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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 *March, 2014*

Lieutenant Suffers Sudden Cardiac Death at Motor Vehicle Crash – Ohio

Executive Summary

On July 1, 2012, a 24-year-old male volunteer lieutenant (LT) was dispatched to a motor vehicle crash at 0208 hours. The LT responded to the fire station where he rode in the fire department's (FD) rescue vehicle to the crash scene. The crashed vehicle had struck a utility pole and slid down an embankment. As crew members were extracting the driver, the LT climbed a 10-foot embankment to retrieve a backboard from the ambulance when he collapsed. He was treated by the on-scene ambulance paramedic and transported to the hospital's emergency department (ED). En route to the ED, the LT suffered cardiac arrest; cardiopulmonary resuscitation (CPR) was begun. Despite CPR and advanced life support (ALS) by ED personnel, the LT died.

The death certificate, completed by the deputy county coroner, and the autopsy, completed by the forensic pathologist, listed "cardiopulmonary arrest due to dilated cardiomyopathy" as the cause of death. Prior to this incident the LT was asymptomatic and not known to have any cardiac problems. Given the LT's underlying dilated cardiomyopathy, the physical stress of responding to the call and climbing the embankment may have triggered a fatal heart arrhythmia.

The following recommendations would not have prevented the LT's death. Nonetheless, NIOSH investigators offer these recommendations to address general safety and health issues.

Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

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

Perform a candidate and an annual physical performance (physical ability) evaluation for all members.

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

Ensure paramedics are trained and follow proper ALS protocols regarding patient assessment and cardiac monitoring.

Ensure that transport vehicles are in proper working order.

Introduction & Methods

On July 1, 2012, a 24-year-old male volunteer LT suffered sudden cardiac death while working at a motor vehicle crash. NIOSH contacted the affected FD on July 19, 2012, to gather additional information, and on July 26, 2013, to initiate the investigation. On August 20, 2013, a safety and occupational health specialist

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Introduction & Methods (cont.)

from the NIOSH Fire Fighter Fatality Prevention and Investigation Program and a visiting scientist conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

Fire chief

- Crew members
- LT's spouse

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD annual report for 2012
- FD incident reports
- Death certificate
- Autopsy report
- Primary care physician records

Investigative Results

Incident. On June 29, 2012, the LT worked a 24-hour shift (0700 hours to 0700 hours) at his career FD. During his shift, he responded to several calls for trees down due to a rain and wind storm. At the last call in the afternoon, the LT and his crew members worked strenuously for about 4 hours cutting and removing a large tree that had fallen across a roadway. His shift ended at 0700 hours on June 30, 2012, and the LT went home.

After resting for about 2 hours, the LT performed yard work until he was dispatched by his volunteer FD at 1130 hours for a fallen tree blocking the roadway. At this call, he assisted in cutting and removing the tree from the roadway and returned home at about 1300 hours. During the rest of the afternoon and evening he was not dispatched to any other calls and went to bed at about 2300 hours.

At 0208 hours on July 1, 2012, the LT was dispatched to a motor vehicle crash. He responded to the fire station and rode in Rescue 8 with one crew member. Engine 9, Tanker 2, Tanker 4, Brush 6, and Squad 1 along with 15 additional personnel also responded.

Units arrived on the scene at 0213 hours to find that a vehicle had struck a utility pole and rolled over a fence and down a 45-degree 10-foot embankment, landing on its roof. The driver suffered non-life threatening injuries and was extricated by crew members. The LT, wearing full turnout gear, was sent to retrieve a long backboard from the ambulance. He walked up the embankment and as he neared the roadside guardrail, he collapsed (approximately 0225 hours). Crew members found him unresponsive, but he was breathing and had a weak pulse. Oxygen was administered via bag-valve-mask; a cardiac monitor was not hooked up. A life flight helicopter was requested but did not respond due to the short distance and time for ambulance transport.

The LT became pulseless, CPR was begun, and he was loaded into Squad 1, which departed the scene at 0236 hours en route to the local hospital's ED. On two separate occasions, Squad 1 requested assistance from the nearby ALS ambulance service, but as the Squad approached the meeting areas the ALS unit had not arrived yet so the Squad proceeded to the ED. En route, a cardiac monitor was attached and revealed asystole as Squad 1 arrived at the ED (0246 hours). For unknown reasons, the rear doors to the squad would not open, and ED personnel provided ALS including intubation inside the ambulance. After about 5 minutes, the doors were opened and the LT was brought inside the ED with ALS and CPR in progress.

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Investigative Results (cont.)

Inside the ED, an intravenous line was placed, and cardiac resuscitation medications were administered. The LT's heart rhythm changed to ventricular fibrillation. One defibrillation attempt (shock) was made; his heart rhythm reverted to pulseless electrical activity. Resuscitation efforts continued for about 25 minutes when the LT was declared dead and resuscitation efforts were stopped (0319 hours).

Medical Findings. The death certificate, completed by the deputy county coroner, and the autopsy, completed by the forensic pathologist, listed "cardiopulmonary arrest due to dilated cardiomyopathy" as the cause of death. Specific autopsy findings are listed in Appendix A.

