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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 *January, 2013*

Fire Chief Suffers Sudden Cardiac Death After Physical Fitness Training – Washington

Executive Summary

On June 27, 2011, a 47-year-old male career fire chief ("the Chief") responded to two medical calls. The first occurred approximately 1 hour prior to his shift, while the other occurred at 0833 hours. He assisted at both calls, but neither patient was transported to the hospital. During the remainder of his shift, the Chief performed apparatus inspection and maintenance and station duty. At 1900 hours, the Chief and the emergency medical service (EMS) officer went to the high school gym to lift weights for about an hour. The Chief returned to his home, and at 2208 hours he commented that he did not feel well and then collapsed. Arriving ambulance personnel described the Chief as having seizure-like movements. As they carried him to the ambulance, the seizure stopped, as did the Chief's pulse and breathing. Cardiopulmonary resuscitation (CPR) and advanced life support were begun as the Chief was transported to the local hospital's emergency department (ED) at 2225 hours, arriving 11 minutes later. Inside the ED, cardiac resuscitation efforts continued for more than 45 minutes, but at 2321 hours the Chief was pronounced dead and resuscitation efforts were stopped.

The death certificate, completed by the county chief deputy coroner, and the autopsy report, completed by the pathologist, listed "cardiac dysrhythmia due to atherosclerotic coronary artery disease and myocardial bridging of anterior descending coronary artery" as the cause of death. Given the Chief's underlying coronary heart disease, NIOSH investigators concluded that the physical stress of performing physical fitness training may have triggered a cardiac arrhythmia and a possible heart attack resulting in his sudden cardiac death.

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

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

Ensure that fire fighters are cleared for 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.

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

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

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Introduction & Methods

On June 27, 2011, a 47-year-old male career fire chief suffered sudden cardiac death shortly after physical fitness training. NIOSH contacted the affected fire department (FD) on July 11, 2011, to gather additional information, and on July 16, 2012, to initiate the investigation. On September 10, 2012, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Current fire chief
- FD EMS officer
- Crew members
- Fire chief's spouse

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD incident report
- Ambulance report
- Hospital ED records
- Death certificate
- Autopsy report
- Primary care physician records

Investigative Results

Incident. On June 27, 2011, the Chief and the ambulance (staffed with two emergency medical technicians) responded to a medical call at 0552 hours. At the scene, the Chief assisted with basic patient care. The patient was not transported to the hospital, and the Chief and the ambulance crew returned to service at 0629 hours.

Investigative Results (cont.)

The Chief began his 8-hour shift at 0700 hours. He performed administrative duties until 0833 hours, when the FD was dispatched to another emergency medical call. Again, the Chief assisted with basic patient care, and the patient elected not to be transported to the hospital. The ambulance cleared the scene at 0847 hours. From 0900 hours to 1100 hours, the Chief performed apparatus inspection and maintenance. After lunch, the Chief performed station duties until 1800 hours, when he went onto standby duty.

At 1900 hours, the Chief and the EMS officer went to the local high school gym to lift weights. They lifted weights until 2000 hours, and the Chief went home. While at the gym, the Chief reported no unusual signs or symptoms. At 2208 hours, the Chief commented to his wife that he did not feel well. As the Chief walked out of the room for a drink of water, he collapsed. His wife called 911, and an ambulance was dispatched at 2211 hours.

The ambulance, staffed with the FD medical officer (trained as an emergency medical technician-intermediate) and two additional emergency medical technicians arrived on-scene at 2220 hours. Crew members found the Chief having an apparent seizure. While being carried to the ambulance the seizure activity stopped, but the Chief remained unresponsive, without any pulse or respirations. CPR was begun, and the Chief was loaded into the ambulance, which departed the scene at 2225 hours en route to the hospital's ED. An automated external defibrillator was placed, and a shock was administered. An oropharyngeal airway was inserted, and oxygen was delivered via bag-valve mask. An intravenous line was placed

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Investigative Results (cont.)

as five additional shocks were administered before the ambulance arrived at the hospital's ED at 2236 hours.

