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28
NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation *March 2010*

Fire Fighter Suffers Cardiac Arrhythmia During Grass Fire Operations and Dies 10 Days Later– North Carolina

SUMMARY

On March 11, 2009, a 60-year-old male volunteer fire fighter (FF) drove a tanker to a 2-acre grass fire. After activating the pump and assisting in pulling the 1¾-inch hoseline, the FF collapsed. Advanced life support treatment was provided at the scene, en route to the hospital's emergency department (ED), and in the ED. The FF was subsequently transferred to a regional hospital where his condition deteriorated, and he died 10 days later.

The death certificate, completed by the Office of the Chief Medical Examiner, listed "complications from ventricular tachycardia/ventricular fibrillation arrest due to ischemic heart disease" as the cause of death. The autopsy, also completed by the Office of the Chief Medical Examiner, listed "complications from cardiac arrest secondary to ischemic cardiomyopathy" as the cause of death. Given the FF's underlying atherosclerotic coronary artery disease (CAD), the stress of performing driver/operator duties related to the grass fire probably triggered his cardiac arrhythmia.

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 cardiac arrhythmia and subsequent 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.
- Perform an annual physical performance (physical ability) evaluation.
- Phase in a comprehensive wellness and fitness program for fire fighters.
- Provide fire fighters with medical clearance to wear a self-contained breathing apparatus (SCBA).
- Conduct annual respirator fit testing.

Fire Fighter Suffers Cardiac Arrhythmia During Grass Fire Operations and Dies 10 Days Later–North Carolina

INTRODUCTION & METHODS

On March 11, 2009, a 60-year-old male volunteer FF suffered an arrhythmia after responding to the fire station, driving a tanker to a grass fire, and pulling 1¾-inch hoseline. Despite cardiopulmonary resuscitation (CPR) and advanced life support administered by the ambulance crew, personnel in the local hospital ED, and the regional hospital, the FF died 10 days later. NIOSH contacted the affected Fire Department (FD) to gather additional information on May 6, 2009, and on November 30, 2009, to initiate the investigation. On December 14, 2009, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to North Carolina to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- FF's family

NIOSH personnel reviewed the following documents:

- FD policies and operating guidelines
- FD training records
- FD annual report for 2009
- FD incident report
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Hospital inpatient records
- Death certificate
- Autopsy report
- Primary care provider medical records

INVESTIGATIVE RESULTS

Incident. On March 11, 2009, the FD was dispatched at 1619 hours to a 2-acre grass fire near a dwelling. The FF responded to the FD and, wearing his turnout coat, drove a tanker with the Assistant Chief to the scene, arriving at 1628 hours. An ambulance was dispatched to stand by at the scene in accordance with dispatch protocols. The weather conditions at this time included a temperature of 80 degrees Fahrenheit and 44% relative humidity [NOAA 2009].

At the fire scene, the FF assisted in pulling the 1¾-inch hoseline. As two additional fire fighters arrived, the FF engaged the tanker's pump and continued to assist in stretching the hoseline. At 1635 hours, while standing at the tanker, the FF collapsed.

Crew members ran to assist the FF and found him unresponsive with a faint pulse but no spontaneous breathing. The ambulance arrived on the scene at 1636 hours. Paramedics found the FF unresponsive, not breathing, and with a faint pulse. Oxygen was administered via bag-valve-mask as the FF was moved into the ambulance. At this point, the FF's pulse stopped, and CPR was begun. Cardiac monitoring revealed ventricular fibrillation, and one shock was delivered. Intubation was performed and tube placement confirmed by bilateral breath

sounds and verified by capnography [AHA 2000]. Intravenous line placement was performed, and cardiac resuscitation medications were administered per advanced life support protocols.

The ambulance departed the scene en route to the local hospital ED at approximately 1640 hours. En route, the FF's pulse returned with the cardiac monitor revealing sinus tachycardia with multifocal premature ventricular contractions. Additional medications were administered, and the FF's heart rhythm stabilized for a short time, then returned to ventricular tachycardia. He was shocked five times, after which his heart stopped. CPR began again, and the FF regained a pulse just as the ambulance arrived at the ED (1658 hours).

