2007
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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

June 25, 2007

Fire Fighter Suffers Sudden Cardiac Death During Extrication Demonstration – Virginia

SUMMARY

On September 16, 2006, a 19-year-old male volunteer Fire Fighter (FF) participated in a parade and an automobile extrication demonstration, which included wearing full bunker gear and cutting into an automobile with heavy hydraulic rescue tools. During the demonstration, the FF complained of not feeling well, passed the tool to a crew member, and collapsed. Crew members and on-scene ambulance paramedics began cardiopulmonary resuscitation (CPR) and advanced life support as they transported the FF to the hospital's Emergency Department. Inside the Emergency Department, despite advanced life support treatment for 13 minutes, the FF died. The death certificate and autopsy (completed by the Medical Examiner) listed "acute cardiac arrhythmia due to dilated cardiomyopathy associated with acute hemorrhage of the membranous septum of the heart" as the cause of death. It is unclear if the FF's sudden cardiac death was triggered by the physical exertion associated with the extrication demonstration.

The following recommendations probably would not have prevented this fire fighter's death. However, NIOSH investigators offer these recommendations to address general safety and health issues:

- ***Perform pre-placement and periodic medical evaluations consistent with National Fire Protection Association (NFPA) 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments.**
- ***Ensure that fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.***
- ***Develop a structured wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***Provide fire fighters with medical evaluations and clearance to wear self-contained breathing apparatus (SCBAs).***

INTRODUCTION & METHODS

On September 16, 2006, a 19-year-old male volunteer FF suffered sudden cardiac death during an automobile extrication demonstration.

The Fire Fighter Fatality Investigation and Prevention Program is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Website at

http://www.cdc.gov/niosh/fire/

or call toll free

1–800–35–NIOSH

NIOSH was notified of this fatality on September 19, 2006 by the United States Fire Administration. NIOSH contacted the affected Fire Department on September 19, 2006 to obtain further information, and on January 10, 2007 to initiate the investigation. On January 23, 2007, 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
- FF's parents

NIOSH personnel reviewed the following documents:

- Fire Department incident report
- 9-1-1 dispatch recordings
- Crew members' statements
- The FF's training records
- Ambulance report
- Hospital records
- Death certificate
- Autopsy
- Primary care physician records

INVESTIGATIVE RESULTS

On September 16, 2006, the FF and a crew member drove from their fire station to a neighboring town for a parade, arriving at about 1000 hours. The parade began at about 1030 hours, concluding about 1230 hours in a parking lot of a local business. Another crew member brought Rescue 10, which was to be used for an automobile extrication demonstration. The FF and crew members, wearing full bunker gear, began tearing apart the demonstration automobile with hydraulic rescue tools. About 10 minutes later (1240 hours), the FF said he did not feel well and asked a crew member to hold the cutter tool (which weighed about 30 pounds). As soon as the FF passed the cutter tool to the crew member, he collapsed. Crew members stopped the operation and on-scene emergency medical technicians (EMTs) and paramedics from the local fire department and ambulance service responded immediately to the FF's location.

Paramedics removed the FF's bunker gear and gave assisted ventilations via bag-valve-mask as he was placed onto a cot and into the ambulance. Assessment in the ambulance found the FF to be unresponsive, not breathing, and without a pulse. CPR was begun followed by advanced life support treatment which included intravenous (IV) line placement, intubation (breathing tube inserted into the trachea), and cardiac monitoring. Intubation was successful on the second attempt; secondary confirmation for proper tube placement was made by an end tidal carbon dioxide test. The cardiac monitor revealed ventricular fibrillation (heart rhythm incompatible with life) and a shock was administered. The FF regained a weak pulse, lasting about 90 seconds, and then his heart rhythm converted to asystole (no heart beat). Cardiac resuscitation medications were administered without improvement in the FF's condition. The ambulance departed the scene at 1257 hours en route to the hospital's Emergency Department. The ambulance arrived at the Emergency Department at 1303 hours (about 23 minutes after his collapse).

Inside the Emergency Department, advanced life support and CPR continued. Cardiac

monitoring revealed ventricular fibrillation and two additional shocks were administered without positive change in the FF's condition. Resuscitation efforts were discontinued and the FF was pronounced dead at 1316 hours.

