Lieutenant Suffers Sudden Cardiac Death at Apartment Fire - District of Columbia

Executive Summary

On May 6, 2015, a 44-year-old male career Lieutenant (LT) was dispatched to a fire on the 9th floor of a 10-story apartment building. His engine company was assigned fire suppression duties. The crew arrived on-scene wearing full turnout gear. They donned their self-contained breathing apparatus (SCBA) and entered the building. The LT, for unclear reasons, entered the building across the street and went to the 9th floor. Finding no emergency, he returned to the street, and entered the building where the fire had been reported. He rode the elevator to the 8th floor. Going "on-air," he climbed the stairs to the 9th floor and walked down the hall to the involved apartment where he joined his engine crew. The fire was declared under control a few minutes later. The LT and his crew walked down the stairs to the 7th floor and doffed their SCBA facepieces. The LT and his crewmembers continued down the stairs and exited the building. As the LT exited the building, he collapsed. On-scene paramedics began cardiopulmonary resuscitation (CPR) and advanced life support. They transported the LT to the hospital's emergency department (ED) where CPR and cardiac resuscitation efforts continued for 70 minutes. Despite these efforts, the LT died.

The Office of the Chief Medical Examiner completed the death certificate and the autopsy report. Both listed "sudden death while fighting fire due to hypertensive atherosclerotic cardiovascular disease" as the cause of death. The autopsy report also listed obesity as a contributory factor. His blood carboxyhemoglobin level was 2.0%, suggesting carbon monoxide poisoning was not an issue. Prior to this incident the LT was not known to have coronary heart disease. Given the LT's underlying heart disease, NIOSH investigators concluded that the physical stress of his activities at the structure fire probably triggered a cardiac arrhythmia, which resulted in his sudden cardiac death.

Key Recommendations

- *Follow current Fire Department policies that restrict fire fighters who cannot reach 12 metabolic equivalents on exercise stress tests, a policy consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments*
- *Perform an annual physical ability evaluation*
- *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*

Lieutenant Suffers Sudden Cardiac Death at Apartment Fire

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).

2015 09

Death in the line of duty...

NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

June 6, 2016

Lieutenant Suffers Sudden Cardiac Death at Apartment Fire

Introduction

On May 6, 2015, a 44-year-old male career LT suffered sudden cardiac death at an apartment fire. NIOSH was notified of this fatality on May 6, 2015, by the U.S. Fire Administration. NIOSH contacted the affected fire department (FD) on May 7, 2015, to gather additional information and on June 30, 2015, to initiate the investigation. On July 8, 2015, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program conducted an on-site investigation of the incident. During the NIOSH investigation, the LT's SCBA was examined. The NIOSH SCBA examination report is included in Appendix A.

During the investigation, NIOSH personnel interviewed the following people:

- Deputy Fire Chief for Training
- Deputy Fire Chief for Risk Management
- Battalion Fire Chief for Medical Services
- International Association of Fire Fighters Local Secretary
- Crewmembers
- LT's spouse

NIOSH personnel reviewed the following documents:

- FD standard operating guidelines
- FD annual report for 2014
- Emergency medical service (ambulance) report
- Hospital ED records
- Death certificate
- Autopsy report
- FD medical evaluation records
- Primary care physician records

Investigation

On May 6, 2015, the LT arrived at his fire station at about 0430 hours for his 24-hour shift. After shift change at 0700 hours, the crew did station maintenance (painting around the station and mowing the grass). At 0810 hours, multiple units (5 Engines, 3 Trucks, 4 ambulance/medic units, 2 Battalion Chiefs (BC), as well as a Safety Officer, the Fire Marshal) were dispatched to a fire in a 10-story apartment building that housed many elderly and disabled residents. Units began to arrive at 0813 hours to find fire showing from the 9th floor. At 0815 hours, a second alarm was transmitted and additional units (5 more Engines, 2 more Trucks, as well as another rescue squad, BC, and the Deputy Fire Chief of Operations) were dispatched.