The LT had no prior complaints or symptoms of cardiac problems. He underwent a preplacement medical evaluation in January 2012 for his career FD and the state's police and fire pension fund. All test results were deemed normal including an electrocardiogram (EKG), a chest x-ray, and an exercise stress test. For the exercise stress test, the LT exercised for 12 minutes on the Bruce protocol, achieving 13.4 metabolic equivalents (METs) and was stopped when he reached 98% of his maximum predicted heart rate. The LT reported no symptoms, the EKG showed no arrhythmias and no ischemic changes, and he had a normal blood pressure response to exercise.

The LT was 73 inches tall and weighed 264 pounds, giving him a body mass index of 34.8 kilograms per meters squared. A body mass index > 30.0 kilograms per meter squared is considered obese [CDC 2011]. The LT had no other documented medical history and was not prescribed any medications. The LT never complained of cardiac symptoms and had no family history of dilated cardiomyopathy.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of two fire stations with 20 volunteer uniformed personnel and served 2,400 residents in a geographic area of 58 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid state driver's license, and pass a preplacement medical evaluation and a drug screen. The applicant is then voted on by the FD membership. The new member is placed in a training program to become certified as a Fire Fighter 1 and 2. The LT was certified as a Fire Fighter 2, apparatus operator, wildland fire fighter, and in hazardous materials operations. He had 3.5 years of volunteer fire fighting experience and 3 months experience as a career fire fighter.

Preplacement Medical Evaluations. Since 2012, the FD has required a preplacement medical evaluation for all applicants. The components of this medical evaluation are determined by the examining physician. The LT did not have a preplacement medical evaluation because he joined the FD prior to 2012, but he did have a normal preplacement medical evaluation from his career FD in January 2012.

Periodic Medical Evaluations. The FD does not require periodic (annual) medical evaluations or medical clearance to wear a respirator. An annual SCBA facepiece fit test is required. Members injured on duty must be evaluated by their personal physician who forwards their opinion for return to duty, but the fire chief makes the final return-to-work determination.

Health and Wellness Programs. The FD does not have a wellness/fitness program, and exercise equipment is not available in the fire stations. No annual physical ability test is required. The LT exercised regularly by running 5 days per week.

Discussion

Cardiomyopathy. Although the LT was asymptomatic, the autopsy revealed dilated cardiomyopathy. Cardiomyopathies involve damage to the heart muscle not due to hypertension, ischemia (coronary artery disease), valvular, pericardial, or congenital heart disease [Wynne and Braunwald 2008]. The three types of cardiomyopathy based on functional impairment are as follows:

1) Dilated, the most common form, accounts for 60% of all cardiomyopathies
2) Hypertrophic, recognized by left ventricular hypertrophy, often with involvement of the interventricular septum and right ventricle
3) Restrictive, the least common form in Western countries, marked by impaired diastolic filling and in some cases with endocardial scarring of the ventricle [Wynne and Braunwald 2008]

Dilated cardiomyopathy is characterized by cardiac enlargement and impaired systolic function of one or both ventricles, congestive heart failure, arrhythmias, and emboli [Dec and Fuster 1994]. 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, and/or weakness. Laboratory studies such as cardiac catheterization, echocardiogram, or imaging studies are necessary to make the diagnosis of dilated cardiomyopathy. Microscopic findings are nonspecific, typically being myocyte hypertrophy (best appreciated as nuclear hypertrophy ["boxcar nuclei"]) with varying degrees of interstitial fibrosis [Dec and Fuster 1994; Virmani 1997; Wynne and Braunwald 2008].

The incidence 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 [Virmani 1997]. Although most cases of dilated cardiomyopathy are of unknown etiology, a variety of acquired or hereditary disorders can cause the disorder. These secondary and potentially reversible forms are listed in Appendix B [Dec and Fuster 1994]. Inherited factors account for approximately one third of all idiopathic dilated cardiomyopathy cases [Fatkin et al. 1999]. The LT did not have a family history of idiopathic dilated cardiomyopathy. Nonetheless, his first-degree relatives (parents, siblings, and children) should consult with their physicians regarding when, or if, a screening echocardiogram is warranted.

Dilated cardiomyopathy is associated with an increased incidence of sudden cardiac death [Dec and Fuster 1994; Bansch et al. 2002; Wynne and Braunwald 2008]. Although sudden death is rarely the initial presentation [Komajda et al. 1990; Sugrue et al. 1992], it is a common cause of death among idiopathic dilated cardiomyopathy patients, accounting for 28% of all idiopathic dilated cardiomyopathy deaths [Dec and Fuster 1994]. Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden cardiac death are hard to identify [Dec and Fuster 1994].

Epidemiologic studies have found that heavy physical exertion sometimes precedes and triggers sudden cardiac death [Albert et al. 2000]. The LT had worked 24 hours, during which time he responded to several calls for cutting and removing trees from roadways. His activities as a volunteer fire fighter responding to downed trees and a motor vehicle crash would have expended about 8 METs, which is considered moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992;

Discussion (cont.)

