

Death in the line of duty...



A summary of a NIOSH fire fighter fatality investigation

April, 2011

Fire Fighter-Paramedic Suffers Sudden Cardiac Death During Ice Rescue Training – New Hampshire

Executive Summary

On January 16, 2011, a 46-year-old male volunteer fire fighter-paramedic (FF/P) participated in ice rescue training. During the training, the FF/P played the role of the victim. After the last evolution, the FF/P walked approximately 400 feet in 13 inches of snow toward the staging area when he complained of shortness of breath. After a transport ambulance arrived, the FF/P went into cardiac arrest. Crew members and ambulance personnel provided cardiopulmonary resuscitation (CPR) and advanced life support as the FF/P was transported to the local hospital's emergency department (ED). CPR and advanced life support continued in the ED for an additional 31 minutes until the ED physician pronounced him dead. The death certificate and the autopsy listed "coronary artery atherosclerosis" as the cause of death. Given the FF/P's underlying coronary artery disease (CAD), NIOSH investigators concluded that the physical exertion involved in the training and in walking through the snow triggered a cardiac arrhythmia resulting in his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unclear whether these recommendations could have prevented the FF/P's death.

Provide preplacement and annual medical evaluations to all fire fighters.

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 National Fire Protection Association (NFPA) 1582.

Phase in a comprehensive wellness and fitness program for fire fighters.

Perform a preplacement and an annual physical performance (physical ability) evaluation.

Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

Conduct annual respirator fit testing.

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 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH "Fire Fighter Fatality Investigation and Prevention Program" which examines line-of-dutydeaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency's reports do not name the victim, the fire department or those interviewed. The NIOSH report's summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency's recommendations and is not intended to be definitive for purposes of determining any claim or benefit. For further information, visit the program website at www.cdc. gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

Introduction & Methods

On January 16, 2011, a 46-year-old male volunteer FF/P died after participating in ice rescue training. NIOSH was notified of this fatality on January 18, 2011, by the U.S. Fire Administration. NIOSH contacted the affected FD on January 25, 2011, to gather additional information, and on January 27, 2011, to initiate the investigation. On February 7, 2011, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- FF/P's daughter

NIOSH personnel reviewed the following documents:

- FD training records
- FD standard operating guidelines
- FD incident report
- Police incident report
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Autopsy report
- Primary care provider medical records

Investigative Results

Incident. On January 16, 2011, the FD scheduled a training exercise in ice rescue (Appendix A). Crew members assembled at the fire station a little before 0800 hours and drove FD apparatus (engine, rescue, medic unit, and a pickup) to the frozen river/pond training site (Figure 1). Twenty crew members, including a paramedic, two emergency medical technician-basics (EMT-B), three EMT-intermediates, and 14 fire fighters participated. Weather conditions included a temperature of 26°Fahrenheit (°F) and 63% relative humidity. The pond was frozen, and the entire area was covered with approximately 13 inches of fresh snow [Weather Underground 2011].



Figure 1. Location of sled training

At the training site, crew members first conducted sled-based ice rescue training. The FF/P, wearing civilian clothing including a winter coat, observed this training from shore. The training lasted approximately 1 hour.

Crew members moved to the end of the pond for in-water ice rescue training. The FF/P donned an ice rescue suit weighing approximately 10 pounds and swam through a culvert to the training

Investigative Results (cont.)



Figure 2. Location of ice rescue training

location (Figure 2). The water at this location was approximately 3 feet deep and at freezing temperature. Speaking to a crew member, the FF/P was concerned about aggravating a recent shoulder surgery. The crew member showed the FF/P how to hold onto the rescue rope while the crew member "rescued" the FF/P. The training lasted approximately 1 hour, and crew members exited the pond area by either climbing the steep snow bank or walking about 400 feet around the river bank. The FF/P walked around the river bank.

As the FF/P neared the staging area, he reported shortness of breath and lay down in the snow. Crew members brought a Stokes® basket to carry the FF/P to the rescue unit and summoned an ambulance (1102 hours). When the FF/P climbed into the Stokes® basket, he began to lose consciousness. Crew members rushed the basket to the rescue unit, 75 feet away, as the FF/P began to have seizure-like activity.

Inside the rescue unit, the FF/P was unresponsive. He stopped breathing and had no pulse. CPR (chest

compressions and oxygen delivery via bag-valve mask) was begun. A cardiac monitor attached to the FF/P revealed two heart beats in rapid succession (bigeminy). One shock (defibrillation attempt) was administered without positive change in the FF/P's clinical condition. A police officer notified the FF/P's daughter of the incident; the daughter relayed pertinent medical history via the police officer to the crew members at the scene.