Engine 6 arrived at 0819 hours as Rescue Squad 1 and Rescue Squad 2 crewmembers were searching

the apartments on the 9th and 10th floors. Engine 6 and Truck 4 crewmembers entered the apartment building. The LT, however, exited Engine 6 and, for unclear reasons, entered the building across the street. The LT was wearing turnout gear and his SCBA (off-air). After climbing the stairs to the 9th floor and finding no emergency, the LT returned to the first floor and crossed the street. He entered the apartment building where the fire response was underway and rode the elevator to the 8th floor. He donned his SCBA facepiece, went "on-air," and climbed the stairs to the 9th floor. He walked to the apartment where crews had extinguished the fire. The Incident Commander called for a personnel accountability report (PAR) as the LT reported to the Incident Commander that he was now with his crew. The LT and his crew were released and began walking down the stairs. At the 7th floor, they removed their SCBA facepieces. The LT remarked that it was time to take a break but reported no symptoms. When the crew descended to the 1st floor, the LT exited the building and collapsed.

On-scene ambulance paramedics were alerted and responded to the LT's location. The LT was placed on a stretcher and moved to Medic-1 where CPR was begun and oxygen was administered via bag-valve-mask. At 0847 hours, Medic-1 departed the scene travelling to the ED located a short distance away. While enroute, the LT was intubated as a cardiac monitor was placed; intravenous placement was attempted but was unsuccessful. The endotracheal tube became dislodged and a King Airway® was placed. Two shocks were administered but his heart rhythm reverted to pulseless electrical activity.

At 0849 hours in the ED the King Airway® was removed and the LT was intubated. Proper tube placement was confirmed by end tidal CO_2 and breath sounds [Neumar et al. 2010]. The LT was treated for possible cyanide poisoning with intravenous hydroxycobalamine. Cardiac resuscitation efforts including CPR continued for 70 minutes until 0957 hours when the attending physician pronounced the LT dead and cardiac resuscitation efforts were discontinued.

Medical Findings

The death certificate and autopsy report, completed by the Office of the Chief Medical Examiner, listed "sudden death while fighting fire due to hypertensive atherosclerotic cardiovascular disease" as the cause of death. The autopsy report listed obesity as a contributory factor. The LT's blood carboxyhemoglobin level was 2.0%, suggesting carbon monoxide exposure was not a factor in the LT's death.

The LT had the following medical conditions:

Hypertension (Stage II) - first diagnosed in 1999 with anti-hypertensive medication begun in 2001. Over the next 14 years, his blood pressure frequently met Stage II criteria (>160 millimeters of mercury [mmHg] systolic or > 100 mmHg diastolic) due, in part, to poor compliance with his medications. His last clinic reading on April 7, 2015 was 146/98 mmHg (normal is 120/80 mmHg). In addition, the LT was noted to have a hypertensive response (diastolic blood pressure increase by > 10 mmHg) during his last fire department exercise stress test (EST) in 2014 [ACSM 2014].

Hyperlipidemia – first diagnosed in 1997 and prescribed a lipid-lowering medication in 2001. Despite treatment, his most recent (November 20, 2014) readings included an elevated blood cholesterol level of 259 milligrams per deciliter (mg/dL) (normal is < 200 mg/dL) and an elevated blood low density lipoprotein (LDL) level of 192 mg/dL (normal is <130 mg/dL). His blood triglyceride level of 81 mg/dL and blood high density lipoprotein (HDL) level of 51 mg/dL were normal.

Abnormal Electrocardiograms (EKGs) – Since 2003, his EKGs revealed left ventricular hypertrophy (LVH). An echocardiogram in 2013 also showed mild concentric LVH. His autopsy confirmed the presence of concentric LVH (Appendix B).

Sinus Tachycardia – Since 2008, the LT was frequently noted to have a fast heart beat (rate > 100 beats per minute) during visits to his primary care physicians. Similar findings were noted prior to ESTs conducted by his cardiologist in 2011 and 2013.

Obstructive Sleep Apnea – The LT was diagnosed with sleep apnea in 2010. At the time his body mass index was 38.1 kilograms per meters squared. He was treated with continuous positive airway pressure and, according to medical records, was compliant with the treatment.