Inside the ED, advanced life support treatment continued. The FF was reintubated and placed on mechanical ventilation. An electrocardiogram (EKG) showed anterolateral ischemia. Cardiac enzyme testing revealed an elevated blood level of creatine kinase (279 international units per liter [IU/L]; normal level is 18–263), an elevated blood level of troponin I (0.038 nanograms per milliliter [ng/mL]; normal level is 0–0.012), but a normal blood level of creatine kinase-MB (CKMB) [de Winter et al. 1995]. These tests suggested a possible heart attack; the FF was transferred at 1900 hours to a regional hospital for emergent cardiac catheterization.

After arriving at the regional hospital, emergent cardiac catheterization was performed, revealing CAD and ischemic cardiomyopathy. The FF had a left ventricular ejection fraction of 25%, a totally (100%) occluded right coronary artery (RCA), a previously stented left anterior descending (LAD) coronary artery with 50% occlusion, and a 70% occlusion in the circumflex coronary artery. Repeat cardiac enzyme tests were normal. An EKG revealed an old inferior infarction. Over the next few days he was stabilized but remained unresponsive. An electroencephalogram revealed the FF had suffered hypoxic brain injury during his cardiac arrest. Intensive care treatment continued for 10 days without positive change in the FF's condition. On March 21, 2009, life support equipment was removed, and the FF was pronounced dead.

Medical Findings. The death certificate, completed by the Office of the Chief Medical Examiner, listed "complications from ventricular tachycardia/ventricular fibrillation arrest due to ischemic heart disease" as the cause of death. The autopsy, also completed by the Office of the Chief Medical Examiner, listed "complications from cardiac arrest secondary to ischemic cardiomyopathy" as the cause of death. Findings from the autopsy are listed in Appendix A.

The FF was 73 inches tall and weighed 161 pounds, giving him a normal body mass index (BMI) of 21.2 kilograms per meters squared (kg/m2) [CDC 2010]. His risk factors for CAD included male gender, age over 45, high blood pressure, high blood cholesterol, and diabetes mellitus. He also had a history of atrial fibrillation. In 2006 the FF was hospitalized for acute congestive heart failure and underwent

cardiac catheterization, revealing severe CAD. He had a completely occluded RCA that had caused an old inferior heart attack. He had new anterior ischemia due to significant narrowing of his LAD, and two stents were placed. Follow-up with three imaging exercise stress tests and an echocardiogram in 2007 and 2008 revealed a very low exercise capacity – reaching only 5 to 7 metabolic equivalents (METs) on the Bruce protocol before stopping because of fatigue and shortness of breath. The test also demonstrated a large anterior and inferior wall defect from a heart attack. This defect resulted in heart failure, quantified by a left ventricular ejection fraction of 45%; normal is typically ≥ 55%. His medications included two antihypertensives, two diabetes medications, and two blood thinners (coumadin and aspirin), but no cholesterol-lowering or lipid-lowering agents. The FF expressed no recent (within the past 5 months) symptoms of angina or shortness of breath on exertion to his physician, his family, or the FD.

DESCRIPTION OF THE FIRE PROTECTION DISTRICT

At the time of the NIOSH investigation, the volunteer FD consisted of one fire station with 22 uniformed personnel that served a population of 3,800 residents in a geographic area of 10 square miles.

Membership and Training. The FD requires new fire fighter applicants to be at least 18 years of age, pass a background check, have a valid State driver's license, and be in good health. The FD votes on all new members. New members receive monthly fire fighter training and must attend 36 hours of training annually. Members must have driver/operator training to drive fire apparatus. Members are encouraged to attend the County Fire Fighter Rookie School to receive Fire Fighter I training. New members are placed on probation for 6 months and must have attended live fire training to fight structural fires. The State has no minimum requirement for fire fighter certification. The FF was certified as a Driver/Operator and in HazMat; he had 20 years of fire fighting experience.

Medical Evaluation Program. The FD currently does not require a preplacement or an annual medical evaluation. No annual SCBA facepiece fit test is required for interior structural fire fighters. Annual SCBA medical clearance is not required. The FD does not have a return to duty policy following injuries or illnesses.

