



Volunteer Fire Fighter Suffers Sudden Cardiac Death After Participating in Emergency Responses – Maryland

SUMMARY

After responding to two alarms during the previous 6 hours, a 65-year-old male volunteer Fire Fighter (FF) was found dead in his home on January 15, 2004. The death certificate, completed by the Coroner, listed “acute myocardial infarction” as the immediate cause of death. Although neither of the two emergency responses appeared to involve strenuous physical exertion, the stress of responding to the alarm along with his underlying atherosclerotic Coronary Artery Disease (CAD) probably contributed to this FF’s heart attack and subsequent sudden cardiac death. The recommendations below, listed in order of priority, are preventive measures recommended by other fire service groups to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters.

- *Conduct pre-placement and periodic medical evaluations to determine FFs medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.*
- *Phase in a mandatory wellness/fitness program for FFs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.*
- *Perform a pre-placement and an annual physical performance (physical ability) evaluation to ensure FFs are physically capable of performing the essential job tasks of structural fire fighting.*
- *Ensure that physicians knowledgeable about the physical demands of fire fighting and the components of National Fire Protection Association (NFPA) 1582 discuss examination results with FF and clear them for duty.*

INTRODUCTION AND METHODS

On January 14, 2004, a 65-year-old male volunteer FF returned to his home after responding to two alarms over a 6 hour period. The FF did not voice any symptoms and went to bed at approximately 2200 hours. The next morning the FF was found unresponsive by his wife. Emergency medical services were notified, and given his condition, no resuscitation was attempted. On January 29, 2004, NIOSH contacted the affected Fire Department (FD) to initiate the investigation. On May 17, 2004, an Occupational Nurse Practitioner and Occupational Health Specialist from the NIOSH FF Fatality Investigation Team traveled to Maryland to conduct an investigation. During the investigation NIOSH personnel spoke with the following people:

- Fire Chief
- Crew members at the incident with the deceased FF
- Deceased FF’s wife
- Volunteer Firemen’s Association Administrator

During the site visit NIOSH personnel reviewed the following documents:

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 Website at www.cdc.gov/niosh/firehome.html or call toll free 1-800-35-NIOSH



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- FD incident report
- Emergency medical service (ambulance) incident report
- Hospital emergency department report
- Death certificate
- FF's medical records
- FD policies and operating guidelines
- FD training records
- Autopsy report

INVESTIGATIVE RESULTS

Incident. On January 14, 2004 a 65-year-old volunteer FF responded to two alarms during a 6 hour period. The two calls were made at 1616 and 1805 hours, respectively. The FF arrived at the station after the fire apparatus left for both incidents. Therefore, during both incidents he provided station coverage while the other FD members responded. At the station he performed no strenuous activity and returned home at approximately 2130 hours. At this time, the FF voiced no health complaints to his wife and retired for the evening at approximately 2200 hours.

At approximately 0555 hours the next morning, the FF's wife attempted to wake him from sleep, but he was unresponsive. She checked for a pulse, and finding none, she immediately called 911. An ambulance was dispatched with three emergency medical technicians at 0558 hours. The ambulance arrived at the FF's home at 0609 hours, to find the FF in bed with no pulse or respirations, cool extremities, warm trunk, and no rigor. There appeared to be no signs of struggle or distress. Due to his condition (death several hours earlier) no resuscitation was attempted. Emergency medical services notified the coroner who pronounced the FF dead at 0610 hours.