Obesity – The LT was last weighed by his primary care physician in January 2015. He weighed 212 pounds (69 inches tall), giving him a body mass index of 31.3 kilograms per meters squared [CDC 2015].

Fire Department

At the time of the NIOSH investigation, the FD consisted of 33 fire stations and a fireboat. The FD had 1,900 career uniformed personnel. The FD served 600,000 residents and a daytime population of over 1 million persons in a geographic area of 70 square miles. In 2014, the FD responded to 179,319 incidents: 32,313 fire/other incidents and 147,006 emergency medical incidents.

Employment, Training, and Experience

The FD requires all applicants to pass a written general knowledge test, a background check, a medical evaluation (components described below), and a candidate physical ability test (CPAT) [IAFF/IAFC 2007] prior to receiving a conditional job offer and attending recruit school. The new hire must then pass either the 30-week basic recruit school or the 16-week accelerated recruit school to become trained to the fire fighter/emergency medical technician or fire fighter/paramedic level. After completing the academy, new employees work the following shifts: 24 hours on duty, 72 hours off duty, 0700 hours to 0700 hours.

The LT was certified as a Fire Fighter II, Driver/Operator, Emergency Medical Technician-Basic, HazMat Technician, Fire Officer I, Fire Instructor I, and in Technical Rescue. He had 24 years of fire fighting experience and was promoted to LT in April 2008.

Medical Evaluations

Preplacement Medical Evaluations

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

- Complete medical history
- Physical examination (including vital signs)
- Psychological assessment
- Complete blood count with lipid panel
- Audiogram
- Vision screen
- Urinalysis
- Urine drug screen
- Resting EKG
- Chest x-ray (baseline only)

The evaluation is performed by a City physician. Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. The LT passed his preplacement medical evaluation when he joined the FD in 1988.

Annual Medical Evaluations

Annual medical evaluations are required by the FD. The medical evaluation is performed by a City physician. Once this evaluation is complete, the City physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. The components of this evaluation are the same as for the pre-placement exam except that a psychological assessment is not done and an EST is added dependent on the member's age. For members age 20-29, the EST is performed as a baseline. For members age 30-39, the EST is performed every 5 years. For members age 40 and over, the EST is performed every 2 years. Members who present with cardiac symptoms are referred to a specialist for immediate cardiac testing. Members with two or more cardiac risk factors (diabetes mellitus, smoking, high blood pressure, high blood cholesterol, and obesity/physical inactivity) must undergo an annual EST. The test is a sub-maximal graded treadmill evaluation, using the Gerkin protocol [Gerkin et al. 1997]. Members must reach a minimum of 12 metabolic equivalents (METs) during the EST. The fire department groups the results of the ESTs into four categories that determine whether further evaluation is needed or the individual is cleared for duty (see Appendix C).

The LT's first EST was in January 2011. Following the Bruce protocol, the LT exercised for 11 minutes, 1 second achieving 13.4 METs. He reached 105% of his maximum predicted heart rate and the test was stopped. He had a resting heart rate of 130 beats per minute (tachycardia) which rose to 190 beats per minute during the EST.

The LT's last EST was in November 2013. Following the Bruce protocol, the LT exercised for 4 minutes, 46 seconds achieving 7 METs. The test was stopped when he reached 93% of his maximum predicted heart rate. He reported no symptoms, and had no ischemic changes or arrhythmias noted on

the EKG tracing. However, he was noted to have a hypertensive blood pressure response to exercise (diastolic blood pressure rose from 82 mmHg [resting] to 98 mmHg [peak exercise]) [ACSM 2014]. Given that the LT failed to reach 12 METs on this EST, he should have been placed into Category 3, "temporary job restrictions." This did not occur.

Medical clearance to wear SCBA is not required. Members injured on duty must be evaluated by the City physician and the results are provided to the FD, which makes the final determination regarding return to work.

Wellness/Fitness Programs

Fitness equipment (strength and aerobic) is available in the fire stations. Members may exercise during their shift, however their company is not taken out of service to exercise. The LT participated in the FD's fitness program by walking vigorously and exercising on an elliptical machine during each shift. An annual physical ability test (PAT) is not required.

