 increasing age, male gender, heredity, tobacco smoke, high blood cholesterol, high blood pressure, physical inactivity, obesity and overweight, and diabetes.[3] Besides gender, the deceased fire fighter had four of these risk factors: family history, cigarette smoking, lack of regular aerobic physical activity, and obesity/overweight.

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 (thrombosis) forming on top of atherosclerotic plaques. Sudden cardiac death is often the first overt manifestation of ischemic heart disease.[7] The deceased fire fighter had atherosclerotic plaque in the major coronary arteries, with fresh thrombus blocking one of them.

Blood clots, or thrombus formation, in coronary arteries is initiated by disruption of atherosclerotic plaques. Certain characteristics of the plaques (size, composition of the cap and core, presence of a local inflammatory process) predispose the plaque to disruption.[6] Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased heart rate, increased catecholamines, and shear forces, which occur during heavy exercise.[8,9]

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[10] Fire-fighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and persist through the course of fire suppression activities.[11-13] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[14-18] The deceased fire fighter had pulled and held hose for about 15 minutes, then he did not engage in strenuous physical for the half hour before he sought help for chest pain. Pulling and handling hose involves moderate to strenuous exertion, more than most home and yard maintenance tasks.[15, 19-21]

EST can be used to screen individuals for obstructive CAD. Unfortunately, it has problems with both false negatives (inadequate sensitivity) and false positives (inadequate specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of CAD), particularly in young men, and women.[22, 23] Despite these problems, NFPA 1582, the National Fire Protection Association's *S tandard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians*, nevertheless recommends EST for fire fighters without risk factors for CAD beginning at age 40.[24] Other expert groups do not recommend EST for asymptomatic individuals without risk factors for CAD.[25-27]

When these asymptomatic individuals have risk factors for CAD, recommendations vary by organization. NFPA 1582 recommends biannual EST for fire fighters with CAD risk factors beginning at age 35.[24] For medical certification for the commercial drivers license (CDL) issued by the U. S. Department of Transportation (DOT), DOT recommends EST for drivers over the age of 45 with more than two CAD risk factors.[25] Since the deceased fire fighter was qualified as a driver/operator for the Fire Department, this regulation would seem to have relevance, but municipal fire departments are exempt from the DOT regulations.[28] In addition, the DOT medical advisory criteria are just that, advisory. In any case, the deceased fire fighter was not only younger than the DOT-recommended age (45) to begin EST in those without a history of CAD, he was also younger than the DOT-recommended age (40) to begin routine ECG.

The American College of Cardiology/American Heart Association (ACC/AHA) do not think that "there is evidence and/or general agreement that [EST] is useful and effective" in asymptomatic persons without known CAD, but they identify four groups of such persons for which "there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy" of EST. In these groups, EST "usefulness/efficacy is less well established by evidence/opinion" (as opposed to the "weight of evidence/opinion [being] in favor of usefulness/efficacy")."[26]

- Group 1: Persons with multiple risk factors. Five risk factors for CAD are defined: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic blood pressure greater than 140 mm Hg or diastolic pressure greater than 90 mm Hg), smoking, diabetes, and family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

- Group 2: Men over the age of 40 and women over the age of 50 (especially if sedentary) who plan to start vigorous exercise.

- Group 3: Men over the age of 40 and women over the age of 50 who are at high risk for CAD due to other diseases (e.g., chronic renal failure).

- Group 4: Men over the age of 40 and women over the age of 50 who are involved in occupations in which impairment might impact public safety.

The deceased fire fighter did not meet the criteria for any of these groups. He was under age 40 and, though his father had coronary artery bypass surgery, he did not have a heart attack or sudden cardiac death. Thus, the fire fighter had only one of the five Group 1 risk factors, smoking.

Finally, the U.S. Preventive Services Task Force (USPSTF) 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).[27] The

USPSTF indicates that evidence is insufficient 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."[27] Again, because of his age (less than "middle age"), this occupational criterion would apparently not have applied to the deceased fire fighter.

Although the deceased fire fighter was young, he smoked, did not engage in aerobic exercise on a regular basis, and was substantially overweight. Obesity, however, is not listed by NFPA 1582 as either a Category A (disqualifying) or B (possibly disqualifying, depending on degree or severity) medical condition.[24] It is possible that a health promotion program that included smoking cessation, regular aerobic exercise, and weight control might have helped prevent his fatal heart attack. Given his age, neither NFPA 1582 nor the DOT, ACC/AHA, or USPSTF recommendations would have included EST as part of a preplacement or periodic medical evaluation, even in the presence of CAD risk factors. NFPA 1582 does not require an ECG as part of the biannual (at his age) medical examination, but an ECG may be done "if indicated" (that is, if the examining physician thinks it would provide important information). Whether the examining physician would have considered an ECG "indicated" in this fire fighter's case is an open question. It is possible that an ECG would have shown evidence of CAD (such as left ventricular hypertrophy), but unless it did, it is unlikely that further diagnostic testing (such as EST) would have been performed.

