



September 21, 2007

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

SUMMARY

On May 30, 2005, at 2203 hours, a 39-year-old male volunteer fire fighter responded, with his lights and siren operating, to a motor vehicle fire. The call was cancelled 10 minutes before he arrived on the scene. He returned home and went to work the next day. While visiting relatives after his work shift, the fire fighter experienced pain in his chest and left arm. 9-1-1 was called, and ambulance paramedics found him lying on the ground with severe chest pain. The paramedics administered oxygen and applied a cardiac monitor, but during transport to the local hospital's emergency department, he became unconscious with a rhythm of ventricular fibrillation. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) performed in the ambulance and the emergency department for 40 minutes, the fire fighter was pronounced dead on May 31, 2005 at 1722 hours. No autopsy was performed. The death certificate completed by the attending physician stated the cause of death as "acute myocardial infarction" (otherwise known as a heart attack) due to coronary artery disease (CAD). This fire fighter had a known history of CAD since age 32. He had two angioplasty procedures with stent placements in 1998 and 2005.

The NIOSH investigator concluded that the fire fighter's heart attack was due to his underlying CAD, probably triggered by his regular job duties. However, contribution

from responding to the vehicle fire 18 hours earlier cannot be ruled out. NIOSH investigators offer the following recommendations to prevent similar incidents and to address general safety and health issues:

- *Provide mandatory pre-placement and annual medical evaluations to ALL fire fighters to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.*
- *Ensure that fire fighters are cleared for duty by a physician who is knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.*

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

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Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

- *Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the fire department's medical evaluation program.*
- *Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.*
- *Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.*
- *Review EMS treatment protocols for acute myocardial infarction.*
- Fire department policies and operating guidelines
- Fire department training records
- Fire department annual report for 2006
- Fire department incident reports
- Hospital records
- Medical records
- Death certificate

RESULTS OF INVESTIGATION

Incident. On May 30, 2005, at 2203 hours, the fire fighter responded, with his lights and siren operating, to a vehicle fire. The call was cancelled 10 minutes later while he was en-route. He returned home to sleep and awoke the next morning to work his regular job. That day, his job entailed clearing brush from a dam and riverport for 8 hours. After work, he arrived at his sister's house around 1620 hours and complained that he didn't feel good. Around 1625 hours, the fire fighter instructed his relatives to call an ambulance and his wife. An ambulance staffed with two emergency medical technicians (EMTs) and one EMT-paramedic was dispatched at 1631 and arrived at 1635 hours. On arrival, the EMTs found the fire fighter alert and oriented, lying on the ground, and complaining of severe chest pain.

They found a pulse of 114 beats per minute with 16 respirations per minute and a palpable radial pulse. The EMTs administered oxygen, but were unable to start an intravenous line. A cardiac monitor was placed on the fire fighter when the ambulance departed the scene at 1639 hours.

INTRODUCTION AND METHODS

On May 31, 2005, a 39-year-old male volunteer fire fighter suffered a sudden cardiac death after responding to a vehicle fire alarm the previous evening. On June 4, 2007, an occupational health nurse practitioner from the NIOSH Fire Fighter Fatality Investigation Team traveled to Kentucky to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire chief
- Fire fighter's wife

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



Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

At 1642 hours, the fire fighter became unconscious, and the EMTs could not find a pulse. The cardiac monitor showed ventricular fibrillation (a rhythm incompatible with life). CPR was administered, and manual defibrillation was attempted at 1645 hours using three stacked shocks with no change in his clinical condition. In addition, an attempt to intubate the fire fighter (placing a breathing tube into the airway) was unsuccessful, and oxygen was administered using a bag-valve-mask. According to the encounter form, no medications (e.g., aspirin or nitroglycerin) were administered by the ambulance personnel before the fire fighter lost consciousness.

The ambulance arrived at the emergency department at 1650 hours. The fire fighter was intubated (a breathing tube placed in the airway), further defibrillations were attempted, an intravenous line was placed, and ACLS medications were administered. Despite 32 minutes of ALS in the emergency department, the fire fighter's clinical status did not change. At 1722 hours, he was pronounced dead by the emergency department's attending physician, and resuscitation efforts were discontinued.