DISCUSSION

Sudden Cardiac Events

In the United States, atherosclerotic coronary heart disease (CHD) is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development are grouped into non-modifiable and modifiable. Non-modifiable risk factors include age older than 45, male gender, and family history of coronary artery disease. Modifiable risk factors include diabetes mellitus, smoking, high blood pressure, high blood cholesterol, and obesity/physical inactivity [AHA 2015a; NHLBI 2015]. The LT had two non-modifiable risk factors and three modifiable CHD risk factors. His autopsy revealed severe CHD.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2013]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion. 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. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques [Libby 2013]. 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 LT's cardiac enzymes were not tested, no acute coronary artery thrombus was revealed at autopsy, and he did not have a heart rhythm to conduct an EKG. Given the LT's lack of angina and the absence of coronary artery thrombus at autopsy, a primary cardiac arrhythmia, rather than a heart attack, was the likely cause of his sudden cardiac death.

Risk factors for primary cardiac arrhythmias include CHD, LVH, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [Levy et al. 1990; Koren et al. 1991; AHA 2015b; Mayo Clinic 2015]. The LT had two risk factors for primary cardiac arrhythmia: CHD

and LVH. His CHD was undiagnosed prior to this incident, while his LVH was diagnosed in 2003 by EKG, in 2014 by echocardiogram, and concentric LVH was found at autopsy.

Sudden cardiac death can be triggered by heavy physical exertion [Albert et al. 2000]. Among fire fighters, sudden cardiac events have been reported to be triggered by alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The LT's activities at the apartment fire while wearing full turnout gear and SCBA (on-air while on the fire floor) expended about 11 METs, which is considered heavy physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011]. This heavy physical exertion probably triggered an arrhythmia that precipitated the LT's sudden cardiac death.

Hypertension

The LT fluctuated between stage I and stage II hypertension. NFPA 1582 suggests that members with stage I hypertension be referred to their primary care physician to ensure that their blood pressure is controlled and to determine whether screening for end organ damage is indicated [NFPA 2013a]. The LT's hypertension was diagnosed in 1999 and was poorly controlled with medication. Although a comprehensive work-up for end organ damage was not conducted, an EKG and echocardiogram did find LVH, one type of end organ damage due to hypertension. The FD physician referred the LT to his primary care physician for further evaluation in December 2008. The LT saw his primary care physician 3 weeks later and his primary care physician issued a return to work clearance with no restrictions. Since that time, the LT's blood pressure readings were frequently elevated, and sometimes in stage II (systolic ≥160 mmHg or diastolic ≥ 100 mmHg) [NFPA 2013a]. NFPA considers that stage II hypertension or end organ damage (e.g., LVH) compromises the member's ability to safely perform essential job tasks. Therefore, according to the National Fire Protection Association (NFPA), the LT's stage II hypertension and LVH should have resulted in work restrictions [NFPA 2013a].

Exercise Stress Test

The LT's first EST in 2011 was normal. However, during his second EST in 2013, he exercised for less than 5 minutes before reaching his maximally predicted heart rate. At this point the test was stopped with his only reaching 7 METs; far below the 12 MET FD requirement. In addition, he was noted to have a diastolic hypertensive blood pressure response to exercise (diastolic blood pressure rose from 82 mmHg [resting] to 98 mmHg [peak exercise]) [ACSM 2014]. A diastolic hypertensive response has been reported to be associated with CHD and exertional ischemia [Akhras 1985; Paraskevaidis et al. 1993; ACSM 2014]. Because of the LT's failure to achieve 12 METs on his most recent EST, according to the FD's own policy, he should have been placed in limited duty status with mandatory participation in the FD's wellness/fitness program.

Other Medical Conditions

Sinus Tachycardia - The LT was noted to have episodic sinus tachycardia during clinic visits and his EST. Sinus tachycardia is a rhythm that produces a heart rate >100 beats per minute and represents a normal or appropriate response to physiologic stress, such as occurs with exercise, anxiety, or fever [Marchlinski 2008]. The cause of the LT's episodic sinus tachycardia is unclear.

