2012
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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 *May, 2013*

Fire Fighter/Driver Operator Suffers Sudden Cardiac Death After Responding to a Residential Burning Odor Call – Illinois

Executive Summary

On November 11, 2012, a 61-year-old male career driver/operator ("D/O") and his truck company (Truck 40) were dispatched at 2205 hours to a three-story apartment building for a report of a burning odor. At the scene, the D/O set up the ladder and carried a ventilation saw to the roof. Fire fighters inside the building determined the smoke was caused by cooking and notified the D/O that ventilation was not necessary. When the D/O descended the ladder and reached the ground he was breathing rapidly. His shortness of breath persisted during the return trip to the fire station. While cleaning Truck 40 at the station, the D/O's shortness of breath worsened, and he reported some chest pain to crew members. They gave him oxygen and summoned an ambulance. The ambulance paramedics began treatment for pulmonary edema with oxygen, diuretics, and nitroglycerin and transported the D/O to the hospital's emergency department (ED). Shortly after arriving in the ED, the D/O had a cardiac arrest. Cardiopulmonary resuscitation was started followed by advanced life support including intubation with 100% oxygen. After 40 minutes in the ED, the D/O was pronounced dead at 2321 hours, and resuscitation efforts were stopped.

The death certificate and autopsy report listed "hypertensive cardiovascular disease" as the cause of death with "coronary atherosclerosis" as a contributing factor. Additional autopsy findings included coronary artery disease, cardiomegaly (enlarged heart), and left ventricular hypertrophy (LVH). Given the D/O's underlying heart disease, NIOSH investigators concluded that the physical stress of responding to the call and ascending/descending the aerial ladder to the roof of a three-story building probably triggered his sudden cardiac death.

NIOSH investigators offer the following recommendations to address safety and health issues and prevent similar incidents in the future.

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

Conduct exercise stress tests into the fire department medical evaluation program for fire fighters at increased risk for coronary heart disease (CHD).

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

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

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

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Introduction & Methods

On November 11, 2012, a 61-year-old male career D/O suffered sudden cardiac death after responding to a call about a burning odor in a residential structure. NIOSH contacted the affected fire department (FD) on November 13, 2012, to initiate the investigation. On November 28, 2012, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program went on site to investigate.

During the investigation, NIOSH personnel interviewed the following people:

- Battalion Chief
- Director of the FD medical clinic
- Vice-president of the fire fighter's union
- Crew members

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD incident report
- Police incident report
- Ambulance report
- Hospital ED records
- Death certificate
- Autopsy report

Investigative Results

Incident. On November 11, 2012, the D/O arrived at his fire station at 0700 hours to begin his 24-hour shift along with three other fire fighters. He was assigned to Truck 40, which responded to two calls for medical assistance (0821 hours and 1435 hours) and one call for a motor vehicle crash (1758 hours). During each response, the D/O remained with the truck and monitored the radio. Each response lasted less than 45 minutes after which Truck 40 returned to quarters.

Investigative Results (cont.)

At 2205 hours, Truck 40, Engine 120, Engine 121, Truck 24, and Battalion 21 were dispatched to a burning odor call in a three-story apartment building. At the scene, the D/O walked around the structure for a visual assessment and set up Truck 40 for aerial operations. The D/O, wearing full turnout gear without SCBA, retrieved the ventilation saw (weighing approximately 25 pounds) and climbed the ladder to the roof. Once there, he awaited orders to ventilate the roof. Crew members inside the structure determined the smoke originated from cooking, not a fire. They advised the D/O that roof ventilation was not needed and to descend the ladder. Upon reaching the ground, the D/O had difficulty breathing. As Truck 40 was returning to quarters (2220 hours), the D/O continued to have shortness of breath.

After returning to the fire station, the D/O cleaned and inspected Truck 40. Shortly thereafter, crew members found him standing beside the truck sweating profusely and complaining of shortness of breath and chest pain. Crew members helped him sit down and provided oxygen via nonrebreather mask as an ambulance was called (2224 hours).