The ambulance arrived on the scene at 1111 hours and found the FF/P unresponsive, not breathing, with no pulse, and with CPR in progress. The FF/P was intubated, and lung sounds were verified by capnography [AHA 2000]. An intravenous line was placed, and cardiac resuscitation medications were administered through the IV line. The ambulance departed the scene en route to the hospital's ED at 1130 hours. During those 19 minutes the FF/P's heart rhythm alternated between ventricular fibrillation, pulseless electrical activity, ventricular/ bradycardia, and supraventricular tachycardia. Three additional shocks were administered without improvement in the FF/P's clinical condition. CPR and advanced life support continued throughout the transport. The ambulance arrived at the hospital's ED at 1147 hours.

Inside the ED, advanced life support continued without positive change in the FF/P's clinical condition. Resuscitation measures continued until 1218 hours, when the attending physician pronounced the FF/P dead.

Medical Findings. The death certificate and autopsy listed "coronary artery atherosclerosis" as the cause of death. The FF/P's blood was not tested for carboxyhemoglobin (a measure of carbon monoxide exposure), but nicotine was identified.

Investigative Results (cont.)

The FF/P's known risk factors for CAD included smoking, high blood cholesterol (207 milligrams per deciliter [normal is <200] [elevated on the first and only cholesterol level measured]), and obesity (based on a body mass index of 34.7 kilograms per meters squared [> 30.0 kilograms per meters squared is considered obese]) [AHA 2011; CDC 2011].

In 2005 the FF/P was hospitalized for chest pain, but testing showed no evidence of a heart attack. To screen for possible CAD, a stress echocardiogram was performed. The FF/P exercised for 10 minutes on the Bruce protocol [Sport Fitness Advisor 2011], achieving 9.7 metabolic equivalents (METs). He stopped when he reached 85% of his maximum agepredicted heart rate (160 beats per minute). He had no reported angina, normal blood pressure response, and no ischemic changes on electrocardiogram. Echocardiogram imaging revealed a normal left ventricle size, wall motion, and ejection fraction. He was diagnosed with pericarditis and discharged from the hospital.

The FF/P last visited his primary care physician in September 2010, but had more recent visits to his neurospinal specialist for shoulder surgery and follow-up. At his December 20 visit, he was released for duty by his neurospinal specialist.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of one fire station with 45 uniformed volunteer personnel. It served 6,000 residents in a geographic area of 17 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age (21 years to drive fire apparatus), have a valid state driver's license, be a resident of the town, and have the approval of the committee of fire engineers. The applicant is then voted in or out by the members at the next general meeting. New members receive 220 hours of fire fighter training to become certified as a Fire Fighter 1, an additional 160 hours to become certified as a Fire Fighter 2, and an additional 200 hours to become an emergency medical technician. The state has no mandatory minimum training levels for volunteer fire fighters. The FF/P had 3 years of fire fighting experience and was State-certified as Fire Fighter 1, Apparatus Operator, Paramedic, and in hazardous materials operations. He was a member of this FD for 2 months.

Preplacement and Periodic Medical Evaluations.

The FD does not require preplacement or periodic (annual) medical evaluations for members. No annual SCBA medical clearance or annual SCBA facepiece fit test are required. Members injured on duty must be evaluated by their primary care physician who forwards a decision regarding return to work to the State Office of Workers' Compensation. The State Office of Workers' Compensation makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has no formal wellness/fitness program. No strength training equipment is available in the fire station; however, a local gym offers a 30% membership discount to FD members. No physical ability test is required for candidates or members.

Discussion

Atherosclerotic Coronary Artery Disease. 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 2011; NHLBI 2011]. The FF/P had five CAD risk factors (age older than 45, male gender, smoking, high blood cholesterol, and obesity).

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 electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, the heart monitor in the rescue unit did not show changes indicating an acute heart attack. His cardiac enzymes were not tested, but the FF/P died before the enzymes would be expected to increase. These enzymes take at least 4 hours after a heart attack to become positive. No coronary artery thrombus was identified at autopsy. Based on the clinical scenario, the FF/P suffered either a primary heart

arrhythmia (most likely) or an asymptomatic heart attack (less likely), either of which could have caused his sudden cardiac 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]. 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]. The FF/P participated in ice rescue training and walked to and from the training site in 13 inches of snow. These activities expended about 8 METs, which is considered moderate physical activity [AIHA 1971; Ainsworth et al. 2000].

Occupational Medical Standards for Structural Fire Fighters. 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 (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria. The FF/P was a smoker and had elevated blood cholesterol, but these conditions, by themselves, should not trigger fire fighter duty restrictions. However, these two factors could have warranted a referral for an exercise stress test to screen for CAD. Recommendations for conducting exercise stress tests on asymptomatic individuals without known heart disease are varied. The following paragraphs summarize the positions of widely recognized organizations on this topic.

Discussion (cont.)