Obstructive Sleep Apnea. NFPA 1582 considers untreated obstructive sleep apnea as a condition that could impair a fire fighter's ability to perform essential job tasks. They recommend restricting duty until the condition is under treatment [Somers et al. 2008; NFPA 2013a]. According to medical records, the LT was compliant with treatment by using CPAP.

Recommendations

Recommendation #1: Follow current Fire Department policies that restrict fire fighters who cannot reach 12 metabolic equivalents on exercise stress tests; a policy consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Discussion: We applaud the fire department for its comprehensive medical evaluation program. The fire department requires that fire fighters who cannot reach 12 METs on their EST be considered "Not fit for duty (on a temporary basis)" and referred to the fire department's wellness/fitness program. This policy is consistent with NFPA 1582.

Recommendation #2: Perform an annual physical ability evaluation.

Discussion: 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]. Once developed by the FD, this evaluation could be performed as part of the FD annual training program.

Recommendation #3: 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 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 [Stein et al. 2000; Aldana 2001]. 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 et al. 2013].

The FD has an outstanding voluntary wellness/fitness program. However, NIOSH recommends a mandatory formal, structured wellness/fitness program to ensure ALL members receive the benefits of a health promotion program. In addition, during exercise time, employees should be taken out of service to ensure uninterrupted member participation.

Recommendation #4: 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 public employees in states operating OSHA-approved state plans [OSHA 2015]. An OSHA-approved state plan is not in effect here; therefore, the fire department is not required to ensure all members have been medically cleared to wear an SCBA. However, NIOSH investigators recommend voluntary compliance with this recommendation to improve fire fighter health and safety. In addition, this clearance could easily become a part of the FD's medical program. The FD currently provides its members with annual medical evaluations which include an annual SCBA mask fit test. The FD has a respiratory protection plan and is in compliance with annual member SCBA testing.

References

ACSM [2014]. Resource manual for guidelines for exercise testing and prescription. 7th ed. American College of Sports Medicine. Philadelphia, PA: Wolters Kluwer.

AHA (American Heart Association) [2015a]. Understand your risk of heart attack. Dallas, TX: American Heart Association. [http://www.heart.org/HEARTORG/Conditions/HeartAttack/UnderstandYourRiskofHeartAttack/Understand-Your-Risk-of-Heart-Attack_UCM_002040_Article.jsp]. Date accessed: December 2015.

AHA [2015b]. Understand your risk for arrhythmia. Dallas, TX: American Heart Association. [http://www.heart.org/HEARTORG/Conditions/Arrhythmia/UnderstandYourRiskforArrhythmia/Understand-Your-Risk-for-Arrhythmia_UCM_002024_Article.jsp]. Date accessed: December 2015.

Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS [2011]. Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc *43*(8):1575–1581.

Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE [2000]. Triggering of sudden death from cardiac causes by vigorous exertion. N Engl J Med *343*(19):1355–1361.

Aldana SG [2001]. Financial impact of health promotion programs: a comprehensive review of the literature. Am J Health Promot *15*(5):296–320.

Blevins JS, Bounds R, Armstrong E, Coast JR [2006]. Health and fitness programming for fire fighters: does it produce results? Med Sci Sports Exerc *38*(5):S454.

CDC (Centers for Disease Control and Prevention) [2015]. Assessing your weight. [http://www.cdc.gov/healthyweight/assessing/index.html]. Date accessed: December 2015.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Dempsey WL, Stevens SR, Snell CR [2002]. Changes in physical performance and medical measures following a mandatory firefighter wellness program. Med Sci Sports Exerc *34*(5):S258.

Gerkin R, Kelley P, Perry R [1997]. Correlation of VO2max during maximal treadmill stress testing with VO2 at 85% predicted maximal heart rate: A retrospective review of the Phoenix fire department treadmill protocol. Technical report to the medical director of the Phoenix Fire Department Medical Center.

Gledhill N, Jamnik VK [1992]. Characterization of the physical demands of firefighting. Can J Spt Sci *17*(3):207–213.

