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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 *August, 2010*

Fire Chief Suffers Sudden Cardiac Death During Emergency Medical Response – Utah

Executive Summary

On December 24, 2009, a 44-year-old male volunteer fire Chief responded to a medical call for a non-life-threatening condition. At the scene, the Chief assisted in loading the patient onto the stretcher and into the ambulance for transport to the local hospital's emergency department (ED). While assisting in the patient compartment of the ambulance, the Chief collapsed. A second ambulance (squad) was dispatched to assume care and transport of the first patient, while the ambulance crew turned its attention to the Chief. He was not breathing but had a weak pulse. The EMTs provided oxygen as they waited approximately 2 minutes for the second ambulance to arrive. The Chief's condition did not change during transport, but as the ambulance arrived in the ED, the Chief suffered cardiac arrest. Cardiopulmonary resuscitation (CPR) and advanced life support were begun and continued in the ED for 40 minutes. At 1911 hours the ED physician pronounced him dead, and resuscitation efforts stopped. The death certificate and the autopsy listed "atherosclerotic coronary artery disease" as the cause of death with "cardiomegaly" as a contributory condition. Given the Chief's underlying atherosclerotic coronary artery disease (CAD), NIOSH investigators concluded that the physical exertion involved in responding to the call and assisting in loading a patient onto a stretcher and into an ambulance triggered his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unclear if these recommendations could have prevented the Chief's death.

Provide preplacement and annual medical evaluations to all fire fighters.

Perform a preplacement and an annual physical performance (physical ability) evaluation.

Ensure 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 National Fire Protection Association (NFPA) 1582.

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

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

Conduct annual respirator fit testing.

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Introduction & Methods

On December 24, 2009, a 44-year-old male volunteer Chief collapsed while transporting a patient to the ED. NIOSH was notified of this fatality on December 30, 2009, by the U.S. Fire Administration. NIOSH contacted the affected Fire Department (FD) on January 5, 2010, to gather additional information, and on May 11, 2010, to initiate the investigation. On May 24, 2010, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Utah to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Current Fire Chief
- Ambulance crew members
- Chief's spouse

NIOSH personnel reviewed the following documents:
- FD training records
- FD incident report
- Emergency medical service (ambulance) incident reports
- Hospital ED records
- Death certificate
- Autopsy report
- Primary care provider medical records

Investigative Results

Incident. On December 24, 2009, the FD ambulance and a mutual aid ambulance (squad) were dispatched at 1802 hours to a residence where a person had fallen. The Chief responded from his home to the fire station and rode in the FD ambulance to the scene.

The FD ambulance and the squad arrived on the scene at 1811 hours and found a person who had fallen and was injured. The patient was stabilized with a neck collar. The Chief assisted with loading the patient onto a stretcher and then placing the stretcher into the ambulance. The ambulance departed the scene en route to the ED at 1818 hours with the Chief riding in the patient care bay of the ambulance.

En route to the ED, the Chief asked the other crew member for a pen light to check the patient's pupil reaction. After handing the light back to the crew member, the Chief collapsed. The crew member notified the driver, who alerted dispatch that they "needed help with a crew member" (1821 hours). He also radioed the squad that had responded to the initial call to turn around and assume care and transport of the neck injury patient.

The driver stopped the ambulance as crew members removed the first patient from the ambulance. The Chief was then placed onto a stretcher and evaluated in the bay of the ambulance. He was unresponsive and not breathing but had a weak pulse. His head was repositioned, and oxygen was provided via bag-valve-mask as the ambulance departed the scene at about 1825 hours. As the ambulance arrived at the ED 5 minutes later (1830 hours), the Chief aspirated and became pulseless. The crew rushed the Chief into the ED as hospital staff began CPR and advanced life support.

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Investigative Results (cont.)

The Chief was intubated, and an intravenous line was placed. Cardiac resuscitation medications were administered, and a cardiac monitor revealed ventricular fibrillation. The Chief was shocked (defibrillated) 11 times over 30 minutes with no clinical change in his condition or positive change in his heart rhythm. Resuscitation efforts continued for 40 minutes (until 1911 hours), when the attending physician pronounced the Chief dead, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy completed by the Office of the Medical Examiner listed "atherosclerotic coronary artery disease" as the cause of death with "cardiomegaly" as another condition. Specific findings from the autopsy are listed in Appendix A.

