Pump Operator/Paramedic Suffers Sudden Cardiac Death After Physical Fitness Training - Texas

Executive Summary

On November 16, 2014, a 40-year-old male career pump operator/paramedic ("Pump Operator") responded to a standby call and later ran 1 mile and lifted weights in the gym during his 24-hour shift. After performing fitness training, the Pump Operator went into one of the fire station's restrooms. A crew member entered the restroom about an hour later, and found the Pump Operator collapsed on the floor. A cardiac monitor revealed asystole (no heart beat); dispatch was notified and an ambulance responded. After further assessment, the Pump Operator was declared dead on the scene at 2238 hours.

The death certificate, completed by a justice of the peace, listed "atherosclerotic cardiovascular disease" as the cause of death. The autopsy, completed by the forensic pathologist, listed "severe atherosclerotic cardiovascular disease" with "myocardial bridging left anterior descending coronary artery" as the cause of death. Given the Pump Operator's undiagnosed heart disease, NIOSH investigators concluded that the physical stress of physical fitness training probably triggered a heart arrhythmia, which resulted in sudden cardiac death.

Key Recommendations

- *Provide preplacement and annual medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to identify fire fighters at increased risk for coronary heart disease (CHD)*
- *Perform symptom-limiting exercise stress tests (ESTs) on fire fighters at increased risk for CHD*
- *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 components of NFPA 1582*
- *Phase in a mandatory comprehensive wellness and fitness program for fire fighters*
- *Provide fire fighters with medical clearance to wear a self-contained breathing apparatus (SCBA) as part of the fire department's medical evaluation program*

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The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH "Fire Fighter Fatality Investigation and Prevention Program" which examines line-of-duty-deaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency's reports do not name the victim, the fire department or those interviewed. The NIOSH report's summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency's recommendations and is not intended to be definitive for purposes of determining any claim or benefit.

For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

2014 23

Death in the line of duty...

NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

May 22, 2015

Pump Operator/Paramedic Suffers Sudden Cardiac Death After Physical Fitness Test - Texas

Introduction

On November 16, 2014, a 40-year-old male career Pump Operator suffered sudden cardiac death after performing physical fitness training. NIOSH contacted the affected fire department on November 20, 2014, to gather additional information, and on November 24, 2014, to initiate the investigation. On December 10, 2014, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire chief
- Local union president
- Crew members
- Deputy state fire marshal
- Pump Operator's spouse

NIOSH personnel reviewed the following documents:

- Fire department standard operating procedures
- Fire department annual report for 2013
- Emergency medical service (ambulance) report
- Death certificate
- Autopsy report
- Primary care physician records
- Police investigation report

Investigation

On November 16, 2014, the Pump Operator arrived for duty at about 0745 hours for his 24-hour shift at Station 8. Throughout the day he exhibited no signs or symptoms of cardiac problems. At 1325 hours, Engine 8 was dispatched for a smoke investigation call. At 1346 hours, Engine 8 returned to quarters. At 1855 hours, Engine 8 was dispatched to standby during a police call. At 1945 hours, Engine 8 was released and returned to quarters. At each call, the Pump Operator remained with the engine and had minimal physical exertion.

At approximately 2000 hours, the Pump Operator's wife visited the fire station. The Pump Operator was preparing for his on-shift physical fitness training, and the two talked for about 10 minutes. After his wife left, the Pump Operator performed stretching exercises and began his 1-mile run near the fire station, taking about 12 minutes. Weather conditions included a temperature of 68 degrees Fahrenheit (°F) and relative humidity of 90%, giving a heat index of 69°F [NOAA 2014].

Upon completing the run, the Pump Operator returned to the fire station and lifted weights in the

station's gym. About 1 hour later (2130 hours), the Pump Operator entered one of the fire station restrooms. About 1 hour after that, at 2232 hours, a crew member entered the restroom and found the Pump Operator collapsed on the floor. He assessed the Pump Operator and noted him to be cool to the touch and deceased for some time. After the captain was notified, a cardiac monitor was utilized, revealing asystole (no heart beat). Dispatch was notified, and an ambulance responded. The Pump Operator was assessed, but because of obvious signs of death, no resuscitation efforts were performed. A justice of the peace was notified and pronounced the Pump Operator dead at 2325 hours in Station 8.