Ainsworth et al. 2011]. NIOSH investigators conclude that the LT had a fatal cardiac arrhythmia due to his dilated cardiomyopathy possibly triggered by his moderate physical activity.

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 2013a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The city-contracted physician conducted an exercise stress test in January 2012. The LT showed excellent aerobic capacity by exercising for 12 minutes and achieving 13.4 METs. He was asymptomatic and had no ischemic changes or arrhythmias on his EKG. There was no indication or suspicion of any underlying cardiac conditions; therefore, he was appropriately given medical clearance for unrestricted duty.

Recommendations

The following recommendations would not have prevented the LT's death. Nonetheless, NIOSH investigators offer these recommendations to address general safety and health issues.

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

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 2013a; 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. To ensure improved health and safety of candidates and members, and to ensure continuity of medical evaluations, it is recommended the FD comply with this recommendation. However, the FD is not legally required to follow the NFPA standard or the Wellness/Fitness Initiative.

Applying this recommendation involves economic repercussions and may be particularly difficult for smaller 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 emergency medical technicians 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, by personal insurance, 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.

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Recommendations (cont.)

Recommendation #2: Phase in a mandatory 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 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 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 [Pelletier 2009; Baicker et al. 2010]. 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; Poston et al. 2013]. 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 2013].

The FD currently does not offer a wellness/fitness program and exercise equipment is not available in the fire station. Given the FD's structure, the National Volunteer Fire Council program would be applicable [USFA 2004], but NIOSH would recommend a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #3: Perform a candidate 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 2013b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2013b]. This could be incorporated into the annual task-level training program.

Recommendation #4: 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 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans. Ohio does not operate an OSHA-approved state plan; therefore the FD is not required to ensure all members have been medically cleared to wear an SCBA. However, we recommend voluntary compliance with this recommendation to improve fire fighter health and safety.

Recommendations (cont.)

Recommendation #5: Ensure paramedics are trained and follow proper advanced life support protocols regarding patient assessment and cardiac monitoring.

Patient assessment means conducting a problem-oriented evaluation of a patient and establishing priorities of care based on existing and potential threats to human life [Bledsoe et al. 2011]. For the unresponsive medical patient, the paramedic should perform a primary assessment followed by a secondary assessment consisting of a head-to-toe exam looking at medical signs and symptoms. The primary assessment's goal is to identify and correct immediately life-threatening conditions, including airway, breathing, and circulation. If the patient's pulse rate is very fast or very slow, it may indicate a life-threatening cardiac dysrhythmia. A weak, thread pulse usually indicates poor perfusion due to fluid loss, pump failure, or massive vasodilation [Bledsoe et al. 2011]. In this case, the LT's pulse was weak suggesting a circulation problem for which cardiac monitoring was indicated both prior to and during transport.

Recommendation #6: Ensure that transport vehicles are in proper working order.

The Squad's rear doors were not functioning properly. While this did not significantly affect the LT's care, this problem highlights the need to ensure that all equipment associated with emergency response is working properly.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Assisting Mr. Baldwin with the investigation was Rafid Kakel, MD, a visiting scientist with the University of Cincinnati College of Medicine. 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).

Appendix A

Autopsy Findings

- Dilated cardiomyopathy
  - Atria and ventricles markedly dilated; the right ventricle more than the left (no measurement documented)
- Cardiomegaly (enlarged heart; heart weighed 510 grams [g]; predicted normal weight is 429 g [ranges between 325 g and 566 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
- Normal cardiac valves
- No evidence of a coronary artery thrombus (blood clot)
- No evidence of coronary artery atherosclerosis
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative

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Appendix B

Known Causes of Dilated Cardiomyopathy [Dec and Fuster 1994]

Toxins

Ethanol
Chemotherapeutic agents (doxorubicin, bleomycin)
Cobalt
Anti-retroviral agents (zidovudine, didanosine, zalcitabine)
Phenothiazines
Carbon monoxide
Lead
Cocaine
Mercury

Metabolic Abnormalities

Nutritional deficiencies (thiamine, selenium, carnitine)
Endocrinologic disorders (hypothyroidism, acromegaly, thyrotoxicosis,
Cushing disease, pheochromocytoma, diabetes mellitus)
Electrolyte disturbances (hypocalcemia, hypophosphatemia)

Infectious

Viral (coxsackie virus, cytomegalovirus, human immunodeficiency virus)
Rickettsial
Bacterial (diphtheria)
Mycobacterial
Fungal
Parasitic (toxoplasmosis, trichinosis, Chagas disease)

Appendix B (cont.)

Noninfectious

Collagen vascular disorders (scleroderma, lupus erythematosus, dermatomyositis)
Hypersensitivity myocarditis
Sarcoidosis
Peripartum dysfunction

Neuromuscular Causes

Duchenne muscular dystrophy
Facioscapulohumeral muscular dystrophy
Erb limb-girdle dystrophy
Myotonic dystrophy