IAFF, IAFC [2007]. Candidate physical ability test. 2nd ed. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

IAFF, IAFC [2008]. The fire service joint labor management wellness/fitness initiative. 3rd ed. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ health: a global access science source. 2:14. [http://www.ehjournal.net/content/2/1/14]. Date accessed: December 2015.

Kales SN, Soteriades ES, Christophi CA, Christiani DC [2007]. Emergency duties and deaths from heart disease among fire fighters in the United States. N Engl J Med *356*(12):1207–1215.

Koren MJ, Devereux RB, Casale PN, Savage DD, Laragh JH (1991). Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. Ann Intern Med *114*(5): 345–352.

Kuehl KS, Elliot DL, Goldberg L, Moe EL, Perrier E, Smith J [2013]. Economic benefit of the PHLAME wellness programme on firefighter injury. Occup Med *63*(3):203–209.

Levy D, Garrison RJ, Savage DD, Kannel WB, Castelli WP [1990]. Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Heart Study. N Engl J Med *323*(24):1706–1707.

Libby P [2013]. Mechanisms of acute coronary syndromes and their implications for therapy. N Engl J Med *368*(21):2004–2013.

Marchlinski F [2008]. The tachyarrhythmias. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1425–1443.

Mayo Clinic [2015]. Heart arrhythmias. [http://www.mayoclinic.com/health/heart-arrhythmias/DS00290/METHOD=print&DSECTION=all]. Date accessed: December 2015.

Meyerburg RJ, Castellanos A [2008]. Cardiovascular collapse, cardiac arrest, and sudden cardiac death. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1707–1713.

NFPA [2008]. Standard on health-related fitness programs for fire fighters. Quincy, MA: National Fire Protection Association. NFPA 1583.

NFPA [2013a]. Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association. NFPA 1582.

NFPA [2013b]. Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association. NFPA 1500.

NHLBI [2015]. Who is at risk for coronary artery disease? National Heart, Lung, and Blood Institute. [http://www.nhlbi.nih.gov/health/health-topics/topics/cad/atrisk.html]. Date accessed: December 2015.

NIOSH [2007]. NIOSH alert: preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events. [http://www.cdc.gov/niosh/docs/2007-133/]. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2007-133.

OSHA (Occupational Safety and Health Administration) [2015]. State occupational safety and health plans. [http://www.osha.gov/dcsp/osp/index.html]. Date accessed: December 2015.

Schneider EL [2010]. Firefighter fitness: a health and wellness guide. New York: Nova Science Publishers.

Siegel RJ [1997]. Myocardial hypertrophy. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology acquired diseases. Philadelphia, PA: Lippencott-Raven, pp. 55–57.

Somers VK, White DP, Amin R, Abraham WT, Costa F, Culebras A, Daniels S, Floras JS, Hunt CE, Olson LJ, Pickering TG, Russell R, Woo M, Young T [2008]. Sleep apnea and cardiovascular disease: an American Heart Association/American College of Cardiology Foundation scientific statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing Council. J Amer Coll Cardiol *52*(8):686–717.

Stein AD, Shakour SK, Zuidema RA [2000]. Financial incentives, participation in employer sponsored health promotion, and changes in employee health and productivity: HealthPlus health quotient program. J Occup Environ Med *42*(12):1148–1155.

Womack JW, Humbarger CD, Green JS, Crouse SF [2005]. Coronary artery disease risk factors in firefighters: effectiveness of a one-year voluntary health and wellness program. Med Sci Sports Exerc *37*(5):S385.

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

Status Investigation Report of a Self-Contained Breathing Apparatus Submitted By the Fire Department NIOSH Task Number 20251

(Note: The full report is available upon request)

Background

At the request of the Fire Department, the National Personal Protective Technology Laboratory (NPPTL) agreed to examine and evaluate a SCBA unit identified as Scott Health and Safety model AirPak 50, 4500 psi, 60-minute, self-contained breathing apparatus (SCBA). This SCBA status investigation was assigned NIOSH Task Number 20251. The Fire Department was advised that NIOSH NPPTL would provide a written report of the inspections and any applicable test results.

