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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 *October, 2012*

Instructor-in-Charge Suffers Sudden Cardiac Death During Live Fire Training – Pennsylvania

Executive Summary

On September 25, 2011, a 38-year-old male volunteer lieutenant (LT) was serving as the instructor-in-charge during live fire training. The LT spent about 60 minutes setting up the training drills and then spent about 30 minutes debriefing and orienting the instructors and trainees. He was inside the specially designed burn building attending the fires when his low air alarm sounded and he exited the building. After changing his air cylinder, he began debriefing the fire department (FD) chief when he suddenly lost consciousness. Fellow fire-fighters immediately began cardiopulmonary resuscitation (CPR) and attached an automated external defibrillator (AED) which delivered a series of shocks that did not revive the LT. An ambulance arrived on scene about 12 minutes after the LT collapsed and provided advanced life support (ALS) while en route to the local hospital's emergency department. Despite these efforts, the LT never regained consciousness and was pronounced dead at the hospital at 1120 hours, approximately 40 minutes after losing consciousness. The death certificate and autopsy listed "cardiac dysrhythmia due to hypertrophic cardiomegaly" as the cause of death. Given the underlying heart abnormalities found at autopsy, the moderate-to-heavy physical exertion during the training most likely triggered a sudden cardiac event.

The following recommendations probably would not have prevented this 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.

Develop a mandatory comprehensive wellness and fitness program to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Perform an annual physical performance (physical ability) evaluation.

Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the FD annual medical evaluation program.

Provide on-scene emergency medical services with advanced life support and transport capability during live fire training as required in NFPA 1403, Standard on Live Fire Training Evolutions.

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Introduction & Methods

On September 25, 2011, a 38-year-old male volunteer LT died after suffering a sudden cardiac event during firefighting training. The LT was the instructor-in-charge during a live fire training drill when he suddenly collapsed between training evolutions. NIOSH was notified of this fatality on September 26, 2011, by the United States Fire Administration. NIOSH contacted the affected department on September 29, 2011, and again on April 25, 2012, to obtain further information and to initiate the investigation. On May 1, 2012, , a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Deputy Chief
- Crew members involved in training exercises
- Responding ambulance emergency medical technician (EMT) and paramedic
- LT's wife

NIOSH personnel reviewed the following documents:

- FD incident report
- FD training records
- Emergency Medical Services (EMS) report
- Hospital records
- Death certificate
- Autopsy report
- Primary care physician medical records

Investigative Results

Incident. The LT's FD and two other area FDs held a live fire training exercise on September 25, 2011. The LT was the "instructor-in-charge" and arrived at the facility at approximately 0730 hours, along with other instructors, to prepare for the training. In addition to instructor-in-charge duties, the LT performed moderate to strenuous work that included carrying and positioning pallets and straw in the burn.

Members began arriving at approximately 0830 hours and the training began at 0900 hours. It was a cool morning with temperature peaking at approximately 75 degrees (°) Fahrenheit (F) by noon [Weather Underground 2012]. Prior to training the LT gave a full briefing and walk through of the training structure for all members, emphasizing safety and egress features of the building, parameters of the burn, mayday procedures, emergency exits, radio protocol, and the overall goals of the training. At approximately 0900 hours the first fire was lit. The fire did not burn well due to moisture in the burn material and the LT and other instructors spent approximately 45 minutes getting the proper building temperature. At approximately 0945 hours the first evolution was performed, with crews entering the building, advancing through a large open room, entering the burn room, and extinguishing the fire. It was estimated that the evolution took 5-7 minutes.

Because the fire was not burning well on the first floor, the LT and another instructor went to the second floor to start a second fire while two other instructors stayed on the first floor to continue with another evolution of fire suppression drills. The LT and another instructor started a fire on the second floor. Shortly thereafter, their low-air alarms sounded and both instructors exited the building to change their air cylinders.

While having his air cylinder changed, the LT spoke with several firefighters and instructors who noted his

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Investigative Results (cont.)

red face, but all thought he was interacting in a normal manner. When asked about his red face, the LT responded that he was "somewhat hot" but he felt fine. Once his air cylinder was changed, the LT discussed the specifics of the day's training with the FD chief and other officers. He was on one knee talking with the chief when he suddenly collapsed.

Firefighters trained in EMS immediately began CPR. A police officer who witnessed the collapse immediately radioed the dispatch center and an ambulance was dispatched at 1038 hours. On-scene personnel removed the LT's clothing while others retrieved an AED. The AED leads were attached to the LT and the AED advised that a shock be administered. A total of 6 shocks were advised by the AED and administered by personnel on-scene. CPR was continued with oxygen provided by bag-valve mask.

