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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *May, 2011*

Fire Fighter Suffers Sudden Cardiac Death While Fighting Wildland Fire – Virginia

Executive Summary

On September 24, 2010, a 54-year-old male volunteer fire fighter (FF) responded to a wildland fire at approximately 1756 hours. At the scene, the FF stretched 300 feet of 1½-inch hoseline and extinguished an area of fire for about 35 minutes. After reporting that he did not feel well, the FF collapsed upon entering his brush truck. Cardiopulmonary resuscitation (CPR) and advanced life support were begun, and the FF was transported to the local hospital's emergency department (ED). CPR and advanced life support continued in the ED for 5 minutes. At 1950 hours the ED physician pronounced the FF dead, and resuscitation efforts stopped. The death certificate and the autopsy listed "cardiomegaly" as the cause of death. Given the FF's underlying congenital heart block, cardiomegaly, and left ventricular hypertrophy (LVH), NIOSH investigators concluded that the physical exertion involved in responding to the call and performing fire suppression duties triggered an arrhythmia resulting in his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is possible if these recommendations had been implemented, the FF's death may have been prevented.

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.

Perform a preplacement and 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 self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

Ensure fire fighters wear personal protective clothing appropriate to the incident.

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Introduction & Methods

On September 24, 2010, a 54-year-old male volunteer FF collapsed after fighting a wildland fire. NIOSH was notified of this fatality on September 27, 2010, by the U.S. Fire Administration. NIOSH contacted the affected Fire Department (FD) on October 1, 2010, to gather additional information, and on October 27, 2010, to initiate the investigation. On November 15, 2010, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Virginia to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Fire Chief
- Ambulance crew members
- FF's family and friends

NIOSH personnel reviewed the following documents:
- FD training records
- FD incident report
- Emergency medical service (ambulance) incident reports
- Hospital ED records
- Death certificate
- Autopsy report

Investigative Results

Incident. On September 24, 2010, at 1756 hours, a neighboring town requested mutual aid for a large, fast moving brush and woods fire. Twenty-one FD personnel responded with an engine, a brush truck, a tanker, and a rescue unit. An ambulance had been dispatched at 1731 hours as part of the first alarm assignment and was on scene when the other personnel arrived.

The FF rode in the engine, arriving at 1804 hours. Weather conditions at this time included a temperature of 81°Fahrenheit (F), 69% humidity (heat index of 84.5°F), and wind gusts up to 25 miles per hour [NOAA 2008; Weather Underground 2010]. Crew members, including the FF, wearing structural fire fighting gear (coat, pants, boots, helmet, gloves) deployed 300 feet of 1½-inch firehose and began fighting the 4-acre fire. Meanwhile, the ambulance crew set up a rehabilitation (rehab) sector.

At approximately 1840 hours (after about 35 minutes of fire fighting), the FF reported not feeling well. He handed his hoseline to a crew member, and walked out of the woods toward the brush truck, which was about 35 feet away. The FF knelt beside a tree before continuing on to the brush truck. As the FF entered the cab of the brush truck he collapsed (1902 hours). Crew members, including the ambulance crew from rehab, pulled him from the cab and laid him on the ground. The FF was unresponsive, not breathing, and had no pulse. CPR was begun, and an automated external defibrillator (AED) was applied. The FF was shocked three times without a change in his clinical condition. He was then carried into the ambulance. An oropharyngeal airway and an intravenous line were placed through which cardiac resuscitation medications were administered.

Investigative Results (cont.)

The ambulance departed the scene at 1913 hours en route to the ED. During transport, the FF was defibrillated two additional times, and his heart rhythm reverted to asystole. A King™ airway was inserted, oxygen was administered via bag-valve mask, and CPR continued with no change on his condition. The ambulance arrived at the ED at 1945 hours, approximately 45 minutes since his collapse. Inside the ED, cardiac resuscitation efforts continued for 5 minutes, when the attending physician pronounced the FF dead, and resuscitation efforts were discontinued (1950 hours).

Medical Findings. The death certificate and the autopsy completed by the Office of the Medical Examiner listed "cardiomegaly" as the cause of death. Specific findings from the autopsy are listed in Appendix A.