The ambulance arrived at 2226 hours and found the D/O alert and oriented but in severe respiratory distress. He was diagnosed with acute pulmonary edema and treated with sublingual nitroglycerin followed by an intravenous push of Lasix (furosemide). His nonrebreather mask was exchanged for a tight fitting mask for continuous positive air pressure of 100% oxygen. The D/O's respiratory distress improved somewhat with this treatment. Vital signs revealed a blood pressure of 190/120 millimeters of mercury (mmHg) (normal range is 80–120/60–80 mmHg), pulse rate of 130 beats per

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Investigative Results (cont.)

minute (normal is 60–100), and a respiratory rate of 30 breaths per minute (normal is 8–12). The ambulance departed the scene at 2231 hours and arrived at the hospital's ED at 2236 hours.

In the ED the D/O was noted to be semiconscious and in severe respiratory distress. He had 2+ pitting edema of his left and right lower extremities, a pulse of 51 beats per minute, blood pressure of 190/110 mmHg, and an oxygen saturation of 30% (normal > 95%). He was intubated and given 100% oxygen. Shortly thereafter his heart rhythm changed to pulseless electrical activity, and cardiopulmonary resuscitation was initiated. Advanced life support continued in the ED for 40 minutes before the attending physician pronounced the D/O dead, and resuscitation efforts were stopped (2231 hours). Blood tests during the resuscitation showed a normal blood level of the cardiac enzyme troponin but slightly elevated levels of the enzyme CKMB (8.6 nanograms per milliliter [normal is 0.0–6.7 ng/mL]).

Medical Findings. The death certificate and autopsy, completed by the county coroner and assistant county medical examiner listed "hypertensive cardiovascular disease" as the cause of death with "coronary atherosclerosis" as a contributing factor. Additional findings at autopsy included an 80% focal narrowing of the left anterior descending coronary artery, cardiomegaly (enlarged heart), and LVH. Other pertinent findings from the autopsy are listed in Appendix A.

The D/O had two known medical problems:

- Hypertension: Primary care physician medical records were not available to the NIOSH investigator at the time of this report. It is unclear if the D/O was prescribed a blood pressure-lowering medication.
- Obesity: He was 72 inches tall and weighed 237 pounds, giving him a body mass index of 32.1 kilograms per meter squared [CDC 2011].

The D/O's other known risk factor for CHD was smoking. It is unclear if the D/O had a prior exercise stress test, electrocardiogram, or echocardiogram. The D/O intermittently participated in the FD's exercise program. He had no recent complaints of increasing fatigue or shortness of breath on exertion.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of 98 fire stations with 4,314 career uniformed personnel. It served 2.8 million residents in a geographic area of 228 square miles. All advanced life support ambulances were provided by the FD. In 2011, the FD responded to 274,661 calls including 28,264 fire calls, 234,328 fire/EMS calls, and 271,365 EMS calls. The total includes multi-unit responses.

Hiring and Training. The FD requires all new fire fighters to pass a pre-employment physical examination, a timed physical agility test, and a written civil service test. Once hired, the fire fighter must complete the 6-month Fire Fighter II and emergency medical technician (EMT) training, which is given at the city fire academy. Recruits are tested by state personnel. Once recruit training is completed, the fire fighter is assigned to a shift.

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Description of the FD (cont.)

Fire fighters assigned to the operations division work a 24 hour-on/48-hour off schedule with three platoons or shifts. The FD operates 24 battalions in five divisions. Subsequent training is conducted on-shift.

The state minimum requirement for fire fighter certification is 180 hours of training certifying to NFPA 1001 Standard on Fire Fighter Professional Qualifications Fire Fighter I [NFPA 2013a]. The state minimum requirement for career fire fighters is 240 hours of certifying training. Prior to completing fire fighter certification, each candidate must be certified as a state EMT-Basic. The FD requires an additional 60 hours of training to become certified as a Fire Figher II. Fire fighters are required to participate in 2 hours of training per work shift. New company officers receive 4 weeks of training that includes Management 1, Tactics 1, Instructor 1, and 1 week of departmental officer orientation and management training. The D/O was certified as a Fire Fighter 2, Driver/Operator, and EMT. He had 18 years of fire fighting experience.

Preplacement Medical Evaluations. A preplacement medical evaluation is required for all applicants. The components of the medical evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)
- Laboratory blood tests including complete blood count and lipids
- Urinalysis
- Urine drug screen
- Spirometry
- Resting electrocardiogram
- Exercise stress test
- Chest x-ray (baseline)
- Audiogram
- Vision screen

These evaluations are performed by a city physician on the basis of Illinois state guidelines. The physician determines medical clearance for fire fighting duties and forwards this decision to the FD.