Medical Findings

The death certificate, completed by the justice of the peace, listed "atherosclerotic cardiovascular disease" as the cause of death. The autopsy, completed by the forensic pathologist, listed "atherosclerotic cardiovascular disease" and "myocardial bridging, left anterior descending coronary artery" as the cause of death. Pertinent autopsy findings showed severe coronary artery disease, myocardial bridging, and borderline left ventricular hypertrophy (LVH) (Appendix A).

The Pump Operator was 67 inches tall and weighed 169 pounds, giving him a body mass index of 26.5 kilograms per meters squared [CDC 2014]. The Pump Operator had a history of the following pertinent medical problems:

Hypertension – diagnosed in 2005/2006 and prescribed a blood pressure-lowering medication with no complications, although a stress echocardiogram in 2012 noted borderline concentric LVH.

Hyperlipidemia – diagnosed in 2008 and moderately controlled with diet.

Fire Department Medical Evaluations. At his promotion medical evaluation in 2013, a resting electrocardiogram (EKG) revealed arrhythmias and changes suggestive of coronary disease, which triggered a cardiology consultation. A resting EKG during his cardiology evaluation revealed nonspecific ST-T wave changes and LVH by voltage criteria. An echocardiogram revealed mild concentric LVH (1.02 centimeters [cm]) (normal is 0.6–1.0 cm by echocardiography [Connolly and Oh 2012] and 0.76–0.88 cm [Colucci and Braunwald 1997] on autopsy), and diastolic dysfunction with normal wall motion and a normal left ventricular ejection fraction (60%). He also had a mildly thickened mitral valve with moderate left atrial enlargement.

An EST was performed; the Pump Operator exercised for 12 minutes, 50 seconds and stopped because of fatigue, achieving 14.9 metabolic equivalents and 88% of his maximal predicted heart rate. His EKG tracing showed nonspecific T-wave abnormalities. His imaging test showed a reversible mild to moderate inferior apical wall defect. The defect was considered an artifact due to "diaphragmatic attenuation," and the Pump Operator was cleared for work. Five months later (May 2014), the Pump Operator complained of occasional left-sided chest pain during physical activities. A follow-up visit in November 2014 (5 days before his death) with his cardiologist suggested this activity-related chest pain had resolved.

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Fire Department

At the time of the NIOSH investigation, the fire department consisted of nine fire stations with 187 career uniformed personnel. It served 180,000 residents in a geographic area of 152 square miles and an additional 30,000 Emergency Service District/County residents in a geographic area of 100 square miles. In 2013, the fire suppression division responded to 7,238 incidents: 233 structure fire calls, 251 vegetation fire calls, 125 vehicle fire calls, 94 trash fire calls, 2,704 emergency medical assist calls, 1,300 accident calls, 732 fire alarm calls, 301 investigation calls, 1,032 welfare calls, and 466 other calls. The emergency medical service division responded to 18,258 calls including 3,139 advanced life support calls and 3,139 basic life support calls.

Employment, Membership, Training, and Experience

The fire department requires new fire fighter applicants to be 18–35 years of age; have a valid state driver's license; and pass a background check, a fire department board review, a preplacement medical evaluation, and a drug screening prior to being hired. The new member then begins the 12-week fire fighter I and II and emergency medical technician-basic training (unless state-certified) and/or the 9-month paramedic training. The Pump Operator was certified as a fire fighter II, apparatus/operator (promoted in November 2013), paramedic, instructor, and in hazardous materials operations. He had 14 years of fire fighting experience**.**

Preplacement and Annual Medical Evaluations/Return to Work Medical Evaluations

The fire department requires preplacement medical evaluations for all applicants. Components of this evaluation include the following:

- Complete medical history
- Physical examination (including vital signs – height, weight, blood pressure, pulse, and respirations)
- Vision test (acuity, color, peripheral fields, and depth perception)
- Audiogram
- Electrocardiogram
- Urine drug screen
- Urinalysis
- Blood tests: complete blood count
- Chest x-ray (baseline)
- Purified protein derivative test for tuberculosis
- Functional capacity exam (Appendix B)

The functional capacity exam is performed during the medical evaluation at the contracted clinic facility. The candidate/member wears gym shorts and athletic shoes. The medical evaluation is performed by a contracted physician. Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the fire department. The Pump Operator had a baseline medical evaluation when he joined the fire department

in 2000. However, this medical record was not available to the NIOSH investigator at the time of this report.

