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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 *January 2010*

Fire Fighter Suffers Sudden Cardiac Death While Working at a Residential Fire – Mississippi

SUMMARY

On December 31, 2008, a 54-year-old male volunteer fire fighter (FF) was dispatched to a residential fire. On scene, he stretched 200 feet of uncharged 1¾-inch hoseline to the front door of the residence, operated the engine's pump panel, and carried a portable ventilation fan to the front porch of the residence. After discussing pump panel operation with a crew member, the FF collapsed. Finding the FF unresponsive, without a pulse, and not breathing, the crew began cardiopulmonary resuscitation (CPR). Despite CPR and advanced life support (ALS) administered on scene, en route to the hospital, and at the hospital, the FF died. The death certificate, completed by the coroner, listed "cardiopulmonary arrest due to atherosclerotic cardiovascular disease" as the cause of death. No autopsy was performed. Given the FF's probable underlying heart disease, NIOSH investigators conclude that the physical stress of driver operator duties probably triggered his sudden cardiac death.

The NIOSH investigators offer the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the FF's collapse, his sudden cardiac death may have been prevented.

- *Provide preplacement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.*
- *Incorporate exercise stress tests following standard medical guidelines into a fire department medical evaluation program*
- *Ensure fire fighters are cleared for return to 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.*
- *Phase in a comprehensive wellness and fitness program for fire fighters.*
- *Perform an annual physical performance (physical ability) evaluation.*
- *Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the Fire Department's annual medical evaluation program.*
- *Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.*
- *Perform an autopsy on all on-duty fire fighter fatalities.*

Fire Fighter Suffers Sudden Cardiac Death While Working at a Residential Fire – Mississippi

INTRODUCTION & METHODS

On December 31, 2008, a 54-year-old male volunteer FF suffered sudden cardiac death after performing driver/operator duties and carrying a portable ventilation fan at a residential fire. Despite CPR and ALS administered by crew members, the ambulance crew, paramedics, and personnel in the hospital's emergency department, the FF died. The United States Fire Administration notified NIOSH of this fatality on January 5, 2009. NIOSH contacted the affected Fire Department (FD) to gather additional information on January 9, 2009, and on July 10, 2009, to initiate the investigation. On July 20, 2009, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Mississippi to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Training Officer
- Family members of the FF

NIOSH personnel reviewed the following documents:

- FD policies and operating guidelines
- FD training records
- FD annual report for 2008
- FD incident report
- Emergency medical service (ambulance) incident report
- Hospital emergency department records
- Death certificate
- Primary care provider medical records

RESULTS OF INVESTIGATION

Incident. On December 31, 2008, the FD was dispatched to a residential fire at 1731 hours. Six fire fighters were at the fire station when the alarm sounded. Engine 423 (driver/operator [the FF] and an officer) responded, arriving on-scene at 1733 hours. The other fire fighters responded in Engine 421. Fire fighters found a single family dwelling of ordinary construction, measuring approximately 1,200 square feet. Fire was emitting from the bedroom windows on the A/B side of the dwelling.

The FF, wearing his turnout coat, assisted in pulling 200 feet of uncharged 1¾-inch hoseline to the front door of the residence. He then operated the engine's pump panel. The fire was knocked down within approximately 7 minutes, and horizontal ventilation was requested. The FF carried a portable ventilation fan weighing approximately 35 pounds to the front porch. The FF returned to the engine and discussed pump panel operations with a crew member. Suddenly, the FF collapsed (1759 hours).

Dispatch was notified, and an ambulance was dispatched at 1802 hours. Crew members assessed the FF, finding him unresponsive, not breathing, and without a pulse; CPR was begun. The ambulance arrived on scene at 1813 hours. The ambulance crew also found the FF unresponsive, with no pulse, and not breath-

ing. The FF was placed into the ambulance where a cardiac monitor revealed asystole (no heart rhythm). The FF was intubated with tube placement verified by bilateral breath sounds, but secondary technology tests to confirm placement were not performed [AHA 2000]. Oxygen was administered, and an intravenous line was placed. Cardiac resuscitation medications consistent with ALS protocols were administered without change in the FF's clinical condition. The ambulance departed the scene at 1823 hours en route to the hospital's emergency department.