Health and Wellness Programs. The FD has no wellness/fitness program; however, exercise (strength and aerobic) equipment is available in the fire station. The FD does not require an annual physical ability test. No health maintenance programs are available from the County.

DISCUSSION

In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2010]. The FF had five known risk factors (age older than 45, male gender, high blood pressure, high blood cholesterol, and diabetes mellitus), and was found to have severe CAD, an old heart attack, and heart failure in 2006.

The 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.

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In the FF's case, he had a known old inferior heart attack based on his 2006 EKG and 2006 cardiac catheterization (100% occluded right coronary artery). During this incident, however, his EKG revealed new ischemia, but no injury (infarct) pattern. His cardiac catheterization showed no thrombus formation. These findings coupled with his mild cardiac enzymes (troponin) elevation suggest that if the FF had an acute heart attack, it was a small one. More likely, the FF had cardiac ischemia, which caused a prolonged cardiac arrhythmia, anoxic brain damage, and subsequent death.

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]. The FF responded to the alarm, drove the tanker to the scene, and stretched a hoseline. These activities expended about 8 metabolic equivalents, which is considered moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Heart attacks in fire fighters have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. Given the FF's underlying CAD, NIOSH investigators conclude that the stress of performing fire fighting duties probably triggered his cardiac arrhythmia, resulting in his collapse, anoxic brain damage, and subsequent death.

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the FF was found to have left ventricular hypertrophy (LVH) and an enlarged heart. LVH was identified during an echocardiogram in June 2008. Both LVH and cardiomegaly increase 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 (reduced blood supply to the heart muscle) [Siegel 1997]. The FF had high blood pressure and chronic cardiac ischemia.

Rhythm Disturbances – Atrial Fibrillation. Atrial fibrillation is a disturbance of the heart's conduction system. During atrial fibrillation, the heart's two small upper chambers (the atria) beat very rapidly in a nonproductive, quivering manner [Waktare 2002; Wang et al. 2004]. A September 2008 episode of atrial fibrillation probably was due to underlying CAD and heart failure. It was unsuccessfully treated by cardioversion, necessitating treatment with a rate limiting medication (a beta blocker) and anticoagulants (coumadin and aspirin).

Occupational Medical Standards for Structural Fire Fighters. According to the medical records available to NIOSH, the FF's physicians never addressed whether he was medically fit for duty as a fire fighter. 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]. This voluntary industry standard provides medical requirements for candidates and current fire fighters.

The FF had a number of medical conditions (CAD, atrial fibrillation, and anticoagulation therapy) that precluded work as a fire fighter. NFPA 1582 states that CAD compromises a member's ability to safely perform many of the essential job tasks of structural fire fighting, specifically wearing SCBA and advancing water-filled hoselines [NFPA 2007a]. The standard states that the physician shall report the applicable job limitations to the FD if any one of the following is present:

1. Current angina pectoris even if relieved by medication

2. Persistent significant stenosis in any coronary artery (greater than 70% lumen diameter narrowing) following treatment

3. Lower than normal left ventricular ejection fraction as measured by radionuclide scan, contrast ventriculography, or echocardiography

4. Maximal exercise tolerance of less than 42 milliliters of oxygen per minute per kilogram or less than 12 METs

5. Exercise-induced ischemia or ventricular arrhythmias observed by radionuclide stress test during an evaluation reaching at least a 12-MET workload

6. History of myocardial infarction, angina, or coronary artery disease with persistence of modifiable risk factor(s) for acute coronary plaque rupture (e.g., tobacco use, hypertension despite treatment or hypercholesterolemia with cholesterol greater than or equal to 180, or low density lipoproteins

greater than or equal to 100 despite treatment, or glycosylated hemoglobin greater than 7 despite exercise and/or weight reduction) [NFPA 2007a]

The FF had many of these conditions and therefore should have been precluded from fire fighting.