Inside the ED, cardiac resuscitation efforts continued with five additional defibrillation attempts, intravenous cardiac resuscitation medications, and intubation. A blood test revealed elevated creatinine-kinase (265 units per liter [normal is 30–200]) and elevated troponin (0.046 nanograms per milliliter [normal is 0.000–0.028]). Resuscitation efforts continued without success until 2321 hours when the Chief was pronounced dead, and resuscitation efforts were stopped.

Medical Findings. The death certificate, completed by the county chief deputy coroner, and the autopsy report, completed by the pathologist, listed "cardiac dysrhythmia due to atherosclerotic coronary artery disease and myocardial bridging of anterior descending coronary artery" as the cause of death. Other pertinent findings from the autopsy are listed in Appendix A.

The Chief was 70 inches tall and weighed 200 pounds, giving him a body mass index of 28.7 kilograms per meters squared, which is considered overweight [CDC 2011]. The Chief was diagnosed with hypertension in 2009 and was prescribed a blood pressure-lowering medication. A blood test in 2009 also revealed elevated levels of cholesterol (288 milligrams per deciliter [mg/dL], normal < 200 mg/dL) and triglycerides (349 mg/dL, normal <150 mg/dL), but no lipid-lowering medication was prescribed. The Chief's last primary care medical evaluation was in November 2010 at which he complained of rib pain from a fall. The Chief regularly drank protein drinks containing ephedrine, including after his workout the day of this incident.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of three fire stations with 25 volunteer uniformed personnel and two career personnel. It served 2,300 residents in a geographic area of 49 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid state driver's license, and be voted on by the membership. The new member must pass a respirator medical evaluation (explained below). The new member receives training at the fire station and at regional and state fire schools. State fire fighter certification to the fire fighter 1 (FF1) level is mandatory. There is no state mandatory FF1 refresher training. The Chief was certified as a fire fighter 2, fire officer, wildland fire fighter, driver/operator, and emergency medical technician. He had 16 years of fire fighting experience, including 7 years serving as fire chief.

Preplacement and Annual Medical Evaluations. A preplacement respirator medical evaluation is required for all applicants, and respirator medical evaluation is required annually for career members and biannually for volunteers. The components of the respirator medical evaluations include the following:

- Complete medical history
- Respirator questionnaire (adapted from 29 CFR 1910.134) (Occupational Safety and Health Administration [OSHA])
- Physical examination including vital signs
- Spirometry

These evaluations are performed by a contract physician. The physician determines medical clearance for respirator use and fire fighting duties and forwards this decision to the FD.

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Description of the FD (cont.)

An annual self-contained breathing apparatus facepiece fit test is required. Members injured on duty are required to be cleared for return to duty by their primary care physician with guidance from the state labor and industry office.

Health and Wellness Programs. The FD does not have a wellness/fitness program, and exercise equipment is not available in the fire stations. No candidate or annual physical ability test is required. The Chief regularly participated in an exercise program, primarily by lifting weights.

Discussion

Myocardial Bridging. Myocardial bridging occurs when a portion of a coronary artery tunnels into the myocardium, creating a muscle-bridge overlap. Myocardial bridging is very common. It has been reported in up to 40% of angiographic studies, and in 15% to 85% of autopsies [Mohlenkamp et al. 2002; Erbel et al. 2009]. Compression of the coronary artery due to the muscular band occurs during systole, and sometimes extends into diastole. Myocardial bridging has been associated with sudden cardiac death [Morales et al. 1980; Bestetti et al. 1991; Desseigne et al. 1991; Cutler and Wallace 1997], ischemia [Furniss et al. 1990; Ge et al. 1994; Schwarz et al. 1996], myocardial infarction [Chee et al. 1981; van Brussel et al. 1984; Feldman and Baughman 1986; Bestetti et al. 1987; Vasan et al. 1989], arrhythmia [den Dulk et al. 1983; Kracoff et al. 1987; Feld et al. 1991], and coronary artery spasm [Teragawa et al. 2003]. The Chief's myocardial bridging in his left anterior descending coronary artery may have triggered a small heart attack (as suggested by the elevated troponin blood test) and sudden cardiac death.