The SCBA unit was delivered to the NIOSH facility in Morgantown, WV on May 22, 2015. As delivered, the unit was contained within a paper bag inside a cardboard shipping container. The unit was taken to the lower floor of Lab H-1513 for secured storage. The SCBA unit was removed for inspection on June 2, 2015 and was returned to the locked evidence cage after inspection until it was tested on June 11, 2015.

SCBA Inspection

The unit was initially removed from the shipping container June 2, 2015 in Lab H-1513 for inspection by Jay Tarley, Physical Scientist; Mike Commodore, Engineer Technician; and Julian Nwoko, Contractor, Morgantown Testing Team (MTT), NPPTL. The SCBA was identified as the Fire Department SCBA. The SCBA was extensively examined, component by component, in the condition received to determine the conformance of each unit to the NIOSH-approved configuration. The unit was identified as the Scott Health and Safety Company model AirPak 50, 60 minute, 4500 psi, NIOSH approval numbers TC-13F-0096CBRN. The visual inspection process was documented photographically.

Once all the inspections were completed, the SCBA unit was repackaged and placed back in the locked evidence cage. Also, on July 1, 2015 the SCBA data logger was downloaded by the MTT in Lab H-1513.

The complete SCBA inspection is summarized in **Appendix I** of the full report. The condition of each major component of the SCBA that were photographed with a digital camera is contained in **Appendix III** of the full report.

It was judged that the SCBA could be safely pressurized and tested in the condition received. The

SCBA was tested on June 11, 2015 by the MTT in Lab H-1513, Morgantown, WV.

SCBA Testing

The purpose of the testing was to determine the conformance of each SCBA to the approval performance requirements of Title 42, *Code of Federal Regulations*, Part 84 (42 CFR 84). Further testing was conducted to provide an indication of the conformance of the SCBA to the National Fire Protection Association (NFPA) Air Flow Performance requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*, 1997 Edition.

NIOSH SCBA Certification Tests (in accordance with the performance requirements of 42 CFR 84):
1. Positive Pressure Test [§ 84.70(a)(2)(ii)]
2. Rated Service Time Test (duration) [§ 84.95]
3. Static Pressure Test [§ 84.91(d)]
4. Gas Flow Test [§ 84.93]
5. Exhalation Resistance Test [§ 84.91(c)]
6. Remaining Service Life Indicator Test (low-air alarm) [§ 84.83(f)]

National Fire Protection Association (NFPA) Tests (in accordance with NFPA 1981, 1997 Edition):
7. Air Flow Performance Test [Chapter 5, 5-1.1]

The SCBA was tested June 11, 2015.
Appendix II of the full report contains the complete NIOSH test report for the SCBA. **Tables ONE, TWO, THREE and FOUR** summarize the NIOSH and NFPA test results.

Summary and Conclusions

The SCBA was submitted to NIOSH/MTT/NPPTL by the Fire Department for evaluation. The SCBA was delivered to NIOSH on May 22, 2015 and extensively inspected on June 2, 2015. The unit was identified as a Scott Health and Safety model AirPak 50, 4500 psi, 60-minute, SCBA (NIOSH approval number TC-13F96CBRN). The MTT performed a downloading of the data logger on July 1, 2015 in the Morgantown Lab, H-1513. The unit was in good condition when received. The cylinder valve, as received, was in the closed position. The cylinder gauges showed approximately 2900 psi. The cylinder valve hand-wheel could be turned on both units. The regulator and facepiece mating and sealing area were relatively clean. Visibility through the facepiece lens was good. The NFPA approval label was present and readable. The personal alert safety system (PASS) functioned.

The SCBA did meet the requirements of all NIOSH Tests. The HUD alarm did not function; however, the base and remote gauge LEDs functioned and readings could be taken from those for an average alarm point pressure as indicated in the test results. The bypass was functional. When pressurized to full cylinder-pressure, the furthest right red LED on the HUD would activate for a small period until the pressure was decreased.

The unit did not pass the NFPA test even though the facepiece pressure was within the NFPA requirements. The unit failed the test due to the HUD not functioning. The LEDs on the remote gauge and PASS control unit functioned normally.