In 1964 at age 8 the FF was diagnosed with acute rheumatic fever with complete heart block, a diagnosis later changed to congenital heart block with varying degrees of A-V dissociation. The FF seemed to tolerate this condition well until 2002 when he presented to the hospital with intermittent chest discomfort and fatigue. An EKG confirmed the complete heart block with junctional escape complexes at about 35–40 beats per minute and right bundle branch block. An echocardiogram revealed mild left ventricular hypertrophy with a normal left ventricular ejection fraction (LVEF) of 63%. A permanent dual chamber pacemaker was implanted followed a month later with a persantine cardiolite stress test. The stress test revealed a reduced LVEF at 48% and multiple reversible changes suggestive of ischemia (anteroapical, inferior, and lateral walls of the heart). However, the report noted that these findings could be due to left bundle branch block and cardiomyopathy.

The cardiologist felt these stress test EKG changes were due to the FFs congenital heart condition and that a cardiac catheterization to diagnose and/or treat coronary heart disease was not necessary.

During his most recent exercise stress test with imaging (August 2009), the FF exercised for 9 minutes, achieving 10.1 metabolic equivalents (METs). The test was stopped because of fatigue. The FF reached 88% of his maximum predicted heart rate (147/167 beats per minute), had no symptoms of angina, no wall motion abnormalities, normal blood pressure response, and no ischemic changes on EKG. However, at peak exercise the rhythm strip did note some premature ventricular contractions.

The FF was 70 inches tall and weighed 261 pounds, giving him a body mass index of 37.4 kilograms per meters squared (kg/m2), which is considered obese [CDC 2010]. The FF's risk factors for coronary artery disease (CAD) included high cholesterol and obesity/lack of exercise. He was prescribed an 81 milligram aspirin once a day beginning in 2003, but according to his 2009 medical records, the FF had stopped taking this medication.

During the week prior to this incident, the FF spoke with his cardiologist and, according to the FF's fiancé, the cardiologist told the FF he could "do anything he wanted." The day of this incident, the FF had an elevated temperature, but worked at his regular job for the town water department and had not expressed symptoms or signs of heart problems.

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Description of the Fire Department

At the time of the NIOSH investigation, the volunteer FD consisted of one fire station with 42 uniformed personnel that served 1,600 residents in a geographic area of 26 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, and pass a background check. The applicant is then voted upon at a general meeting. The new member has 1 year to be trained as a Fire Fighter I or an Emergency Medical Technician (EMT). The FF had 38 years of fire fighter experience and was certified as a Fire Fighter 1, Apparatus Operator, EMT, and a Fire Investigator.

Preplacement and Periodic Medical Evaluations. The FD does not require preplacement or periodic (annual) medical evaluations for members. No annual SCBA medical clearance is required; however, an annual SCBA facepiece fit test and spirometry are required. Members injured on duty must be evaluated by their primary care physician, who forwards the evaluation results to the Fire Chief to make the final determination regarding return to duty.

Health and Wellness Programs. The FD has no formal wellness/fitness program, and no strength training equipment is available in the fire station. No annual physical ability test is required.

Discussion

Both the death certificate and autopsy attribute the FF's death to cardiomegaly (an enlarged heart). The most common cause for an enlarged heart is ischemic or hypertensive (chronic high blood pressure) heart disease [Wynne and Braunwald 2008]. These conditions were not present in the FF as evidenced by the lack of significant coronary atherosclerosis at autopsy and no history of high blood pressure in his medical records. Most likely the FF's cardiomegaly was related to his congenital heart block or some type of underlying cardiomyopathy. Cardiomegaly, left ventricular hypertrophy, and cardiomyopathy, independently, increase the risk of life threatening arrhythmias and sudden cardiac death [Siegel 1997].

Cardiomyopathies are a diverse group of diseases of the heart muscle. Hypertrophic cardiomyopathy (HCM) is the most common cardiomyopathy. HCM is a genetic disease that is defined by a hypertrophied, nondilated left ventricle in the absence of another disease capable of producing a thickened wall [Maron et al. 2006]. On autopsy the FF had marked left ventricular hypertrophy of no known etiology. Therefore, it is possible this FF had an underlying HCM associated with congenital heart block.