Discussion (cont.)

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 non-modifiable factors (age older than 45, male gender, and family history of CHD) and five modifiable factors (smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes) [AHA 2012; NHLBI 2012]. The Chief was over the age of 45 and had two of five modifiable CHD risk factors (high blood pressure, high blood cholesterol) at the time of his death.

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 EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, an EKG did not reveal characteristic changes, and no thrombus was identified at autopsy, but cardiac enzymes were slightly elevated, indicating the probability of a small, asymptomatic heart attack several hours previously. This small heart attack could have been due to bridging in the left anterior descending coronary artery, and/or to the physical exertion associated with lifting weights (discussed below).

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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 [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 lifted weights for approximately 1 hour. This activity expended about 6 METs, which is considered moderate physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

Nutritional (Energy) Supplements. Energy drinks are popular among young individuals and are marketed to college students, athletes, and active individuals between the ages of 21 and 35 [Iyadurai and Chung 2007]. Some energy drinks contain ephedra alkaloids (ephedrine). In addition to energy drinks, ephedra is found in at least 200 over-the-counter products. The U.S. Food and Drug Administration has received more than 1,000 reports of adverse effects due to ephedra that include minor complaints (e.g., palpitations), hypersensitivity myocarditis, ischemic stroke, ventricular arrhythmia, myocardial infarction, and death [Theoharides 1997; Soni et al. 2004]. It is unclear what role, if any, the energy drink played in the Chief's 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 (NFPA) developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Chief had one known condition relevant to medical clearance (use of a beta blocker medication) and one undiagnosed condition (CHD).

Beta Blocker Therapy. The Chief was diagnosed with hypertension in 2009 and was prescribed an antihypertensive beta blocker. The NFPA considers use of beta blockers to potentially preclude safely wearing the fire protective ensemble and safely climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces, and operating near electrical power lines or other hazards because of the risk for dehydration, electrolyte disorders, lethargy, and disequilibrium [NFPA 2007a].

Coronary Heart Disease. On autopsy, the Chief was found to have mild to moderate CHD. Prior to his death, the Chief was not known to have CHD. Exercise stress tests can be used to 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 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. Maximal (i.e., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

Discussion (cont.)

- 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 "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 coronary heart disease
- 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 coronary heart disease events. For individuals at increased risk for coronary heart disease 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 Chief's age and CHD risk profile (two modifiable CHD risk factors), the NFPA, the ACC/AHA, and the Department of Transportation would have recommended a symptom limiting exercise stress test.

Recommendations

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

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

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

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians from the local ambulance service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Ensure that fire fighters are cleared for 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 and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; 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.

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Recommendations

Recommendation #3: 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, the National Volunteer Fire Council 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 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 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 does not have a wellness/fitness program. Given the FD's structure, the National Volunteer Fire Council program would be very helpful [USFA 2004]. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #4: 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 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]. This could be incorporated into the annual task-level training program.

References

AHA (American Heart Association) [2012]. 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: November 2012.

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.

References (cont.)

Bestetti RB, Finzi LA, Amaral FT, Secches AL, Olivera JS [1987]. Myocardial bridging of coronary arteries associated with an impending acute myocardial infarction. Clin Cardiol *10*(2):129–131.

Bestetti RB, Costa RS, Kazava DK, Olivera JSM [1991]. Can isolated myocardial bridging of the left anterior descending coronary artery be associated with sudden death during exercise? Acta Cardiol *46*(1):27–30.

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.

Blumenthal RS, Epstein AE, Kerber RE [2007]. Expert panel recommendations. Cardiovascular disease and commercial motor vehicle driver safety. [http://www.mrb.fmcsa.dot.gov/documents/CVD_Commentary.pdf]. Date accessed: November 2012.