Medical Findings. The death certificate and autopsy (completed by the Medical Examiner) listed "acute cardiac arrhythmia due to dilated cardiomyopathy associated with acute hemorrhage of the membranous septum of the heart" as the cause of death. Pertinent findings from the autopsy, conducted on September 18, 2006, included the following:

- Mild cardiomegaly: heart weighed 370 grams (g) (normal estimate for his body size was up to 350 g)[1]
- Cardiomyopathy
  - Dilated spherical shape and biventricular dilatation (increased volume)
  - Hypertrophic (enlarged in thickness)
    - Left Ventricular Hypertrophy (wall thickness was 1.7 centimeters [cm] [normal is 0.6 cm - 1.1 cm])[2]
    - Mild Right Ventricular Hypertrophy (wall thickness was 0.5 cm [normal is 0.3 cm - 0.5 cm])[3]
    - Microscopic examination revealed "patchy myocyte hypertrophy with a slight increase in interstitial fibrous tissues"
    - No microscopic evidence of acute myocarditis or obvious vasculitis
- Normal conduction tissue
- No gross evidence of acute infection
- No significant coronary artery atherosclerosis
- No evidence of mitral valve prolapse
- No evidence of a pulmonary embolus
- Toxicology results were negative for alcohol and drugs

The FF had no known medical problems or no known history of dilated cardiomyopathy. According to primary care physician records from 1995 to 2006, there was no history of a viral infection consistent with viral myocarditis or a family history of cardiomyopathy. One week prior to his death, the FF passed the medical evaluation for entry into the Virginia Fire Academy. According to his family members, the FF recently expressed episodes of fatigue which were attributed to an active lifestyle and his working for a lawn care service. The FF was 70 inches tall and weighed 165 pounds, giving him a "normal" body mass index (BMI) of 23.6 kilograms per square meter (kg/m^2).[4]

The night before the fatal incident, the FF worked a shift at the Fire Department in which he responded to three calls: a medical call, a motor vehicle crash, and a carbon monoxide alarm. After the last alarm, he returned to the station and went to sleep until he awakened at 0800 hours.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this volunteer Fire Department consisted of 45 volunteer fire fighters, served a local population of 9,000 in an 18-square mile area, and had one fire station.

Membership and Training. The Fire Department requires all applicants to:

- Be at least 18 years of age
- Complete an application
- Possess a valid State driver's license
- Have a good driving record
- Pass a background check
- Pass an oral interview

The application is reviewed by the membership committee while the applicant is present. The committee then makes a recommendation for membership to the Fire Department's general membership, and the applicant is voted on for probationary membership. The new member is placed on probation for 6 months, during which time the member attends training and Fire Department functions. The member must demonstrate knowledge and abilities to function as a fire fighter, including performing a physical agility test. After 6 months, the member is voted on for full membership. Within one year of membership, the fire fighter must obtain Fire Fighter I, Hazardous Materials Awareness, and/or Emergency Medical Technician – Basic (EMT-B) Hazardous Materials Awareness levels. The State requires Fire Fighter I and Hazardous Materials Awareness certifications as minimum requirements for structural fire fighters.

The FF was certified as a Fire Fighter II and in Hazardous Materials Awareness. He had 3 years of firefighting experience; beginning at age 16 as a Junior Firefighter.

Pre-placement and Annual Medical Evaluations. No pre-placement or annual medical evaluation is required by the Fire Department. Medical clearance to wear an SCBA is not required. A return-to-duty medical clearance is required from the fire fighter's primary care physician for duty-related injuries. If a non-duty-related illness prevents fire fighters from performing their duty, the Fire Department may require a return-to-duty clearance by the fire fighter's primary care physician.

Health/Wellness. There is no wellness/fitness program, however exercise equipment (strength and aerobic) is available at the Fire Department; participation is voluntary. Members have access to a local gym at reduced cost. A physical agility test is performed as part of mandatory routine training.

DISCUSSION

Cardiomyopathy and Sudden Cardiac Death. The FF was diagnosed at autopsy with dilated cardiomyopathy. Cardiomyopathies are conditions that involve damage to the heart muscle not due to hypertension, ischemia (coronary artery disease), valvular, pericardial, or congenital heart disease.[5] There are three types of cardiomyopathy based on functional impairment:

1) dilated, the most common form, which accounts for 60% of all cardiomyopathies
2) hypertrophic, recognized by inappropriate left ventricular hypertrophy, often with involvement of the interventricular septum
3) restrictive, the least common form in Western countries, marked by impaired diastolic filling and in some cases with endocardial scarring of the ventricle[5]

This FF had components of both dilated and hypertrophic cardiomyopathy.