The ambulance (an ALS unit) arrived on scene at 1050 hours. EMS personnel found the LT not breathing, pulseless, unresponsive and cyanotic (bluish in color). The LT was placed on a backboard and attached to a LUCAS® device, which provides automated chest compressions. He was then moved to a stretcher and loaded into the ambulance. The LT was attached to a cardiac monitor that revealed ventricular fibrillation. The LT was defibrillated six times prior to departure from the training facility at 1058 hours. En route to the hospital's ED, the paramedic secured the LT's airway with a double lumen device (King airway®) because oral intubation was unsuccessful. Placement was confirmed by bilateral breath sounds and end tidal carbon dioxide monitoring. Intravenous access was either not attempted or unsuccessful, so intraosseous access was gained in the LT's right tibial tuberosity; normal saline was administered. The LT was also provided with three doses of epinephrine. A second rhythm check revealed continued ventricular fibrillation and the LT was defibrillated again with a rhythm change to asystole, which persisted throughout transport. CPR and bag-value mask ventilations with supplemental oxygen were continued throughout transport.

The ambulance arrived at the Emergency Department at 1118 hours, approximately 40 minutes after the LT's collapse. Given that the LT had been in cardiac arrest for such a long period of time, CPR and ALS continued in the ED for only 2 minutes. The LT was declared dead at 1120 hours.

Medical Findings. The death certificate and autopsy, which were completed by a forensic pathologist in the coroner's office, listed "cardiac dysrhythmia due to hypertrophic cardiomegaly" as the cause of death. The autopsy findings included evidence of cardiomegaly, biventricular dilation, left ventricular hypertrophy, and minimal atherosclerotic coronary artery disease. Specific findings from the autopsy report are listed in Appendix A. The LT was 71.5 inches tall and weighed approximately 290 pounds, giving him a body mass index of 39.9 kilograms per square meter. A body mass index of 30 kilograms per square meter or greater is considered obese [CDC 2011].

The LT had his last medical examination with his primary care physician in March 2010. The medical evaluation and laboratory work indicated that the LT had hypothyroidism, a normal electrocardiogram (EKG), and "elevated blood pressure without diagnosis of hypertension." His blood pressure during this visit was 142/96 millimeters of mercury. The LT's medical records include a finding of "mild cardiac enlargement" reported from a chest x-ray in March 2008, prior to a minor surgical procedure. Medical records available to NIOSH suggest this finding was never further evaluated.

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Description of the Fire Department

At the time of the NIOSH investigation, this volunteer FD consisted of two fire stations with 60 uniformed personnel. It served a population of approximately 18,000 residents in a geographical area of approximately 16 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid driver's license, and pass a background check. Probationary new members must attend meetings and departmental training and are allowed to ride along on emergency calls. After 6 months, the Fire Chief presents the new probationary member to the Board to be voted on for continuing membership. The LT had been a member of the department for approximately 20 years and had served in the rank of lieutenant for 5 years.

Preplacement and Periodic Medical Evaluations. The FD does not require preplacement medical evaluations for applicants, or periodic (annual) evaluations for members. The FD does not require medical clearance for SCBA use nor does it require a physical ability tests for candidates or members. Members who have a serious injury or illness must be cleared by their personal physician before they can return to firefighting responsibilities.

Discussion

The Pathophysiology of Sudden Cardiac Death. This LT experienced a cardiac arrest and sudden cardiac death while serving as the instructor-in-charge of live fire training. The most common risk factor for cardiac arrest and sudden cardiac death is coronary heart disease, defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2012]. The autopsy report found no evidence of either coronary thrombosis or significant coronary atherosclerosis. Thus, it appears that the LT did not suffer a heart attack (myocardial infarction).

Sudden cardiac death can also be caused by fatal arrhythmias (disruption in the electrical signal of the heart). Autopsy findings suggested the LT had several cardiac conditions associated with sudden cardiac death (fatal arrhythmias) including mitral valve prolapse, myocardial bridging, left ventricular hypertrophy, and possible hypertrophic cardiomyopathy (HCM).

Mitral Valve Prolapse. The LT was not diagnosed with mitral valve prolapse but autopsy findings included evidence of ballooning degeneration in the mitral valve which is consistent with mitral valve prolapse. Mitral valve prolapse occurs when one or both of the mitral valve leaflets slip into the left atrium during systole (contraction of the heart muscle). It is the most common heart valve disorder, affecting about 2-4% of the population. Both sexes and all ages can be affected [Braunwald 2005].