The ambulance arrived at the hospital at 1835 hours. Inside the emergency department, resuscitation efforts continued without change in the FF's clinical condition until 1850 hours (51 minutes since his collapse), when the FF was pronounced dead by the attending physician.

Medical Findings. The death certificate, completed by the coroner, listed "cardiopulmonary arrest due to atherosclerotic cardiovascular disease" as the cause of death. No autopsy was performed.

The FF was 72 inches tall and weighed 256 pounds, giving him a body mass index (BMI) of 34.7. A BMI > 30.0 kilograms per meter squared is considered obese [CDC 2008]. The FF's risk factors for coronary artery disease (CAD) included male gender, age over 45, high blood pressure, high blood cholesterol, family history of CAD, and obesity.

In 1996, the FF was diagnosed with hypertension (high blood pressure) and was prescribed a blood-pressure lowering medication. His high blood cholesterol was diagnosed in 2008, and he was prescribed a cholesterol-lowering medication. The FF had two syncopal episodes for which he sought medical evaluation. The first, in 1996, was thought to be related to heat exposure. The second, in 2000, was thought to be related to antihypertensive therapy and transient hyperglycemia.

The FF had an exercise stress test in 1997 as part of his National Guard cardiac assessment. The FF exercised for 7 minutes, 45 seconds, reaching stage II of the Bruce protocol and achieving 7 metabolic equivalents (METs). His blood pressure reached 200/80 millimeters of mercury with no definite ischemic-appearing ST-T segment changes or ectopy noted. The physician determined the FF needed an "improved functional/exercise tolerance."

The FF visited the hospital for episodes of chest pain in 2003, 2004, and 2005. Workup in 2003 included an exercise stress test; the FF exercised for 7 minutes, 17 seconds, reaching stage II of the Bruce protocol and achieving 7 METs. His maximum heart rate reached 149 beats per minute, which was 87% of his maximal age-predicted heart rate. The test was stopped due to achieving > 85% of his target heart rate (a submaximal test). Again, the FF expressed no symptoms of angina, had a normal blood pressure response, and had no electrocardiogram (EKG) changes or arrhythmias consistent with ischemia.

Following his episode of chest pain in 2004, the FF had a cardiolite exercise stress test. The FF exercised for 8 minutes, reaching stage III of

the Bruce protocol and achieving 10 METs. His maximum heart rate reached 153 beats per minute, which was 90% of his maximal age-predicted heart rate. The test was stopped due to knee pain. Again, the FF expressed no symptoms of angina, had a normal blood pressure response, and had no EKG changes or arrhythmias consistent with ischemia.

An echocardiogram was performed after his 2005 hospital visit for chest pain. The echocardiogram revealed a normal left ventricular ejection fraction (>50%) but decreased left ventricular compliance with diastolic dysfunction. It also revealed concentric left ventricular hypertrophy and septal hypertrophy. Both of these conditions are complications of long-standing hypertension.

On the day of this incident, the FF was at the fire station eating dinner when the fire department was dispatched. He did not express any symptoms of cardiac problems.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the volunteer FD consisted of one fire station with 25 uniformed personnel that served a population of 2,500 residents in a geographic area of 5 square miles. In 2008, the FD responded to 64 calls: 21 building fires, 4 vehicle fires, 14 brush/grass fires, 1 other fire, 15 vehicle accidents, 2 hazardous condition calls, and 7 other calls.