Medical Findings. The death certificate was completed by the Deputy Coroner, who listed "acute myocardial infarction" as the immediate cause of death. Significant findings from the

autopsy, performed by the Assistant Medical Examiner, were as follows:

- Cardiomegaly (an enlarged heart) weighing 670 grams (upper limit of normal is 400 grams)
 - Four chamber dilatation
 - Biventricular hypertrophy
- Atherosclerotic CAD
- Acute plaque rupture and thrombosis, left obtuse marginal artery (recent heart attack)
- Total occlusion of mid left circumflex artery by healed plaque rupture with organized and recanalized thrombus (old, healed heart attack)
- Healed transmural infarction, posterolateral left ventricle at base
- Diffuse 50%-90% narrowing of coronary arteries:
 - 50% narrowing of left main coronary artery
 - 80% narrowing of the proximal left anterior descending artery (LAD)
 - 90% narrowing of the mid LAD, first diagonal, and proximal left obtuse marginal artery
 - 70% narrowing of the left circumflex artery
 - 60% proximal right coronary artery (RCA)
 - 75%-80% mid and distal RCA
- Penetrating organized thrombus, right atrium; undetermined etiology

The FF never visited a healthcare provider for a heart condition. A physical examination in 1998 was unremarkable. At his last physician visit, on February 15, 2002, his blood pressure was 148/88 millimeters of mercury (mm/Hg). Blood work from January 31, 2001, showed a blood glucose of 115 milligrams (mg) per deciliter (dL) (normal was 72-110 mg/dL), triglycerides 87 mg/dL (normal 60-200 mg/dL), cholesterol 225 mg/dL (normal 175-240 mg/dL), HDL cholesterol 46 mg/dL (normal > 34 mg/dL), and LDL cholesterol 162 mg/dL (normal 105-200 mg/dL).



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At autopsy, the FF weighed 220 pounds and measured 5'10" tall. He had the following risk factors for CAD: family history, male gender, physical inactivity and obesity (Body Mass Index [BMI] of 31.6 kilograms/meter² [kg/m²]). A BMI above 30 kg/m² indicates obesity¹. The FF did not exercise regularly, either by aerobic or strength training. He did not complain of heart symptoms days or weeks preceding his death.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the volunteer FD consisted of 29 active volunteer FFs. The FD served a population of 13,000 in a 142 square mile geographic area from one fire station.

Training. Individuals over 16 years of age may apply for membership. The membership committee conducts a background and reference check. Once approved by the membership committee, the entire FD votes on the application. If selected the FF is placed on a six month probation status, as an “associate.”

During the 6-month probation period, the associate must attend the following classes: 30-hour Fire Fighter I, Hazmat, Cardiopulmonary Resuscitation, and bloodborne pathogens. After completing these classes, associates may ride FD apparatus to the fire grounds, but they remain at the pump operator’s side. After the probationary period, the associate is voted in by the FD members. However, entry into burning structures remains at the discretion of the FD Chief.

Pre-placement and Periodic Evaluations.

The FD does not require pre-placement or periodic medical evaluations or physical ability tests for candidates or members. However FFs are encouraged to receive a complete physical examination through their employer or at their own expense. In addition, medical clearances for self-contained breathing apparatus use are required annually. FFs injured on duty

must be cleared for return to work by their personal physician. Neither strength nor aerobic equipment is available at the fire station. No wellness program is available.

DISCUSSION

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

In the United States, CAD is the most common risk factor for cardiac arrest and sudden cardiac death.² According to the American College of Cardiology/American Heart Association (ACC/AHA), risk factors for CAD development include advancing age, male gender, family history of coronary artery disease, smoking, high blood pressure (systolic >140 mm/Hg or diastolic > 90 mm/Hg), high blood cholesterol (total cholesterol > 240 mg/dL), obesity/physical inactivity, and diabetes.^{3,4} The FF had three of these risk factors (family history, male gender, and physical inactivity/obesity).

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 This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. Blood clots, or thrombus formation, in coronary arteries are 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.⁷ Disruption then occurs from biomechanical and hemodynamic forces, such as the increased blood pressure, increased heart rate, increased catecholamines, and shear forces, that occur during heavy exercise.^{8,9} The FF had thrombi on



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autopsy and moderate to severe atherosclerotic disease in multiple coronary arteries.

Firefighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.¹⁰ Firefighting activities are strenuous and often require FFs 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 to persist through the course of fire suppression activities.¹¹⁻¹³ 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.¹⁴

Epidemiologic studies have found that heavy physical exertion sometimes precedes and triggers the onset of acute heart attacks.¹⁵⁻¹⁸ During the time leading up to the FF's declared time of death, he had participated in two emergency responses. Angina is the most common presenting symptom of myocardial ischemia and underlying CAD, but he never complained of any health condition. Although neither of the two emergency responses appeared to involve strenuous physical exertion, the stress of just responding to the alarms along with his underlying atherosclerotic CAD probably contributed to this FF's heart attack and subsequent sudden cardiac death. Heart arrhythmias associated with heart attacks are responsible for sudden cardiac death. These arrhythmias can occur up to 24 hours after the heart attack.¹⁹⁻²¹ This may explain why his death did not occur until several hours after the alarms.

Use of Exercise Stress Tests (EST) to Screen for CAD

To reduce the risk of heart attacks, sudden cardiac arrest, and other medical conditions among FFs, the National Fire Protection Association (NFPA) has developed the NFPA 1582 guideline entitled *Comprehensive Occupational Medicine*

*Program for Fire Departments.*²² The 2003 edition recommends a comprehensive medical examination to be performed **annually** on all members. This standard also recommends screening for obstructive CAD by an exercise stress test (EST) for FFs with two or more of the following CAD risk factors: family history of premature (less than age 60) cardiac event, hypertension, diabetes mellitus, hypercholesterolemia (total cholesterol greater than 240 mg/dL or HDL cholesterol less than 35 mg/dL), and cigarette smoking.²² These recommendations are slightly different from those of the American College of Cardiology/American Heart Association (ACC/AHA).²³ According to NFPA 1582 criteria, the FF had one CAD risk factor. Therefore, according to these criteria, the FF would not have been recommended for an EST.

Atherosclerosis in a coronary artery may cause ischemic heart disease that occurs when the blood flow within a coronary artery is limited to the point where the oxygen needs of the heart muscle cannot be met. The FF was found, on autopsy, to have had a previous MI. Sudden cardiac death is associated with MIs due to the instability of the heart's conduction system. Chronic ischemic heart disease also causes hypertrophy of the heart muscle and cardiomegaly. All of these factors, independently and in combination (ischemia, cardiomegaly, or myocardial infarction), increase the risk of cardiac arrhythmia and sudden cardiac death.

On autopsy the FF was found to have biventricular hypertrophy, severe CAD, and evidence of old heart attacks. Long-standing cardiac ischemia (reduced blood supply to the heart muscle) was probably responsible for the FF's biventricular hypertrophy. Even though the pathologist conducting the autopsy diagnosed biventricular dilatation, the report only documented a left ventricular cavity measurement (4.5 cm) (normal 3.7-5.6 cm).²⁴ There was no documented measurement for the right ventricular cavity. But, with this pathological diagnosis, the FF had a



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mixed hypertrophic and dilated cardiomyopathy. Although most cases of dilated cardiomyopathy are of unknown etiology (idiopathic), a variety of acquired or hereditary disorders can cause the disorder. These secondary and potentially reversible forms are listed in Table 1.²⁵

Could a comprehensive FD pre-placement medical evaluation have identified any of this FF’s underlying medical conditions? As noted earlier, this department did not require a pre-placement or annual medical evaluation. If a resting electrocardiogram (EKG) had been done, it could have detected his enlarged and hypertrophied heart. Whether an EKG finding of left axis deviation or left ventricular hypertrophy would have led to further evaluation or treatment is unclear. As mentioned earlier, the NFPA 1582 and the AHA/ACC practice guidelines would not have recommended an EST in this asymptomatic individual. Therefore, without a history of chest pain similar to angina, it is unlikely his sudden death could have been prevented.

RECOMMENDATIONS

The first three recommendations below are preventive measures recommended by other fire service groups to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. The final recommendation addresses a potential safety issue related to this particular event. These recommendations are listed in order of priority.