Clinical presentations range from asymptomatic heart murmurs to severe mitral valve regurgitation with symptoms of fatigue, short-

Discussion (cont.)

ness of breath on exertion, and reduced exercise tolerance [Braunwald 2005]. Individuals with mitral valve prolapse are at increased risk of sudden cardiac death. Studies estimate the risk of ventricular tachycardia and ventricular fibrillation to be about 2% per year with a 1% mortality rate [Vohra et al. 1993; Martini et al. 1995]. Risk factors for sudden cardiac death among mitral valve prolapse patients include a family history of sudden cardiac death at a young age, a history of fainting or previous cardiac arrest, prolonged QT interval on EKG, complex ventricular arrhythmias, severe mitral regurgitation, increased left ventricle or left atrial size, and thickened and redundant mitral valve leaflets [Kligfield et al. 1987; Boudoulas and Wooley 2000; Priori et al. 2002].

Myocardial Bridging. At autopsy, the LT had evidence of myocardial bridging in the left anterior descending coronary artery. Myocardial bridging is when a portion of a coronary artery tunnels into the myocardium, creating a muscle-bridge overlap. Myocardial bridging is relatively common. It has been reported in 0.5% to 16% of angiographic studies and 15% to 85% of autopsies [Mohlenkamp et al. 2002]. Compression of the coronary artery due to the muscular band occurs during systole and sometime extends into diastole. It has been associated with sudden cardiac death [Morales et al. 1980; Cutler and Wallace 1997], ischemia [Ge et al. 1994; Schwarz et al. 1996], myocardial infarction [Chee et al. 1981; Feldman and Baughman 1986; Bestetti et al. 1987; Vasan et al. 1989], arrhythmia [den Dulk et al. 1983; Kracoff et al. 1987; Feld et al. 1991], and coronary artery spasm [Teragawa et al. 2003].

Left Ventricular Hypertrophy. Left ventricular hypertrophy increases the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997].

Hypertrophic Cardiomyopathy. At autopsy the LT had evidence suggestive of hypertrophic cardiomyopathy, including occasional patchy fibrosis, hypertrophic myocytes, and wavy fibers. However, there was no evidence of myocardial disarray which is a histopathological hallmark of hypertrophic cardiomyopathy [Ho and Seidman 2006].
HCM due to no known cause (idiopathic) is a relatively rare heart condition, affecting approximately 0.2% of the population [Spirito et al. 1997]. Diagnosis is typically made by echocardiogram and EKG findings. The majority of patients are asymptomatic, and sudden cardiac death is often the first clinical manifestation [Wynne and Braunwald 2001]. Myocardial bridging has been found in up to 30% of patients with HCM with some authors hypothesizing that myocardial bridging explains the cardiac ischemia frequently found in HCM patients [Kitazume et el. 1983; Navarro-Lopez et al. 1986; Cannon et al. 1991; Crowley et al. 1997; Kyriakidid et al. 1997; Yetman et al. 1998]. Approximately half of the idiopathic HCM cases are transmitted genetically, typically as an autosomal dominant trait. Because of this, medical evaluation of first-degree relatives is warranted to determine whether screening tests (e.g., echocardiogram) are appropriate.

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Discussion (cont.)

The LT was asymptomatic had no documented history of high blood pressure or a heart valve problem. On autopsy, the FF was found to have cardiomegaly (an enlarged heart), left ventricular hypertrophy, ballooning degeneration of the mitral valve, and myocardial bridging. An echocardiogram is the most common method of detecting valvular problems, left ventricular hypertrophy, or cardiomegaly but would not be indicated without cardiac symptoms. A chest x-ray performed in 2008 noted mild heart enlargement but there is no indication that this finding was seen as significant. Although the EKG is an insensitive screening test for left ventricular hypertrophy, it can sometimes indicate the need for additional testing. The LT had an EKG performed by his primary care physician in 2010, but no indication of abnormal results. Based on the autopsy findings and the clinical scenario, the NIOSH investigators conclude that the LT died from a cardiac arrhythmia triggered by physical exertion. It is unclear which underlying condition, or combination of conditions, was responsible for the arrhythmia.