Membership and Training. The FD requires all new fire fighter applicants to be 18 years of age for fire fighter duties and 21 years of age to operate fire apparatus, have a valid state driver's license, pass a background check, and be voted in by the FD membership. New members are assigned to an experienced member and receive orientation, apparatus familiarization, and in-house fire fighter training. Members are urged to attend training at the local fire college, but the State has no mandatory minimum training requirement for volunteer fire fighters. The FF was certified as a Fire Fighter I, Driver/Operator, HazMat for first responders, and had 15 years of fire fighting experience.

Pre-placement and Periodic Medical Evaluations. The FD does not require a pre-placement or annual medical evaluation for its members. Annual medical clearance to wear SCBA is not required. Return to duty clearance is required for duty-related injuries. The primary care physician provides the medical clearance to the Fire Chief.

Health and Wellness Programs. The FD does not have a wellness/fitness program, and no exercise (strength and aerobic) equipment is available in the fire station. Health maintenance programs are not available from the city. No annual physical ability test is required.

DISCUSSION

Atherosclerotic Cardiovascular Disease. In the United States, atherosclerotic coronary artery disease (CAD) is the most common risk fac-

tor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age over 45, male gender, family history of CAD, smoking, high blood cholesterol, high blood pressure, obesity/physical inactivity, and diabetes [AHA 2009]. The FF had six of these risk factors (age over 45, male gender, family history of CAD, high blood cholesterol, high blood pressure, and obesity/physical inactivity).

Narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. 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]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques. Because no autopsy was performed, it cannot be determined if the FF had a blood clot causing a heart attack.

Establishing the occurrence of a recent heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In the FF's case, neither the EKG performed in the ambulance nor in the hospital revealed changes consistent with an acute (abrupt onset) heart attack; cardiac enzymes were not tested, and no autopsy was performed to find a coronary artery thrombus. Therefore, no definitive conclusion can be made regarding whether the FF experienced a heart attack.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Siscovick et al. 1984; Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks in fire fighters have been associated with fire suppression and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The FF had responded to the structure fire and stretched 200 feet of 1¾-inch hoseline to the front door of the residence, performed driver/operator duties, and carried a ventilation fan to the porch of the residence while wearing a turnout coat. These activities expended at least 8 METs, which is considered moderate physical activity [Gledhill and Jamnik 1992; AIHA 1971]. Given the FF's medical history, it is probable that the physical stress of conducting emergency response and driver/operator duties triggered a cardiac arrhythmia or a heart attack, resulting in his sudden cardiac death.

Left Ventricular Hypertrophy. Although no autopsy was performed, left ventricular hypertrophy (LVH) was identified by an echocardiogram in 2005. LVH increases the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure, a heart valve problem, or chronic cardiac ischemia (coronary artery disease) [Siegel 1997]. The FF had a history of hypertension, which most likely caused his LVH because (1) his echocardiogram showed no valve problems and (2) the pattern of his LVH (concentric) was consistent with hypertension.

Occupational Medical Standards for Structural Firefighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. Like the ACC/AHA, this voluntary industry standard recommends exercise stress tests (ESTs) for asymptomatic members over the age of 45 with two or more CAD risk factors [Gibbons et al. 2002]. This FF had several CAD risk factors and therefore appropriately had ESTs in 2003 and 2004. However, these ESTs were not symptom-limiting (i.e., they were stopped due to knee pain and a 90% maximal heart rate). In both years, the tests were negative for ischemic heart disease. Imaging ESTs have a 5% false negative rate [Gibbons et al. 2002]. The FF's test results appear to have been falsely negative. Had the FF's symptom-limiting EST occurred more recently, it is possible his CAD would have been identified, and he would have been referred for further evaluation and treatment.

RECOMMENDATIONS

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the FF's collapse, his sudden cardiac death may have been prevented.

Recommendation #1: Provide preplacement and annual medical evaluations to fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000; NFPA 2007a]. These guidelines help to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, FDs are not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be difficult for small volunteer FDs to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [USFA 2004; NFPA 2007b].