National Fire Protection Association (NFPA) 1582, a voluntary industry standard, recommends an exercise stress test performed "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (e.g., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease
- two or more risk factors for CAD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter), hypertension (diastolic blood pressure greater than 90 mm of mercury), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The American College of Cardiology/American Heart Association (ACC/AHA) has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA guideline states that the evidence to conduct stress tests in asymptomatic individuals with diabetes mellitus is "Class IIa," which is defined as "conflicting evidence and/ or a divergence of opinion about the usefulness/ efficacy but the weight of the evidence/opinion is in favor." The ACC/AHA guideline states the evidence is "less well established" (Class IIb) for

the following groups:

- persons with multiple risk factors (defined similarly to those listed by the NFPA)
- asymptomatic men older than 45 years and women older than 55 years:
 - who are sedentary and plan to start vigorous exercise
 - who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters)
 - who are at high risk for coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation provides guidance for those seeking medical certification for a commercial driver's license. An expert medical panel recommended exercise tolerance tests (stress tests) for asymptomatic "high risk" drivers [Blumenthal 2007]. The panel defines high risk drivers as those with any of the following:

- diabetes mellitus
- peripheral vascular disease
- age 45 and above with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart disease events. For individuals at increased risk for coronary heart disease events, the USPSTF found "insufficient evidence to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning...." Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking,

Discussion (cont.)

and diabetes) [USPSTF 2004]. The USPSTF does note that "For people in certain occupations, such as pilots, and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than the health benefit to the individual patient may influence the decision to screen for coronary heart disease."

Given the FF/P's age and CAD risk profile, only the ACC/AHA would have "recommended" a symptom limiting exercise stress test. This recommendation, however, was based on a "category IIb" indication: "usefulness/efficacy is less well established by evidence/opinion" [Gibbons et al. 2002].

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unclear if these recommendations could have prevented the FF/P's death.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2007a]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, the FD is not legally required to follow this standard. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments to implement.

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 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.

Recommendation #2: Ensure that 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]. According to this guideline, the FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty. The physician should review job descriptions and essential job tasks required for all FD positions and ranks to understand the physiologi-

Recommendations (cont.)

cal 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. The FD does not currently have a physician to oversee return to work clearances. Sharing the financial responsibility for this recommendation between the FD, the City, the State, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #3: Phase in a comprehensive wellness and fitness program for fire fighters.

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in the National Volunteer Fire Council (NVFC) Health and Wellness Guide, NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; NFPA 2008; Schneider 2010]. 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 coronary artery disease 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 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].

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 #4: Perform a preplacement and an annual physical performance (physical ability) evaluation.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD 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 for structural fire fighters [NFPA 2007b]. Examples of these evaluations include tests found in the National Volunteer Fire Council (NVFC) Health and Wellness Guide, Candidate Physical Ability Test, and fitness evaluations as part of the IAFF/IAFC wellness/fitness initiative [USFA 2004; IAFF/IAFC 2007; IAFF/IAFC 2008].

Recommendation #5: Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical

Recommendations (cont.)

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 2011]. New Hampshire does not operate an OSHA-approved State plan. Therefore, the FD is not required to comply with this standard. However, NIOSH recommends voluntary compliance to ensure that all members are medically cleared to wear an SCBA.

Recommendation #6: 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, New Hampshire does not have an OSHA-approved State plan; however, it is recommended that the FD follow this OSHA standard voluntarily [OSHA 2011].

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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 coauthored 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 coauthored 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).

Appendix A

Ice Rescue Training Lesson Plan for January 16, 2011

- Rescue Alive familiarization
- Techniques to remove a patient from the ice/water
 - o Rescue alive
 - Stokes basket
 - o Ropes
- Shoreline party activities
- In-water techniques for rescuers
 - o Proper wear of ice-rescue PPE
 - Movement on ice
 - Movement to open water
 - o Entering water
 - o Exiting water
 - Movement in the water
 - o Patient rescue techniques
 - Self-rescue
 - Dope-on-a-rope

Training Officer: Deputy Chief

Safety Officer: Fire Chief

Apparatus:

- 56F1 (Forestry pickup truck)
- 56R1 (Rescue-EMS)
- 56E2 (Engine)
- 56M2

EMS Support:

- Paramedic
- FF/EMT-B
- EMT-B

Appendix B

Autopsy Findings

- Atherosclerotic cardiovascular disease
 - o Severe (75%) focal narrowing of the left anterior descending coronary artery
 - o Mild focal narrowing of the circumflex coronary artery
 - o Mild focal narrowing of the right coronary artery
 - Microscopic evidence of myocyte hypertrophy and diffuse moderate perivascular fibrosis with thickened intramural arterioles
 - Left ventricular hypertrophy (LVH)
 Left ventricular wall and interventricular septum thickened (1.2 cm); normal measurement by autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997];
 normal measurement by echocardiography is 0.6–1.1 cm [Armstrong and Feigenbaum 2001]
 - Cardiomegaly
 Heart weight of 450 grams (g); predicted normal weight is 399 g (between 302 g and 526 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Mild thickening of the mitral and tricuspid valve leaflets
- No evidence of a thrombus (blood clot in the coronary arteries)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Severe infrarenal aortic atherosclerosis
- Toxicology results were negative for drugs and alcohol; positive for nicotine (carbon monoxide not tested)

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