Hypertrophic Cardiomyopathy. HCM is a relatively rare heart condition, affecting approximately 0.2% of the population [Spirito et al. 1997]. Diagnosis is typically made by an echocardiogram that shows the left ventricular thickening. Most patients are asymptomatic, and sudden cardiac death is often the first clinical manifestation [Wynne and Braunwald 2005]. Risk factors for sudden death among HCM patients include young age (<30 years old) at diagnosis, a family history of HCM with sudden death, an abnormal blood

Discussion (cont.)

pressure response to exercise, severe symptoms, nonsustained ventricular tachycardia, marked hypertrophy, marked left atrial dilatation, and genetic abnormalities associated with increased prevalence of sudden death [Spirito et al. 1997; Olivotto et al. 1999; Wynne and Braunwald 2005; Maron et al. 2006].

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers sudden cardiac death [Albert et al. 2000]. The FF had deployed 300 feet of 1½-inch firehose and fought a 4-acre wildland fire while wearing structural fire fighting gear (coat, pants, boots, helmet, gloves). This activity expended about 9 METs, which is considered heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992].

Given the FF's cardiomegaly, left ventricular hypertrophy, congenital heart disease, and possible HCM, the stress of responding to the call and performing fire suppression duties probably triggered an arrhythmia resulting in his sudden cardiac death.

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 had a pacemaker implanted in 2002. According to NFPA 1582, paragraph 9.4.10.1, a medical condition requiring a pacemaker or automatic implantable defibrillator compromises the member's ability to safely perform essential job task 13 (functioning as an integral component of a team), and the physician shall report the applicable job limitations to the FD [NFPA 2007a]. Following NFPA 1582 would have restricted the FF from performing fire fighting duties, and may have prevented his sudden cardiac death at this time.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is possible if these recommendations had been implemented, the FF's death may have been prevented.

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 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. 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 or this initiative. 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

Recommendations (cont.)

physicians. Another option is having the annual medical evaluations completed by paramedics and EMTs from the local ambulance 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] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008]. According to these guidelines, 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 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. Even though the FF's primary care physician cleared him for "physically demanding work," NFPA 1582 would have restricted him from fire suppression because of his pacemaker. It is unclear if the FF's physician was aware that his patient was a fire fighter. His medical records never mentioned medical clearance for fire fighting duty, and the FD does not require medical clearance for its members or candidates.

Recommendation #3: 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]. This evaluation could be included in the FD's annual training program. The FF's last exercise stress test revealed an aerobic capacity of 10.1 METs. This is considered the lower range needed to successfully complete the essential job tasks of fire fighting [Gledhill and Jamnik 1992; NFPA 2007a].

Recommendation #4: 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

Recommendations (cont.)

found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; IAFF, IAFC 2008; 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 #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 evaluations and clearance for employees using respiratory protection [29 CFR[1] 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved State plans [OSHA 2010]. Virginia operates an OSHA-approved State plan. Therefore, the FD is required to comply with this standard and ensure that all members are medically cleared to wear an SCBA.

Recommendation #6: Ensure fire fighters wear personal protective clothing appropriate to the incident.

NFPA 1500, Fire Department Occupational Safety and Health Program, states that the fire department shall provide each member with protective clothing and protective equipment that is designed to provide protection from the hazards to which the member is likely to be exposed and is suitable for the tasks that the member is expected to perform [NFPA 2007b]. The protective clothing and protective equipment shall also be used whenever the member is exposed or potentially exposed to the hazards for which it is provided [NFPA 2007b]. In this incident, the FF wore boots and pants meant for structural fire fighting, which are heavier than wildland fire fighting gear. The heavier boots and pants hinder movement and place extra physical stress on the fire fighter. If the FD frequently responds to grass and brush fires, the FD should consider wildland fire fighting gear as recommended in NFPA 1977, Standard on Protective Clothing and Equipment for Wildland Fire Fighting [NFPA 2011].

[1]Code of Federal Regulations. See CFR in references.

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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

Autopsy Findings

- Cardiomegaly (enlarged heart) (heart weighed 600 grams [g]; predicted normal weight is 425 g [between 322 g and 561 g] as a function of sex, age, and body weight) [Silver and Silver 2001]
- Left ventricular hypertrophy
  - left ventricular wall thickened (1.6 centimeters); interventricular septum thickened (1.7 centimeters)
  - normal by autopsy 0.76–0.88 cm [Colucci and Braunwald 1997]
  - normal by echocardiography 0.6–1.1 cm [Armstrong and Feigenbaum 2001]
- No evidence of significant atherosclerosis or thrombosis (blood clot) in the coronary arteries
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Pacemaker located on upper front left chest
- Negative blood tests for carboxyhemoglobin (carbon monoxide) and alcohol
- Negative urine test for drugs

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