Periodic medical evaluations are not required for members. However, promotional medical evaluations are required. The components are the same as the preplacement medical evaluation except that no urine drug screen is performed. The Pump Operator had a promotional medical evaluation in November 2013 as described earlier. Medical clearance to wear a respirator is not required. Members injured on duty or who become ill and miss 90 days must be evaluated by the member's primary care physician who forwards his or her determination for return-to-duty to the fire department. The member must then pass a functional capacity exam to be cleared for unrestricted duty.

Fitness/Wellness Programs

The fire department has a voluntary wellness/fitness program, and exercise equipment is available in each of the nine fire stations. No annual physical ability test is required. The Pump Operator participated in the fire department's voluntary fitness/wellness program by running 1 mile and lifting weights on each shift.

DISCUSSION

Myocardial Bridging

Myocardial bridging, a relatively common condition, occurs when a portion of a coronary artery tunnels under the surface of the myocardium, creating a muscle-bridge overlap [Erbel et al. 2009]. The condition has been reported in up to 40% of angiographic studies, and in 15% to 85% of autopsies [Mohlenkamp et al. 2002; Erbel et al. 2009]. Compression of the coronary artery by the muscular band occurs during systole and sometimes extends into diastole. Myocardial bridging has been associated with the following outcomes:

- Sudden cardiac death [Morales et al. 1980; Bestetti et al. 1991]
- Ischemia [Furniss et al. 1990]
- Myocardial infarction [Feldman and Baughman 1986; Bestetti et al. 1987; Vasan et al. 1989]
- Arrhythmia [den Dulk et al. 1983; Feld et al. 1991]
- Coronary artery spasm [Teragawa et al. 2003]

The Pump Operator's myocardial bridging in his left anterior descending coronary artery may have triggered any of the above, resulting in his sudden cardiac death.

Sudden Cardiac Events

In the United States, atherosclerotic CHD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male gender, family history of coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [NHLBI 2014; AHA 2015]. The Pump Operator had two modifiable CHD risk factors (high blood pressure and high blood lipids), and severe CHD was found on autopsy.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Heart attacks (myocardial infarctions) typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques. Establishing a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, the Pump Operator's cardiac enzymes were not tested, he did not have a heart rhythm to conduct an EKG, and the autopsy did not identify a thrombus. While it is possible the Pump Operator had a silent (no angina) heart attack without a thrombus, a more likely scenario is coronary artery spasm or an arrhythmia due to his left anterior descending bridging and/or his LVH [Davies 1992; Farb et al. 1995; Mehta et al. 1997; Thygesen and Uretsky 2004].

Physiological Stress of Firefighting

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Sudden cardiac events in fire fighters have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The Pump Operator had completed a 1-mile run and lifted weights. This activity expended about 9 metabolic equivalents, which is considered heavy physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

Occupational Medical Standards for Structural Fire Fighters

To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the National Fire Protection Association developed NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2013]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Pump Operator's underlying LVH and mitral valve thickening were identified in 2013 but, according to NFPA 1582, neither of these conditions was of sufficient severity to warrant work restrictions. Although a treadmill EST was abnormal (inferior defect) in December 2013, the Pump Operator's abnormalities were thought to be an artifact due to a "diaphragmatic attenuation." In hindsight, the abnormal EST may have been due to myocardial bridging.

Recommendations

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*, to identify fire fighters at increased risk for CHD.

Discussion: We applaud the fire department for providing preplacement medical evaluations. However, the fire department's medical program could be strengthened by also offering annual medical evaluations, rather than just promotional medical evaluations. 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* [IAFF, IAFC 2008; NFPA 2013]. 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. Following this recommendation will require significant resources and may be particularly difficult for smaller fire departments to implement. The fire department is not legally required to follow the NFPA standard or the IAFF/IAFC guideline.