In light of the information obtained during this investigation, NIOSH has proposed no further action on its part at this time. The SCBA units were returned to storage pending return to the Fire Department.

If these units are to be placed back in service, the SCBAs must be repaired, tested, cleaned and any damaged components replaced and inspected by a qualified service technician, including such testing and other maintenance activities as prescribed by the schedule from the SCBA manufacturer. Typically a flow test is required on at least an annual basis.

Appendix B
Autopsy Findings

- Coronary artery atherosclerosis
  - 80% focal narrowing in the first diagonal left anterior descending coronary artery
  - 80% focal narrowing in the ramus intermedius left circumflex coronary artery
  - 75% focal narrowing in the mid right coronary artery
  - Rare foci of contraction band necrosis of the right ventricle
  - Biventricular myocyte hypertrophy with subendocardial and perivascular interstitial fibrosis on microscopic examination
- Hypertensive heart disease
  - Mild cardiomegaly (heart weighed 460 grams [g]; predicted normal weight is 383 g [ranges between 290 g and 506 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Concentric left ventricular hypertrophy
    - Left ventricle and interventricular septum thickening (1.8 centimeter [cm] and 2.0 cm respectively)
      - 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]
- Discoloration of anterior mitral valve leaflet and chordae
- Atheromatous deposits in anterior mitral leaflet
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood carboxyhemoglobin level 2.0% (suggesting the LT was not exposed to significant levels of carbon monoxide)
- Minimal soot deposition in upper airway
- Negative blood test for drugs and alcohol

REFERENCES

Colucci WS, Braunwald E [1997]. Pathophysiology of heart failure. In: Braunwald, ed. Heart disease. 5th ed. Philadelphia, PA: W.B. Saunders Company, p. 401.

Connolly HM, Oh JK [2012]. Echocardiography. In: Bonow RO, Mann DL, Zipes DP, Libby P, Braunwald E, eds. Heart disease: a text of cardiovascular medicine. 9th ed. Vol. 1. Philadelphia, PA: Elsevier Saunders, p. 216.

Appendix C
Exercise Stress Test Results

Test results are put in the following categories:
- Category 1. "Immediate medical intervention needed"
- Category 2. "Further medical evaluation required but not of an immediate nature"
- Category 3. "Member is out of condition due to inability to perform at the required level of exertion (≥ 12 METs) needed to perform the full duties of a fire fighter. (Not fit for duty temporary)"
- Category 4. "Member is fit for duty."

A member whose test result indicates that he/she is in Category 1, 2, or 3 while testing will receive a letter titled "Abnormal Stress Test Notification" and will be placed in a sick leave status. The member shall report to the next sick call at the fire department medical clinic and be seen by a provider.

A member whose test result indicates that he/she is in Categories 1 and 2 will require medical evaluation by the member's primary physician or specialist, with referral back to the fire department clinic for return to duty evaluation. A member in Category 2 shall be kept in a Sick Leave status or placed in a limited duty status pending further evaluations by the FD clinic. A member in Category 3 will be placed in a limited duty status and shall follow the fire department physician's treatment program. Other program policies include:

1. A member that was evaluated and reported as Category 1 or 2 will need a medical evaluation for return to work at an appropriate time. As medical condition allows, the employee shall report to the fire department medical clinic the next scheduled date it is open, during normal sick call hours.

2. The member with a cardiac stress test reported as Category 3, not fit for duty temporary, his/her duty status shall be changed to limited duty status by the fire department medical clinic until successfully completing the exercise stress test.

3. The fire department medical clinic provider will review the results with the member and make a referral to the wellness department as appropriate.

4. The member will obtain medical clearance from his/her primary physician to participate in a fire department sponsored program if requested by a fire department medical clinic provider.

5. The wellness department will develop a Personal Wellness Profile which may include one-on-one nutritional counseling and monitoring, nutritional classes, smoking cessation, weight management, aerobic exercise classes, and home exercise.

6. Fitness training sessions will be provided with the guidance of Certified Trainers and Peer Fitness Counselors. The fitness instruction shall take place at the fire department training academy or other satellite locations within the agency.