Physiological Stress of Firefighting. Firefighting is widely acknowledged to be physically demanding, requiring fire fighters to work at near maximal heart rates for long periods and causing significant physiological disruption [Barnard and Duncan 1975; Lemon and Hermiston 1977; Manning and Griggs 1983; Jankovic et al. 1991; Smith et al. 2001]. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 beats per minute) owing to the insulative properties of the personal protective clothing [Smith et al. 1995]. The LT had been on site for approximately 3 hours prior to his collapse. An hour and half of those 3 hours were in full turnout gear while consuming one cylinder of air from his SCBA. Given that the LT did not complain of any symptoms of heat-related illness and that the instructors had a difficult time generating heat for the burn building, it is unclear what role, if any, heat stress played in triggering his sudden cardiac death.

The LT was engaged in moderate to heavy physical exertion. Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death [Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Epidemiologic studies among fire fighters have shown that fire suppression, training, alarm response, or strenuous physical activity on the job in the preceding 12 hours increases the risk for a sudden cardiac event [Kales et al. 2003; Hales et al. 2007; Kales et al. 2007]. Given the LT's underlying cardiac abnormalities, the NIOSH investigators conclude that he most likely suffered a heart arrhythmia triggered by the physical activity at the live fire training.

Recommendations

Given the LT's relatively young age (38 years old) and lack of symptoms, the following recommendations probably would not have prevented the LT's death. NIOSH investigators, however, offer these recommendations to address general safety and health issues including the prevention of sudden cardiac death among other members of the FD.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters consistent 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 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. 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 IAFF/IAFC initiative. In addition, 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 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: Develop a mandatory comprehensive wellness and fitness program to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

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 (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

Recommendations (cont.)

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]. The FD currently has a voluntary wellness/fitness program. Given the FD's structure, the NVFC program would be very helpful [USFA 2004]. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #3: Perform an annual physical performance (physical ability) evaluation.

NFPA 1500, Standard on Fire Department Occu¬pational Safety and Health Program recommends that the FD annually evaluate and certify FD members who engage in emergency operations as having met the physical performance requirements identified in Paragraph 10.2.3 of the standard [NFPA 2007b]. This is recommended to ensure that fire fighters are physically capable of performing the essential job tasks of structural fire fighting. The physical ability test could be performed as part of the FD's training program.

Recommendation #4: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the FD's annual 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 CFR1 1910.134]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans [OSHA 2011]. Pennsylvania does not operate an OSHA-approved State plan for the public sector; therefore, public sector employers (including volunteer/paid fire departments) are not required to comply with OSHA standards. Although not required by law, NIOSH investigators recommend providing fire fighters with medical clearance to wear SCBA to ensure a safe and effective FD.

Recommendation #5: Provide on-scene emergency medical services with advanced life support and transport capability during live fire training as required in NFPA 1403, Standard on Live Fire Training Evolutions.

NFPA 1403 requires emergency medical services be on scene during all live fire exercises including exterior props. Emergency medical services are defined as "the provision of treatment, such as first aid, CPR, basic life support, advanced life support, and other pre-hospital procedures including ambulance transportation, to patients." [NFPA 2007c]. These EMS personnel must remain on scene until all exercises are concluded, equipment is restored to an in-service condition, and students are released.

Although it took approximately 12 minutes for an ALS unit to arrive on scene, the LT received immediate CPR and the application of an AED. It is unlikely that on-scene ALS and/or transport would have changed the outcome in this case.

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Instructor-in-Charge Suffers Sudden Cardiac Death During Live Fire Training – Pennsylvania

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Denise L. Smith, Ph.D, led the investigation and coauthored the report. Dr. Smith is Professor of Health and Exercise Sciences, and Director of the First Responder Health and Safety Laboratory at Skidmore College. Dr. Smith is a member of the NFPA Technical Committee on Occupational Safety and Health. She was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component during this investigation. 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

- Heart size/Structure
  - Heart weight = 519 grams
  - Left ventricular hypertrophy (left ventricular wall = 1.5 cm)
  - Right ventricular wall = .5 cm
  - Evidence of biventricular dilation noted
  - Ballooning degeneration to mitral valve noted
- Coronary Arteries
  - Left anterior descending coronary artery – 30% narrowing
  - Circumflex artery - patent
  - Right coronary artery – 20% narrowing
  - No evidence of coronary artery thrombus (blood clot)
- Histological Findings
  - Occasional fibrosis
  - Wavy fibers
  - Hypertrophied myocytes
  - No myocardial disarray [suggests that HCM was not present]
- Carboxyhemoglobin = 6.4%