To overcome the financial obstacle of medical evaluations, the FD 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 emergency medical technicians (EMTs) from the local emergency medical service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could 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 at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for

by the FD, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters. Medical evaluations should occur prior to performing fire suppression duties and/or other physically demanding duties including training.

Recommendation #2: Incorporate exercise stress tests following standard medical guidelines into an FD medical evaluation program.

Despite the apparent false negative results of this FF's exercise stress tests, these tests serve an important function to screen individuals for CAD, particularly if a symptom-limiting test is performed [IAFF, IAFC 2000; Gibbons et al. 2002; NFPA 2007a]. The exercise stress test could be conducted by the fire fighter's personal physician or the FD contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the FD physician, who should be responsible for decisions regarding medical clearance for fire fighting duties. Neither the NFPA nor the ACC/AHA addresses how frequently exercise stress tests should be repeated. Because of this FF's multiple CAD risk factors and his LVH identified by echocardiogram, repeating an exercise stress test every couple of years would have been reasonable.

Recommendation #3: Ensure fire fighters are cleared for return to 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.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000]. According to these guidelines, the FD should have a physician officially designated to guide, direct, and advise the members with regard to their health, fitness, and suitability for duty as required by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2007b]. The physician should review job descriptions, essential job tasks, and personal protective equipment requirements in order to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform. This recommendation should prevent a physician from making an uninformed decision to release a fire fighter to return to the physically demanding stresses of full duty. In this case, there was no indication (i.e., medical record documentation) that the physicians treating the FF specifically cleared him to perform fire fighting duties, nor did the FD require medical clearance.

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

Guidance for FD wellness/fitness programs is found in NFPA 1583, Standard on Health-

Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the National Volunteer Fire Council (NVFC) Health and Wellness Guide [IAFF, IAFC 2000; USFA 2004; NFPA 2008]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of over $1 million for each of four large FDs implementing the IAFF/IAFC wellness/fitness program compared to four large FDs not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007].

Given the FD's structure, the NVFC program might be the most appropriate model [USFA 2004]. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #5: Perform an annual physical performance (physical ability) evaluation.

NFPA 1500 recommends that the FD annually evaluate and certify FD members who engage in emergency operations as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007b]. This is recommended to ensure that fire fighters are physically capable of performing the essential job tasks of structural fire fighting. During the FF's exercise stress test in 1997 and 2003, he was unable to reach 10 METs, the minimum aerobic capacity considered necessary for unrestricted fire fighting duties [Gledhill and Jamnik 1992]. The physical ability test could be performed as part of the FD's training program.

Recommendation #6: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the FD's annual medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR1 1910.134]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans [OSHA 2009]. Mississippi does not operate an OSHA-approved State plan for the public sector; therefore, public sector employers (including volunteer/paid fire departments) are not required to comply with OSHA standards. However, NIOSH investigators recommend following this standard to ensure an increased level of medical fitness and safety.

Recommendation #7: Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

To reduce the risk of improper intubation, the AHA and the International Liaison Committee on Resuscitation published recommendations in the Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care [AHA 2000]. These guidelines recommend confirming tube placement by primary and secondary methods. Primary confirmation is the five-point auscultation: left and right anterior chest, left and right midaxillary, and over the stomach. Secondary confirmation requires a technology test, either an end-tidal carbon dioxide detector or an esophageal detector device. In this incident, the FF had bilateral breath sounds confirmed by auscultation and chest rise; however, secondary confirmation was not performed. We are not able to assess, and it is unlikely that, the endotracheal tube was misplaced or whether this issue contributed to the FF's death. We raise this issue only to ensure that future advanced life support resuscitation efforts follow AHA guidelines.

Recommendation #8: Perform an autopsy on all on-duty fire fighter fatalities.

In 2008, the USFA published the Firefighter Autopsy Protocol [USFA 2008]. With this publication, the USFA hopes 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 incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).