Table 1. Known Causes of Dilated Cardiomyopathy²⁵

Toxins

- Ethanol
- Chemotherapeutic agents (doxorubicin, bleomycin)
- Cobalt
- Anti-retroviral agents (zidovudine, didanosine, zalcitabine)
- Phenothiazines
- Carbon monoxide
- Lead
- Cocaine
- Mercury

Metabolic Abnormalities

- Nutritional deficiencies (thiamine, selenium, carnitine)
- Endocrinologic disorders (hypothyroidism, acromegaly, thyrotoxicosis, Cushing’s Disease, pheochromocytoma, diabetes mellitus)
- Electrolyte disturbances (hypocalcemia, hypophosphatemia)

Infectious

- Viral (coxsackie virus, cytomegalovirus, human immunodeficiency virus)
- Rickettsial
- Bacterial (diphtheria)
- Mycobacterial
- Fungal
- Parasitic (toxoplasmosis, trichinosis, Chagas’ disease)

Noninfectious

- Collagen vascular disorders (scleroderma, lupus erythematosus, dermatomyositis)
- Hypersensitivity myocarditis
- Sarcoidosis
- Peripartum dysfunction

Neuromuscular

- Duchenne’s muscular dystrophy
- Facioscapulohumeral muscular dystrophy
- Erb’s limb-girdle dystrophy
- Myotonic dystrophy

Recommendation #1: Conduct pre-placement and periodic medical evaluations to determine FFs medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

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 1582.²² In addition to providing guidance on the frequency and content of the medical evaluation, NFPA 1582 provides guidance



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on medical requirements for persons performing fire fighting tasks. 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.

This recommendation also involves economic repercussions and may be particularly difficult for small, rural, volunteer fire departments to implement. To overcome the financial obstacle, the FD could urge current members to get annual medical clearances from their private physicians. Another option is to ask the FFs to complete the brief annual medical evaluations recommended by NFPA 1582 themselves. The FFs would complete the medical and occupational history portions, and EMTs from the county's emergency medical service would complete the portions for vital signs, height, weight, visual acuity and resting EKG. 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 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 FD. Sharing the financial responsibility for these evaluations between volunteers, the FD, and willing physician volunteers should reduce the negative financial impact on recruiting and retaining needed volunteers. These and other suggestions can be found in the National Volunteer Fire Council (NVFC) and United States Fire Administration's (USFA) *Health and Wellness Guide for the Volunteer Fire Service*, FA-267/January 2004.²⁶

Recommendation #2: Phase in a mandatory wellness/fitness program for FFs 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. Additionally, physical inactivity, or lack of exercise, is associated with other risk factors: obesity and diabetes.²⁷ NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1583, *Standard on Health-Related Fitness Programs for FFs*, require a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.^{28,29}

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 FF quality of life and maintain physical and mental capabilities of FFs. 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.³⁰ The Fire Department should review these materials to identify applicable elements. Other large-city negotiated programs can also be reviewed as potential models.

In January 2004, the NVFC and USFA published a comprehensive Health and Wellness Guide for the Volunteer Fire Service to address the special circumstances surrounding volunteer departments.²⁶ The guide provided further documentation supporting fire fighter health and also gives suggestions for program initiation and features. Small volunteer fire departments should review the programs and documents mentioned above and determine which components are practical for them.

Recommendation #3: Perform a pre-placement and an annual physical performance (physical ability) evaluation for ALL FFs to ensure FFs are physically capable of performing the essential job tasks of structural fire fighting.



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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 8-2.1.²⁸

Recommendation #4: Ensure that physicians knowledgeable about the physical demands of fire fighting and the components of NFPA 1582 discuss examination results with FF and clear them for duty.

Frequently, private physicians are not familiar with a FF's job duties or with guidance documents such as NFPA 1582. To ensure physicians are aware of these guidelines, we recommend that the Fire Department provide contract and private physicians with a copy of NFPA 1582. In addition, we recommend the Fire Department carefully evaluate the opinion of the private physician regarding return to work. This decision requires knowledge not only of the medical condition but also of the FF's job duties. Lastly, we recommend that all return-to-work clearances be reviewed by a Fire Department contracted physician. Thus, the final decision regarding medical clearance for return to work lies with the Fire Department with input from many sources, including the FF's private physician.

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