The Chief was 72 inches tall and weighed 207 pounds, giving him a body mass index of 28.1 kilograms per meters squared (kg/m2). A body mass index 25.0–29.9 kilograms per meter squared is considered overweight [CDC 2010]. The Chief's risk factors for coronary artery disease (CAD) included hypertension (high blood pressure), hypercholesterolemia (high blood cholesterol), family history of CAD, and lack of exercise. He was prescribed an antihypertensive medication in 2003, but medical records suggested the Chief only took seasonal allergy medications and that the antihypertensive prescription had never been filled.

In 2003 the Chief performed an exercise stress echocardiogram for a history of chest "heaviness" and palpitations. He exercised for 13 minutes, achieving 15.3 metabolic equivalents. The test was stopped because he reached 92% of his maximum predicted heart rate (168/182 beats per minute). The Chief had no symptoms of angina, no wall motion abnormalities, normal blood pressure response, and an electrocardiogram negative for ischemia. However, the rhythm strip did note some premature ventricular contractions (PVCs) and bigeminy during the recovery phase.

The day of this incident the Chief had responded to the medical emergency call and assisted in loading a patient into the ambulance, expending about 7 metabolic equivalents (METs), which is considered moderate physical activity [Ainsworth et al. 1993; Peterson et al. 1999]. During the weeks and months prior to this incident, the Chief had not expressed symptoms or signs of heart problems.

Description of the Fire Department

At the time of the NIOSH investigation, the volunteer FD consisted of one fire station with 23 uniformed personnel that served 2,000 residents in a geographic area of 20 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age (21 years to drive fire apparatus), have a valid State driver's license, and attend meetings and in-house training for 6 months. The applicant is then voted "in or out" at the next general meeting. The town council then approves the applicant as an FD member. Utah has no minimum training levels for fire fighters. The State Fire Fighter I (FF1) certification is voluntary. Although the Chief had 16 years of fire fighter experience and was certified as a Wildland Fire Fighter and an EMT-Intermediate, he was not FF1 certified.

Preplacement and Periodic Medical Evaluation. The State requires preplacement medical evaluations for fire fighters who take the FF1 training, but the FD does not require preplacement or periodic (annual) medical evaluations for members. No annual SCBA medical clearance or annual SCBA facepiece fit test are required. Members injured on duty must be evaluated by their primary care physician, who makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has no formal wellness/fitness program, but strength training equipment is available in the fire station. No annual physical ability test is required, but the State does require a physical ability test for FF1 training.

Discussion

Atherosclerotic Coronary Artery Disease. In the United States, atherosclerotic CAD 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 CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2010; NHLBI 2010]. The Chief had five CAD risk factors (male gender, family history of CAD, hypertension, hypercholesterolemia, and lack of exercise), and the autopsy revealed moderate CAD.

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 the occurrence of a recent (acute) heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. In the Chief's case, no EKG could be performed in the ED because of his cardiac arrest. His cardiac enzymes were not tested, and no coronary artery thrombus was identified at autopsy. Therefore, it is unlikely the Chief suffered a heart attack, but it cannot be ruled out because of the lack of an EKG and cardiac enzyme testing.

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Discussion (cont.)

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Siscovick et al. 1984; Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks 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 Chief had responded to the alarm and assisted in loading a patient into the ambulance. These activities expended about 7 METs, which is considered moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992].

Cardiomegaly/Biventricular Hypertrophy. On autopsy, the Chief was found to have biventricular hypertrophy and an enlarged heart. These findings raise the possibility that, in addition to his atherosclerotic CAD, the Chief could have had some type of mixed dilated/hypertrophic cardiomyopathy. However, the microscopic examination of the Chief's heart tissue was not consistent with this diagnosis [Hughes 2004]. The more likely reason for the Chief's biventricular hypertrophy is chronic ischemia from underlying atherosclerotic CAD or untreated hypertension causing left ventricular hypertrophy. Left ventricular hypertrophy is also associated with sudden cardiac death [Antman et al. 2008].

Mitral Valve Thickening. "Some" mitral valve thickening was identified at autopsy. Given the Chief's normal sized left atrium by both EKG and autopsy, his thickened mitral valve was probably of no clinical significance, i.e., it was not responsible for the biventricular hypertrophy.

Palpitations and Arrhythmias. In 2003, the Chief experienced chest palpitations. Workup included a stress echocardiogram that was negative for ischemia, but asymptomatic PVCs and bigeminy occurred during the recovery phase. After the workup, the Chief's palpitations and PVCs were felt to be related to caffeine ingestion.