Medical Findings. No autopsy was performed. The death certificate completed by the attending physician listed "acute myocardial infarction" as the cause of death.

The fire fighter had a history of hypertension that was diagnosed in 1988 and treated with anti-hypertensive medications. In May 1998, at the age of 32, he underwent an angioplasty and stent placement to one of

his coronary arteries (the diagonal branch). Thirteen days later, he underwent a treadmill exercise stress test using the Bruce protocol, where he achieved 12.9 metabolic equivalents (METs) in 10 minutes without ischemia but with exercise induced-premature ventricular contractions. In June 1998, he underwent 24-hour cardiac monitoring with a Holter monitor. Those results were reported as normal except for rare ventricular ectopy, which the cardiologist correlated with his symptoms of palpitations.

In August 1999, the fire fighter had a physical examination conducted by his primary care provider, who noted hyperlipidemia:

- Total cholesterol was 235 milligrams/deciliter (mg/dL) (normal is <200 mg/dL)
- High-density lipoprotein cholesterol was 22 mg/dL (normal is 32–72 mg/dL)
- Triglycerides were 332 mg/dL (normal for the processing lab is <160 mg/dL)

He was given a lipid lowering medication that returned his triglycerides and cholesterol to the normal range.

In November 2003, the fire fighter requested another exercise stress test for his employer. NIOSH investigators assume the test was needed for a fitness for duty evaluation. An exercise stress test was performed using the Bruce protocol with a stress echocardiogram. He exercised for 14 minutes to 11 METs; the results were reported as normal. There was no angina and



Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

no ischemic changes on his EKG; heart rate and blood pressure response were normal. The echocardiogram was also listed as normal, but no left ventricular ejection fraction was reported.

In January 2005, the fire fighter again exhibited symptoms of a heart attack and was admitted to a hospital where a coronary catheterization was performed. The previous stent (in the diagonal branch placed in 1998) was 96% occluded, and the right coronary artery had a 70% area of blockage. Both lesions were opened and stented. He tolerated the procedure well with no complaints at his last physician visit on February 21, 2005. Return visits were scheduled with both his cardiologist and his primary care provider 2 weeks before his death. For unclear reasons, the fire fighter missed both appointments.

The fire fighter exercised regularly, weighed 198 pounds and was 71 inches tall, giving him a body mass index of 27.6 kilograms per square meter (kg/m^2). A body mass index of 26.0 kg/m^2 to 29.9 kg/m^2 is considered overweight [NHLBI 2007]. He had stopped smoking 5 months before his death.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the fire department consisted of 21 active volunteer fire fighters. Its 3 fire stations served a population of 2,500 in a geographic area of 55 square miles. In 2006, the fire department responded to 107 calls.

Membership and Training. The fire department requires all new fire fighter applicants to complete an application and an interview with the Fire Chief. The application is reviewed by the department officers who advise the Fire Chief. All fire fighters are allowed to respond to fires, but may not perform fire attack until they have completed the State Fire Fighter I program, which accounts for 125 hours of the 150-hour minimum for State volunteer fire fighter certification. Training occurs twice weekly at the station or can be done at a nearby State-sponsored fire training school.

The State requires 20 hours training annually for volunteer fire fighter recertification. The fire fighter was not certified and he was pursuing the approximately 48 hours further training he needed. He had more than 2 years of volunteer fire experience with this fire department.

Pre-placement and Periodic Medical Evaluations. No pre-placement or periodic medical evaluations are required by this fire department. Fire fighters are encouraged to get a complete physical examination through their employer or at their own expense and provide a release form to the fire department. A release form had not been provided by this fire fighter's physician. Medical clearance for SCBA use is not required. Fire fighters who are injured while volunteering are evaluated by and must be cleared for return-to-duty by their personal physician.



Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

Fitness/Wellness Programs. No fitness/wellness programs, and no aerobic or strength training equipment, are available at any of the three stations.