The deceased fire fighter's COHb level (1.4%) reflected about an hour of premortem oxygen administration. Thus, it was likely somewhat higher when he developed the chest pain, theoretically about 2.5% (assuming a half-life of 80 minutes at 100% oxygen[2]), but probably lower since his blood circulation was dependent on CPR rather than normal heart function for the majority of his time on oxygen. Even though a COHb level of 2-4% could be associated with ischemic cardiac effects in a person with CAD, his was below the average (5-6%) for smokers.[29] Considering the deceased fire fighter's smoking history and the absence of soot in his lungs, his slightly elevated COHb level was probably not attributable to fire-related smoke inhalation.

## RECOMMENDATIONS

The following recommendations address health and safety issues identified during this investigation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of on-the-job cardiac arrest among fire fighters. These selected recommendations have not been evaluated by NIOSH, but they represent published research or consensus votes of Technical Committees of the National Fire Protection Association or fire service labor/management groups. Even had the recommended procedures been in place, however, it is unlikely, because of his age, that the affected fire fighter's CAD would have been detected and his sudden cardiac death prevented.

***Recommendation #1: Institute preplacement and periodic medical evaluations. These should incorporate exercise stress testing, depending on the fire fighter's age and coronary artery disease risk factors.***

The purpose of periodic medical evaluations is to ensure that fire fighters have the ability to perform duties without presenting a significant risk to the safety and health of themselves or others. Guidance regarding the content and scheduling of periodic medical examinations for fire fighters can be found in NFPA 1582.[24] In addition to providing guidance on the frequency and content of the medical evaluation, NFPA 1582 provides guidance on medical

requirements for persons performing fire-fighting tasks. NFPA 1582 recommends a limited annual evaluation, including a medical and occupational history, which the Department has instituted, and a limited physical examination (height, weight, blood pressure, heart rate and rhythm), which should be added. In addition, NFPA 1582 recommends a more extensive medical evaluation at an interval of 1 to 3 years, depending on the fire fighter's age. NFPA 1582 recommends that periodic EST begin at age 35 for those with CAD risk factors and at age 40 for those without CAD risk factors.

Applying NFPA 1582 involves legal and economic issues, so it should be carried out in a **confidential**, **nondiscriminatory** manner. Appendix D of NFPA 1582 provides guidance for Fire Department administrators regarding legal considerations in applying the standard. The 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, *S tandard on Fire Department Occupational S afety and Health Program*, addresses these issues in Chapter 8-7.1 and 8-7.2.[30] 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) if the fire fighter is not medically qualified to return to active fire-fighting duties, provide permanent alternate-duty positions or other supportive and/or compensated alternatives. Unfortunately, the second and third requirements may not be workable in a volunteer department and could thus impair both acceptance by fire fighters and the Fire Department's ability to recruit and retain fire fighters. On the other hand, the Fire Department described in this report already provides alternative duty, albeit informally and without medical oversight.

Applying this recommendation involves economic repercussions and may be particularly difficult for small, rural, volunteer Fire Departments to implement. To overcome the financial obstacle, the Fire Department could urge current members to get annual medical clearances from their private physicians (but see Recommendation #2). Another option is having the brief annual medical evaluations recommended by NFPA 1582 completed by the volunteer fire fighters themselves (medical and occupational history) and by EMTs from the county's emergency medical service (vital signs, height, weight, and visual acuity). This information could then be provided to a community physician, perhaps volunteering his or her time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive periodic medical examinations could be performed by a private physician at the fire fighter's expense, provided by a physician volunteer, or paid for by the Fire Department. Sharing the financial responsibility for these evaluations among volunteers, the Fire Department, and willing physician volunteers should reduce the negative financial impact on recruiting and retaining needed volunteers.

***Recommendation #2: Fire fighters should be cleared for duty and for respirator use 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, the National Fire Protection Association's* Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians.**

The decision regarding medical clearance for fire fighters requires knowledge not only of the fire fighter's medical condition but also of the fire fighter's job duties and NFPA 1582 medical fitness criteria. NFPA 1582 recommends that return-to-duty evaluations (after an injury or illness) be done by the

"fire department physician."[24] As part of the return-to-duty evaluation, the fire department physician should review relevant records from the fire fighter's personal physicians and/or discuss with them the fire fighter's illness or injury.

The Occupational Safety and Health administration (OSHA) respiratory protection standard[31] requires employers whose employees are required to use respirators to have a formal respiratory protection program, including periodic medical evaluations. Since Florida does not have an OSHA-approved State plan, public employers, including volunteer fire departments, are not legally subject to OSHA standards.[32] Nevertheless, we recommend that the Fire Department voluntarily adhere to the health- and safety-related provisions of the OSHA standard, including periodic medical evaluations. The medical evaluations for respirator use can be done at the same time as fitness-for-duty examinations, and often they do not involve substantial additional evaluation. (Pulmonary function testing [PFT] may be useful for evaluating respiratory symptoms or physical examination findings, but it is otherwise not needed routinely for a respirator clearance evaluation. NFPA 1582 includes PFT as part of the recommended preplacement and periodic medical evaluations but not the limited annual evaluations prior to age 40.[24])

***Recommendation #3: 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.[30] 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.[33] 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.[34, 35] 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, volunteer fire departments should review the programs mentioned above and determine which components are practical for them.

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## INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by Mitchell Singal, MD, MPH. Dr. Singal is a physician working under contract to the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component, located in Cincinnati, Ohio.