PVCs, in the absence of structural heart disease, are considered benign [Zipes et al. 2006]. However, when PVCs occur during exercise or during the recovery phase of exercise, some research suggests that affected individuals are at slightly increased risk of sudden cardiac death [Jouven et al. 2000; Frolkis et al. 2003]. This slight increase in risk should not have resulted in work restrictions, although periodic stress testing could have been considered given the Chief's CAD risk factors [NFPA 2007a].

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria. The Chief was diagnosed with hypertension and hypercholesterolemia in 2003. Neither of these conditions by themselves would have caused fire fighter duty restrictions. However, together, they increase the risk for a cardiovascular event (CAD or sudden cardiac death).

Exercise stress tests screen people at risk for CAD and sudden cardiac death. NFPA 1582 recommends performing an exercise stress test "as clini-

Discussion (cont.)

cally indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. 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. Diagnostic stress tests (maximal or 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
- 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 [mg/dL]), hypertension (diastolic blood pressure greater than 90 millimeters of mercury [mmHg]), smoking, diabetes mellitus, or family history of premature coronary artery disease (heart attack or sudden cardiac death in a first-degree relative less than 60 years old). This exercise stress test recommendation is similar to that recommended by the American College of Cardiology/American Heart Association (ACC/AHA) and the U.S. Department of Transportation [Gibbons et al. 2002; Blumenthal et al. 2007].

Although the Chief had three of the five CAD risk factors, he was younger (44 years old) than the recommended age for an exercise stress test to be performed (> 45 years old for men). Given the Chief's undiagnosed CAD and left ventricular hypertrophy, the stress of responding to the call and loading the patient into the ambulance probably triggered his sudden cardiac death.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unclear if these recommendations could have prevented the Chief's death.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, the FD is not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments to implement.

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians (EMTs) from the local EMS (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by

Recommendations (cont.)

a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, City, or State. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the City, the State, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: 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.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008]. According to these guidelines, the FD 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. The physician should review job descriptions and essential job tasks required for all FD positions and ranks 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. This recommendation is based on review of the FD health and medical programs. The Chief had been treated by his primary care physician for hypertension and back pain since 2002. In addition, he was treated for heart palpitations in 2003. It is unclear if the Chief's physician was aware that his patient was a fire fighter. His medical records never mentioned medical clearance for duty.

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

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b].

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

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; IAFF, IAFC 2008; NFPA 2008; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001].

Fire service health promotion programs have been shown to reduce coronary artery disease risk factors and improve fitness levels, with mandatory

Recommendations (cont.)

programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007].

Given the FD's structure, the NVFC program might be the most appropriate model [USFA 2004]. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #5: 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 [OSHA 2010]. Utah operates an OSHA-approved State plan. Therefore, the FD is required to comply with this standard and ensure that all members are medically cleared to wear an SCBA.

Recommendation #6: Conduct annual respirator fit testing.

The OSHA respiratory protection standard requires employers whose employees are required to use a respirator (e.g., an SCBA) to have a formal respiratory protection program, including annual fit testing [29 CFR 1910.134]. As mentioned previously, Utah is an OSHA-approved State plan; therefore, the FD is required to follow this OSHA standard [OSHA 2010].

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located 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 Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Appendix A

Autopsy Findings

- Atherosclerotic cardiovascular disease
  - Moderate (60%) focal narrowing of the left anterior descending coronary artery
  - Moderate (60%) focal narrowing of the left circumflex coronary artery
  - Moderate (60%) focal narrowing of the right coronary artery
  - No evidence of recent thrombus (blood clot in the coronary arteries)
- Cardiomegaly (enlarged heart) (heart weighed 510 grams [g]; predicted normal weight is 379 g [between 207 g and 500 g] as a function of sex, age, and body weight) [Silver and Silver 2001]
- Biventricular dilatation
  - Left ventricular hypertrophy (LVH); left ventricular wall and interventricular septum thickened (4.9 centimeters [cm] and 1.5 cm respectively; normal by autopsy 0.76–0.88 cm [Colucci and Braunwald 1997]; normal by echocardiography 0.6–1.1 cm [Armstrong and Feigenbaum 2001]
  - Right ventricular wall thickened (4.0 cm); normal by echocardiography 0.7–2.3 cm [Armstrong and Feigenbaum 2001]
  - Microscopic evidence of myocyte hypertrophy, myocyte disarray, and interstitial fibrosis
- Thickened mitral valve
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Negative blood tests for illegal drugs and alcohol

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