DISCUSSION

Coronary Artery Disease (CAD) and the Pathophysiology of Myocardial Infarction.

In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [AHA 1998]. Risk factors for its development include age over 45, male gender, family history of CAD, smoking, high blood pressure (systolic >140 millimeters of mercury [mmHg] or diastolic >90 mmHg), high blood cholesterol (total cholesterol >240 mg/dL), obesity/physical inactivity, and diabetes [AHA 1998]. The fire fighters had four of these risk factors (male gender, smoking, high blood pressure, and hypercholesterolemia). The fire fighter had stopped smoking in January 2005. The risk of coronary heart disease due to smoking is reduced by half after 1 year of not smoking and then declines gradually until after 15 years of abstinence, when the risk becomes the same as for never-smokers [OSH 1990].

CAD causes a narrowing of the coronary arteries by atherosclerotic plaques and occurs over many years, typically decades [Libby 2001]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. 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 [Fuster et al. 1992]. 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 [Fuster et al. 1992]. 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 and possibly while responding to a fire scene [Kondo and Muller 1995]. The strenuous physical exertion of clearing brush for 8-hours during his regular job probably triggered his heart attack and subsequent sudden cardiac death. However, NIOSH investigators cannot rule out some contribution associated with responding to the vehicle fire 18 hours earlier.

The fire fighter's attending physician attributed his sudden death to a heart attack due to his known CAD. The clinical scenario is consistent with this diagnosis. However, to confirm a heart attack, any of the following are needed: autopsy findings (thrombus formation), EKG findings, or blood tests (cardiac isoenzymes). No autopsy was performed and no EKG was performed before his collapse, but his cardiac isoenzymes were elevated. Although multiple defibrillations can elevate cardiac enzymes, the more likely explanation is that a heart attack triggered the fire fighter's sudden cardiac death [Vikenes et al. 2000; Grubb et al. 1998; Goktekin et al. 2002].



Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

Occupational Medical Standards for Structural Firefighting and CAD. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA has developed NFPA 1582. NFPA 1582 recommends diagnostic screening for CAD using an exercise stress test for asymptomatic fire fighters over the age of 45 (55 for women) with 2 or more risk factors for CAD (family history of premature cardiac event, hypertension, diabetes mellitus, cigarette smoking, and hypercholesterolemia) [NFPA 2007]. This recommendation is consistent with recommendations from the American Heart Association/American College of Cardiology and the Department of Transportation regarding exercise stress tests in asymptomatic persons [ACC/AHA 2002; U.S. DOT 1987]. This recommendation is not relevant to this fire fighter since he had known CAD.

In fire fighters with known CAD, NFPA 1582 recommends an imaging stress test be performed to evaluate for exercise tolerance, exercise-induced ischemia, and/or ventricular arrhythmias. NFPA 1582 also identifies risk factors associated with an increase of sudden incapacitation in fire fighters with known CAD. These include (1) current angina, (2) stenosis greater than 70%, (3) lowered left ventricular ejection fraction, (4) exercise intolerance <12 METS, (5) ischemia or ventricular arrhythmias at <12 METS, and (6) history of myocardial infarction, angina, or CAD with persistence of tobacco use, hypertension, cholesterol \geq 180, Low-density lipoprotein \geq 100, or glycosylated hemoglobin $>$ 6.5. This fire

fighter had known CAD with persistence of tobacco use, and he failed to achieve 12 METS on his 2003 exercise stress test. Thus, according to NFPA guidelines, he should not have been cleared for unrestricted fire fighting. An exercise stress test was not performed after his angioplasty and stent placement in January 2005. A more recent exercise stress test may have identified stent failure/re-occlusion. This could have led to further evaluation and treatment, possibly preventing his sudden cardiac death at this time.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters, and to address general safety and health issues.

Recommendation 1: Provide mandatory pre-placement and annual medical evaluations to ALL fire fighters 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 pre-placement and periodic medical evaluations and examinations for fire fighters can be found in NFPA 1582 and in the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) [2000] Fire Service Joint Labor Management Wellness/Fitness Initiative. However, the fire department is not legally required to follow the guidance provided in any of these documents.



Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

Applying this recommendation involves economic repercussions and may be particularly difficult for small, volunteer or combination 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. Another option is having the annual medical evaluations completed by paramedics and EMTs from the county emergency medical services provider (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician, perhaps volunteering their time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician volunteer or paid for by the fire department. Sharing the financial responsibility for these evaluations between the fire fighter, the fire department, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation 2: Ensure that fire fighters are cleared for duty by a physician who is knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Physicians who provide input regarding medical clearance for fire fighting duties should be knowledgeable about the physical demands of fire fighting and understand that fire fighters frequently respond to incidents in immediately dangerous to life and health environments. They should also be familiar

with a fire fighter's personal protective equipment and the consensus guidelines published by NFPA 1582 [NFPA 2007]. To ensure that physicians are aware of these guidelines, we recommend that the fire department or the fire fighter provide their primary care providers with a copy of NFPA 1582. It is unclear whether the fire fighter's medical providers were aware that their patient was a volunteer fire fighter, or were aware of the NFPA guidelines.

Therefore, NIOSH recommends that the fire department retain a fire department physician to review all medical clearances. Return-to-work decisions require knowledge not only of the medical condition but also of the fire fighter's job duties. Primary care providers may not be familiar with a fire fighter's job duties or with guidance documents such as NFPA 1582. In addition, they may consider themselves patient advocates and dismiss the potential public health impact of public safety officers who may be suddenly incapacitated. Therefore, NIOSH recommends that a fire department physician who has the final decision regarding medical clearance review all return-to-work clearances.

Recommendation 3: Provide fire fighters with clearance to wear self-contained breathing apparatus as part of the fire department's medical evaluation program.

The Occupational Safety and Health Administration (OSHA)'s *Revised Respiratory Protection Standard* requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR* 1910.134]. These



Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. Kentucky does not operate an OSHA-approved State plan; therefore, public sector employers are required to comply with OSHA standards.

Recommendation 4: Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Physical inactivity, or lack of exercise, is associated with other CAD risk factors: obesity and diabetes [Plowman and Smith]. NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being [NFPA 1997]. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days for fire fighters [City Auditor 1997; Garfi et al. 1996; Harger et al. 1999; Dempsey et al. 2002; Stevens et al. 2002; Womack et al. 2005; Blevins et al. 2005] and in other workplaces [Maniscalco et al. 1999; Stein et al. 2000; Aldana et al. 2001]. Guidance for how to implement the components of a wellness and fitness program include the following:

- NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters* [NFPA 2000]

- International Association of Fire Fighters/International Association of Fire Chiefs, *Fire Service Joint Labor Management Wellness/Fitness Initiative* [IAFF/IAFC 2000]
- National Volunteer Fire Council/United State Fire Administration *Health and Wellness Guide for the Volunteer Fire Service* [NVFC/USFA 2004].

NIOSH has supplied the fire department with these documents.

Recommendation 5: Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are capable of performing the essential job tasks of structural firefighting.

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 of the standard [NFPA 1997].

Recommendation 6: Review EMS treatment protocols for acute myocardial infarction.

In the most recent guidelines, the American Heart Association discusses the administration of aspirin, nitroglycerin, and morphine by EMS for the care and hospital preparation of patients with chest discomfort suggestive of ischemia [AHA 2005]. According to the ambulance run report, no aspirin was orally administered by ambulance personnel before the fire fighter lost consciousness. NIOSH investigators could



Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

not determine whether this deviation from AHA guidelines was related to the short response/transport time, or whether the fire fighter had a contraindication. He was hemodynamically unstable (heart rate 114 beats per minute), therefore nitroglycerin and morphine were not administered by ambulance personnel. Since this fire department does not perform EMS as part of its normal duties, this recommendation is included for EMS staffed fire departments.

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Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

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Fatality Assessment and Control Evaluation Investigation Report # F2007-14

Volunteer Fire Fighter Suffers Sudden Cardiac Death Approximately 18 Hours After Responding to an Incident—Kentucky

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INVESTIGATOR INFORMATION

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