NFPA 1582 also considers that atrial fibrillation and full-dose anticoagulation compromise a member's ability to safely perform as an integral component of a team, where sudden incapacitation of a member can result in mission failure or in risk of injury or death to civilians or other team members [NFPA 2007a]. Given the FF's atrial fibrillation and full-dose anticoagulation treatment, he should have been restricted from full fire suppression duties.

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 cardiac arrhythmia and subsequent cardiac death may have been prevented.

Recommendation #1. 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.

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 2008; NFPA 2007a]. However, the FD is not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments 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 hav-

ing the annual medical evaluations completed by paramedics and emergency medical technicians (EMTs) from the local EMS (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, County, or State. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the City, the County, the State, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters older than 45 with two or more CAD risk factors [IAFF, IAFC 2008; 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.

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 2008]. According to these guidelines, the FD should have a physician who is officially responsible for guiding, directing, and advising 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 and essential job tasks required for all FD positions and ranks to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations.

Recommendation #4: Perform an annual physical performance (physical ability) evaluation.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the fire department to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test)

as meeting these physical performance standards [NFPA 2007b]. This will ensure that fire fighters are physically capable of performing the essential job tasks of structural fire fighting.

Recommendation #5: Phase in a comprehensive wellness and fitness program for fire fighters.

Guidance for fire department 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 2008; USFA 2004; NFPA 2008]. Following this guidance will reduce risk factors for cardiovascular disease and improve cardiovascular capacity. NFPA 1583 establishes the minimum requirements for the development of a health-related fitness and exercise program and health promotion for fire department members involved in emergency operations [NFPA 2008]. Members must be cleared annually for participation in a fitness assessment by the fire department physician and are required to participate in a periodic fitness assessment under the supervision of the fire department health and fitness coordinator [NFPA 2008]. The fitness assessment includes (1) aerobic capacity, (2) body composition, (3) muscular strength, (4) muscular endurance, and (5) flexibility. The exercise and fitness program must include (1) education, (2) individualized participation, (3) warm-up and cool-down exercise guidelines, (4) aerobic exercise, (5) muscular strength and endurance, (6) flexibility exercise, (7) healthy back exercise, and (8) safety and injury prevention [NFPA 2008].

The National Volunteer Fire Council and the U.S. Fire Administration Health and Wellness Project document, Health and Wellness Guide, was developed to improve health and wellness within the volunteer fire service [USFA 2004]. This guide provides suggestions for successfully implementing a health and wellness program for volunteer fire departments.

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 et al. 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 recent study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments 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].

Recommendation #6: Provide fire fighters with medical clearance to wear self-contained breathing apparatus.

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 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. North Carolina operates an OSHA-approved State plan; therefore, public sector employers (including volunteer/paid fire departments) are required to comply with OSHA standards. This clearance could be provided as part of the FD medical evaluation program.

Recommendation #7: Conduct annual respirator fit testing.

The OSHA respiratory protection standard requires employers whose employees are required to use a respirator (e.g., an SCBA) to have a formal respiratory protection program, including annual fit testing [29 CFR 1910.134]. As mentioned previously, North Carolina is an OSHA-approved State plan; therefore, the fire department is required to follow OSHA standards [OSHA 2009].

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INVESTIGATOR INFORMATION

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located 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).

The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In fiscal year 1998, the Congress appropriated funds to NIOSH to conduct a fire fighter initiative. NIOSH initiated the Fire Fighter Fatality Investigation and Prevention Program to examine deaths of fire fighters in the line of duty so that fire departments, fire fighters, fire service organizations, safety experts and researchers could learn from these incidents. The primary goal of these investigations is for NIOSH to make recommendations to prevent similar occurrences. These NIOSH investigations are intended to reduce or prevent future fire fighter deaths and are completely separate from the rulemaking, enforcement and inspection activities of any other federal or state agency. Under its program, NIOSH investigators interview persons with knowledge of the incident and review available records to develop a description of the conditions and circumstances leading to the deaths in order to provide a context for the agency's recommendations. The NIOSH summary of these conditions and circumstances in its reports is not intended as a legal statement of facts. This summary, as well as the conclusions and recommendations made by NIOSH, should not be used for the purpose of litigation or the adjudication of any claim. For further information, visit the program website at

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