To overcome the financial obstacle of medical evaluations, the fire department could urge current members to get annual medical clearances from their private physicians through insurance, or paid for by the fire department, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the fire department, the city, and the state may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Perform symptom-limiting ESTs on fire fighters at increased risk for CHD.

Discussion: ACC/AHA recommends an EST for persons whose EKG reveals LVH, among other criteria [Gibbons et al. 2002]. The Pump Operator's abnormal EKG was identified during his promotion medical evaluation and he was appropriately referred for, and received, an imaging EST. However, other fire fighters in this fire department may also be at increased risk for CHD, yet not up for promotion. To identify these fire fighters, we recommend the fire department annually screen for CHD risk factors. Fire fighters found to be at increased risk of CHD should undergo an EST [Gibbons et al. 2002; NFPA 2013].

Recommendation #3: 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.

Discussion: According to 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 [NFPA 2013]. The physician should review job descriptions and essential job tasks required for all fire department positions 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. The fire department currently uses the member's personal physician to initially clear fire fighters who miss work due to illness. Personal physicians may be unaware of the hazardous and physical demands of structural fire fighting and the guidance provided by NFPA 1582.

Recommendation #4: Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Discussion: 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*

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Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC *Fire Service Joint Labor Management Wellness/Fitness Initiative*, and in *Firefighter Fitness: A Health and Wellness Guide* [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 [Chapman 2005; Mills et al. 2007; Pelletier 2009; Baicker et al. 2010]. Fire service health promotion programs have been shown to reduce CAD 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 2013].

The fire department offers a voluntary wellness/fitness program where exercise equipment is available in the fire stations. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program. Installing exercise equipment in each fire station would allow consistent exercise regimens for members who transfer from station to station or work overtime at another station.

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

Discussion: 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 only for public employees in states operating OSHA-approved state plans. Because Texas does not operate a state OSHA plan [OSHA 2015], the fire department is not required to provide medical evaluations for employees using respirators. However, we recommend voluntary compliance with this recommendation to improve fire fighter health and safety.

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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. 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 Health, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

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Appendix A
Autopsy Findings

- Coronary artery disease
  - Myocardial bridging of the left anterior descending coronary artery
  - Severe (75%) focal narrowing of the right coronary artery (atherosclerosis)
  - Severe (75%) focal narrowing of the left circumflex coronary artery (atherosclerosis)
  - No definitive coronary artery thrombus (blood clot)
- Hypertensive heart disease
  - Borderline LVH
    - Left ventricle thickened (1.0 – 1.02 centimeter [cm])
      - Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]
      - Normal by echocardiographic measurement is 0.6–1.0 cm [Connolly and Oh 2012]
  - Microscopic: areas of focal moderate intimal hyperplasia (blood vessel thickened), and mild perivascular (outer area of vascular walls) and interstitial fibrosis (fibrosis between cells), and multiple small discrete foci of moderate replacement fibrosis and late granulation tissue (healing process from a prior episode of occlusion)
- Cardiac valves thin and delicate
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative.

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Pump Operator/Paramedic Suffers Sudden Cardiac Death After Physical Fitness Training - Texas

Appendix B
Functional Capacity Exam

The functional capacity exam consists of the following components:

1. Take vital signs: blood pressure standing and sitting, heart rate standing and sitting. Calculate 85% of the maximum heart rate.
2. Claustrophobia exam.
3. Vision exam. Must be better than 20/30 corrected, or 20/100 uncorrected.
4. Step test. The individual steps at a rate of 22.5 steps per minute for 5 minutes. The heart rate is measured at the end of every minute until the 5 minutes are completed.
5. Kneel, crawl, squat, climb, run in place, stand still. Identify any abnormality and stop the test if needed.
6. Bilateral carry 75 pounds for 50 feet.
7. Drag a 170-pound manikin for 50 feet across the floor.
8. Pull a 170-pound manikin for 50 feet across the floor.
9. Push a 170-pound manikin for 50 feet across the floor.
10. Repeat kneel, crawl, squat, climb, run in place, and stand still. Identify any abnormality and stop the test if needed.
11. Carry/wear 50 pounds with consistency.
12. Walk up 75 feet of stairs.