Annual Medical Evaluations. An annual voluntary medical check is offered by the city. This medical check includes a questionnaire, measuring blood pressure and body mass index, and laboratory tests for cholesterol and triglycerides. The results are provided to the member but are not used in decisions regarding medical clearance for duty. The FD does annual fit testing of the FF's SCBA mask. Members who are ill/injured on or off duty must be cleared for duty by their primary care physician. The clearance is forwarded to the FD medical clinic, which makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program, and exercise equipment is available in the fire stations. The D/O exercised intermittently on the treadmill and bicycle. The FD offers an annual physical fitness incentive program in which the member completes the fitness test off-duty and receives a pay bonus of $450. The D/O did not participate in this program. The FD does not require an annual physical ability test.

Discussion

Atherosclerotic Coronary Heart Disease. 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 include three nonmodifiable factors (age older than 45, male gender, and family history of CHD) and five modifiable factors (smoking, hypertension, high blood cholesterol, obesity/physical inactivity, and diabetes) [AHA 2013; NHLBI 2012]. The D/O had three known modifiable CHD risk factors (smoking, hypertension, and obesity/physical inactivity) and was found to have CHD at 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 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 electrocardiogram (EKG) changes, elevated cardiac enzymes in the blood, or coronary artery thrombus. In this case, an EKG did not reveal characteristic changes, and no thrombus was identified at autopsy. The D/O's cardiac enzymes, however, provide conflicting evidence for a heart attack. He had normal troponin levels but slightly elevated CKMB levels. It should be noted that cardiac enzymes take at least 4 hours post-heart attack to become positive [Lewandrowski at al. 2002]. Because the D/O died approximately 1 hour after his symptoms began, the slight elevation of his CKMB was probably due to his underlying heart failure and not a heart attack.

Heart Failure. Heart failure is the inability of the heart to pump enough blood to meet the body's needs [Mann 2008]. Fatigue, shortness of breath, and dyspnea on exertion are the most common initial presentations of heart failure. Because the body can compensate for impaired cardiac function, a person with heart failure can be asymptomatic. Conditions that commonly cause or exacerbate heart failure symptoms include chronic hypertension, hypertensive crisis (rapid acute elevation of blood pressure), myocardial infarction, discontinuation of heart failure medication, cardiac arrhythmias, pulmonary embolus, heat stress, and physical overexertion. The D/O probably had chronic heart failure as evidenced by his cardiomegaly, LVH, and pedal edema. His acute onset of pulmonary edema was probably an acute exacerbation of his heart failure due to hypertensive crisis. We cannot rule out the possibility of a heart attack.

Left Ventricular Hypertrophy/Cardiomegaly. At autopsy, the D/O had LVH and cardiomegaly. These conditions increase the risk of heart failure and sudden cardiac death [Levy et al. 1990; Meyerburg and Castellanos 2001]. LVH is a relatively common finding among individuals with long-standing high blood pressure (hypertension), a heart valve problem, or cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The D/O's history of hypertension was probably responsible for his LVH and cardiomegaly in addition to his underlying CHD. LVH, cardiomegaly, and CHD led to his heart failure and increased risk for sudden cardiac death.

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Discussion (cont.)

Sudden Cardiac Death. The D/O's sudden cardiac death was probably due to an episode of hypertensive crisis precipitating pulmonary edema. Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers sudden cardiac death [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 D/O's last FD response involved climbing the aerial ladder to the roof of a three-story building while carrying a ventilation saw and wearing full turnout gear without SCBA. This activity expended about 8 METs, which is considered moderate physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011]. This activity probably precipitated the D/O's hypertensive crisis, which caused his acute pulmonary edema and sudden cardiac death.

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 2013b]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The FD does not conduct medical evaluations on members; therefore, the D/O's hypertension and cardiac conditions were unknown to the FD. If these conditions were known by the FD, the following would have applied.

Coronary Heart Disease. On autopsy, the D/O was found to have severe CHD. Prior to his death, the D/O was not known to have CHD. Exercise stress tests can be used to screen for and identify occult CHD. However, recommendations for conducting exercise stress tests on asymptomatic individuals without known heart disease are varied. The following paragraphs summarize the positions of widely recognized organizations on this topic.