Dilated Cardiomyopathy. Dilated cardiomyopathy is characterized by cardiac enlargement and impaired systolic function of one or both ventricles, congestive heart failure, arrhythmias, and emboli.[6] Microscopic findings are non-specific, typically being myocyte hypertrophy (best appreciated as nuclear hypertrophy [e.g. "box-car nuclei"]) with varying degrees of interstitial fibrosis.[6,7] As the ventricular function deteriorates, the following signs and symptoms of congestive heart failure appear: shortness of breath with exertion or when lying flat, ankle swelling, fatigue, weakness, etc. The FF recently experienced fatigue, but had no other symptoms. Laboratory studies (radionuclide and cardiac catheterization) are necessary to reveal left ventricular enlargement and dysfunction, mitral and/or tricuspid regurgitation, elevated left- and often right-sided filling pressures, elevated pulmonary artery wedge pressures, and diminished cardiac output.[5,6] Due to the FF having no symptoms, no laboratory studies were conducted.

The incidence rate of dilated cardiomyopathy in the United States is 5 to 8 cases per 100,000 per year, with an age-adjusted prevalence of 36 cases per 100,000.[7] Although most cases of dilated cardiomyopathy are of unknown etiology (idiopathic), a variety of acquired or hereditary disorders can cause the disorder. These secondary and potentially reversible forms are listed in Table 1.[6]

Inherited factors account for approximately one-third of all idiopathic dilated cardiomyopathy cases, and 20% of patients with idiopathic dilated cardiomyopathy have at least one first-degree relative with a decreased ejection fraction and cardiomegaly.[8-10] Although idiopathic dilated cardiomyopathy can be transmitted as a recessive or X-linked trait, autosomal dominant inheritance occurs most frequently and exhibits both clinical variability and genetic heterogeneity.[11] It is unclear if this FF's idiopathic dilated cardiomyopathy was due to inherited factors or due to post-viral myocarditis. The FF had no medical history consistent with viral myocarditis and no known relatives with cardiomyopathy. In either case, due to the possibility of the condition being inherited, first-degree relatives of this fire fighter should consult with their physicians regarding when, or if, an echocardiogram is warranted for screening purposes.

The prognosis for idiopathic dilated cardiomyopathy is poor; recent studies report an average 5-year death rate of 20%.[12-15] Dilated cardiomyopathy is also associated with an increased incidence of sudden cardiac death, mostly from arrhythmias.[5,6,16] Although sudden death is rarely the initial presentation,[12,13] it is a common cause of death among idiopathic dilated cardiomyopathy patients, accounting for 28% of all idiopathic dilated cardiomyopathy deaths.[6] Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden cardiac death are hard to identify.[6]

Hypertrophic Cardiomyopathy. On autopsy, the FF was found to have left and right ventricular hypertrophy consistent with the diagnosis of hypertrophic cardiomyopathy. Idiopathic hypertrophic cardiomyopathy is a

relatively rare heart condition, affecting approximately 0.2% of the population.[17] The majority of patients are asymptomatic, and sudden cardiac death is often the first clinical manifestation.[18] Risk factors for sudden death among idiopathic hypertrophic cardiomyopathy patients include young age (<30 years old) at diagnosis, a family history of idiopathic hypertrophic cardiomyopathy with sudden death, an abnormal blood pressure response to exercise, severe symptoms, non-sustained ventricular tachycardia, marked hypertrophy, marked left atrial dilatation, and genetic abnormalities associated with increased prevalence of sudden death.[17-19] The FF had at least one (young age) of these risk factors for sudden death.

Approximately half of the idiopathic hypertrophic cardiomyopathy cases are transmitted genetically, typically as an autosomal dominant trait. As with dilated cardiomyopathy, medical evaluation of first-degree relatives is warranted to determine whether screening tests (e.g., echocardiogram) are appropriate.

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.[20] NFPA considers hypertrophic cardiomyopathy a Category B medical condition for FF candidates; defined as "a medical condition that, based on its severity or degree, **could** (our emphasis) preclude a person from performing as a fire fighter in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others." For members, NFPA 1582 considers cardiomyopathy a condition that might compromise a fire fighter's ability to: a) safely perform firefighting tasks, b) wear an SCBA, c) climb six or more flights of stairs while wearing fire-protective ensemble weighing at least 50 pounds or more and carrying equipment/tools weighing an additional 20 to 40 pounds, d) advance water-filled hoselines, e) endure prolonged physical exertion, and f) function as an integral component of a team, where sudden incapacitation can result in mission failure or in risk of injury or death to civilians or other team members.

The FF was asymptomatic, and prior medical evaluations did not detect any cardiac abnormality. NFPA 1582 recommends an EKG and a chest x-ray as part of its candidate medical evaluation. Had an EKG or chest x-ray been conducted as part of the Fire Department's candidate or member medical evaluation, perhaps the FF's enlarged heart would have been detected. This may have led to further medical evaluation (e.g., an echocardiogram) and treatment (an implantable cardiac defibrillator).

Firefighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods.[21-24] The FF participated in an automobile extrication drill while wearing full bunker gear. This is considered a moderate level of physical exertion.[25,26] The NIOSH investigator concludes that the FF had a fatal cardiac arrhythmia associated with his dilated and hypertrophic cardiomyopathy. It is unclear if the moderate physical exertion at the extrication demonstration triggered his sudden cardiac death.

RECOMMENDATIONS

It is unlikely the following recommendations could have prevented this fire fighter's death. However, NIOSH investigators offer these recommendations to address general safety and health issues.

***Recommendation #1: Perform pre-placement and periodic medical evaluations consistent with National Fire Protection Association (NFPA) 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments.**

NFPA 1582 requires fire departments to conduct pre-placement and annual medical evaluations. Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582[20] and in the International Association of Fire Fighters (IAFF) / International Association of Fire Chiefs (IAFC) *Fire Service Joint Labor Management Wellness/Fitness Initiative*.[27] However, the Fire Department is not legally required to follow this standard or this initiative.

NFPA 1582 recommends annual cardiac evaluations which include auscultation of the heart and an EKG. Perhaps if the FF had received an annual medical evaluation, his left ventricular hypertrophy might have been detected, and he could have been referred for further medical evaluation.

Applying this recommendation involves economic repercussions and may be particularly difficult for small, rural, volunteer fire departments to implement. These economic concerns go beyond the costs of administering the medical program; they involve the personal and economic costs of dealing with the medical evaluation results. NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, Chapter 8-7.1 and 8-7.2[28] and the NVFC *Health and Wellness Guide*[29] address these issues.

To overcome the financial obstacle, the Fire Department could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations recommended by NFPA 1582 completed by other members of the volunteer Fire Department (medical and occupational history) and by paramedics and EMTs from the Emergency Medical Service (vital signs, height, weight, visual acuity, EKG). This information could then be provided to a community physician, perhaps volunteering his or her time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical examinations could be performed by a private physician at the fire fighter=s expense, provided by a physician volunteer, or paid for by the Fire Department. Sharing the financial responsibility for these evaluations between volunteers, the Fire Department, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed volunteers.

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

The Fire Department 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 as required by NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program.*[28] The physician should review job descriptions and essential job tasks required for all Fire Department positions and ranks, in order 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. Medical evaluations may be performed by the fire fighter's primary care physician. However, the results must be communicated to the Fire Department physician, who makes the final determination for clearance for duty.

To overcome the financial obstacle, the Fire Department could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations recommended by NFPA 1582 completed by other members of the volunteer Fire Department (medical and occupational history) and by paramedics and emergency medical technicians from the Emergency Medical Service (vital signs, height, weight, visual acuity, EKG). This information could then be provided to a community physician, perhaps volunteering his or her time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical examinations could be performed by a private physician at the fire fighter=s expense, provided by a physician volunteer, or paid for by the Fire Department. Sharing the financial responsibility for these evaluations between volunteers, the Fire Department, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed volunteers.

Recommendation #3: Develop a structured wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Currently, the Fire Department does not have a wellness/fitness program, however, exercise equipment is available in the fire station, and members have access to a local gym at reduced cost. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of physical exercise.

Physical inactivity is the most prevalent modifiable risk factor for coronary artery disease (CAD) in the United States. Physical inactivity, or lack of exercise, is associated with other risk factors, including obesity and diabetes.[30] NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[28] Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[31-33] Health promotion programs in the fire service have been shown to improve CAD risk factors and fitness levels, with mandatory programs showing the most improvement.[34-36] One mandatory program was able to show a cost savings of $68,741 due to reduced absenteeism.[37] A similar cost savings has been reported by the wellness program at the Phoenix Fire Department, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.[38] Guidance for implementation and components of a wellness/fitness program may be found in NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters*,[39] in the IAFF/IAFC, *Fire Service Joint Labor*

Management Wellness/Fitness Initiative,[27] as well as in the National Volunteer Fire Council (NVFC)'s *Health and Wellness Guide*.[29] Given the structure of the FF's Fire Department, the NVFC program might be the most appropriate model.

Recommendation #4: Provide fire fighters with medical evaluations and clearance to wear self-contained breathing apparatus (SCBAs).

The Occupational Safety and Health Administration (OSHA)'s *Revised Respiratory Protection Standard* requires employers to provide medical evaluations and clearance for employees using respiratory protection.[40] Such employees include fire fighters who utilize SCBA in the performance of their duties. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. Virginia is a State-plan State and public sector employers are required to comply with OSHA standards. OSHA respirator clearance is also required by the Fire Academy prior to candidate training.

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