NFPA 1582, a voluntary industry standard, recommends an exercise stress test performed "as clinically indicated by history or symptoms" and refers the reader to its Appendix A [NFPA 2013b]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (i.e., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease (CAD)
- two or more risk factors for CAD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter), hypertension (diastolic blood pressure greater than 90 mm of mercury), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The American College of Cardiology/American Heart Association (ACC/AHA) has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA guideline states the evidence is

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Discussion (cont.)

"less well established" (Class IIb) for the following groups:

- persons with multiple risk factors (defined similarly to those listed by the NFPA)
- asymptomatic men older than 45 years and women older than 55 years:
  - who are sedentary and plan to start vigorous exercise
  - who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters)
  - who are at high risk for CAD due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation provides guidance for those seeking medical certification for a commercial driver's license. An expert medical panel recommended exercise tolerance tests (stress tests) for asymptomatic "high risk" drivers [Blumenthal et al. 2007]. The panel defines high risk drivers as those with any of the following:

- diabetes mellitus
- peripheral vascular disease
- age 45 and above with multiple risk factors for CHD
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for CHD events. For individuals at increased risk for CHD events, the USPSTF found "insufficient evidence to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning..." Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [USPSTF 2004]. The USPSTF does note that "For people in certain occupations, such as pilots, and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than the health benefit to the individual patient may influence the decision to screen for coronary heart disease."

Given the D/O's age and CHD risk profile (three known modifiable CHD risk factors), the NFPA, the ACC/AHA, and the Department of Transportation would have recommended a symptom limiting exercise stress test. If a symptom limiting exercise stress was done, perhaps his underlying CHD would have been identified and the D/O referred for further medical evaluation and treatment.

Recommendations

NIOSH investigators offer the following recommendations to address safety and health issues and prevent similar incidents in the future.

Recommendation #1: Provide 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 [IAFF, IAFC 2008; NFPA 2013b]. These evaluations are performed to determine fire fighters' medical ability

Recommendations (cont.)

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.

Recommendation #2: Conduct exercise stress tests into the fire department medical evaluation program for fire fighters at increased risk for coronary heart disease.

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters older than 45 with one or more coronary artery disease risk factors [IAFF, IAFC 2008; Gibbons et al. 2002; NFPA 2013b]. The D/O was over the age of 45 and had two risk factors for CHD (high blood pressure and smoking). A symptom-limiting exercise stress test may have identified his underlying CAD.

Currently the FD does an exercise stress test on all applicants during their preplacement medical evaluation, regardless of the applicant's age, number of CHD risk factors, or severity of CHD risk factors. While this test has value to ensure the candidate has the aerobic capacity needed to be a fire fighter, its use on individuals at low risk for CHD is an unnecessary expense for the FD [Gibbons et al. 2002].

Recommendation #3: Provide fire fighters with medical clearance to wear SCBA as part of the fire department's medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans. Illinois operates an OSHA-approved state plan [OSHA 2012]; therefore, the FD is required to ensure all structural fire fighters have been medically cleared to wear a respirator/SCBA. This clearance could be incorporated into the FD's current preplacement medical evaluation program.

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

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, 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 CHD 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

Recommendations (cont.)

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 has a voluntary wellness/fitness program. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #5: Perform an annual physical performance (physical ability) evaluation for all members.

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 2013c]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2013c]. The annual evaluation could be incorporated into the annual task-level training program.

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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), 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, led the investigation and co-authored the report. Dr. Thomas Hales (MD, MPH), 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), provided medical consultation and co-authored the report.

Appendix A

Autopsy Findings

- Hypertensive heart disease
  - Cardiomegaly (enlarged heart; heart weighed 646 grams [g]; predicted normal weight is 406 g [ranges between 308 g and 536 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Left ventricular hypertrophy
    - Left ventricle thickened (2.5 centimeter [cm])
    - Interventricular septum thickened (3.0 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]
- Coronary artery atherosclerosis
  - Severe (80%) focal narrowing of the left anterior descending coronary artery
  - Minimal (10%) focal narrowing of the right coronary artery and left circumflex coronary artery
  - No evidence of a coronary artery thrombus (blood clot)
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative
- Respiratory system
  - Pulmonary parenchyma shows congestion and edema

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