CDC (Centers for Disease Control and Prevention) [2011]. Assessing your weight. [http://www.cdc.gov/healthyweight/assessing/index.html]. Date accessed: November 2012.

Chee TP, Jensen DP, Padnick MB, Cornell WP, Desser KB [1981]. Myocardial bridging of the left anterior descending coronary artery resulting in subendocardial infarction. Arch Intern Med *141*(12):1703-1704.

Cutler D, Wallace JM [1997]. Myocardial bridging in a young patient with sudden death. Clin Cardiol *20*(6):581–583.

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.

den Dulk K, Brugada P, Braat S, Heddle B, Wellens HJ [1983]. Myocardial bridging as a cause of paroxysmal atrioventricular block. J Am Coll Cardiol *1*(3):965–969.

Desseigne P, Tabib A, Loire R [1991]. Myocardial bridging of the left anterior descending coronary artery and sudden death: an autopsy study of 19 cases. Arch Mal Coeur Vaiss *84*(4):511–516.

Erbel R, Ge J, Mohlenkamp S [2009]. Myocardial bridging: a congenital variant as an anatomic risk factor for myocardial infarction? Circulation *120*(5):357–359.

Feld H, Guadanino V, Hollander G, Greengart A, Lichstein E, Shani J [1991]. Exercise-induced ventricular tachycardia in association with a myocardial bridge. Chest *99*(5):1295–1296.

Feldman AM, Baughman KL [1986]. Myocardial infarction associated with a myocardial bridge. Am Heart J *111*(4):784–787.

Furniss SS, Williams DO, McGregor CG [1990]. Systolic coronary occlusion due to myocardial bridging-a rare cause of ischemia. Int J Cardiol *26*(1):116–117.

Fuster V, Badimon L, Badimon JJ, Chesebro JH [1992]. The pathogenesis of coronary artery disease and the acute coronary syndromes. N Engl J Med *326*(4):242–250.

References (cont.)

Ge J, Erbel R, Rupprecht HJ, Koch L, Kearney P, Gorge G, Haude M, Meyer J [1994]. Comparison of intravascular ultrasound and angiography in the assessment of myocardial bridging. Circulation *89*(4):1725–1732.

Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL Jr., Antman EM, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Russell RO, Smith SC Jr [2002]. ACC/AHA 2002 guideline update for exercise testing: a report of the American College of Cardiology/ American Heart Association Task Force on Practice Guidelines. Circulation *106*(14):1883–1892.

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

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.

Iyadurai SJP, Chung SS [2007]. Now-onset seizures in adults: possible association with consumption of popular energy drinks. Epilepsy & Behavior *10*(3):504–508.

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: November 2012.

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.

Kracoff OH, Ovsyshcher I, Gueron M [1987]. Malignant course of a benign anomaly: myocardial bridging. Chest *92*(6):1113–1115.

Kuehl K [2007]. Economic impact of the wellness fitness initiative. Presentation at the 2007 John P. Redmond Symposium in Chicago, IL on October 23, 2007.

Libby P [2008]. The pathogenesis, prevention, and treatment of atherosclerosis. 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. 1501–1509.

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.

Mohlenkamp S, Hort W, Junbo G, Erbel R [2002]. Update on myocardial bridging. Circulation *106*(20):2616–2622.

Morales A, Romanelli R, Boucek R [1980]. The mural left anterior descending coronary artery, strenuous exercise and sudden death. Circulation *62*(2):230–237.

References (cont.)

NFPA [2007a]. Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association. NFPA 1582.

NFPA [2007b]. Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association. NFPA 1500.

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

NHLBI [2012]. Who is at risk for coronary heart disease? National Heart, Lung, and Blood Institute. [http://www.nhlbi.nih.gov/health/health-topics/topics/cad/atrisk.html]. Date accessed: November 2012.

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.

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

Schwarz ER, Klues HG, Vom DJ, Klein I, Krebs W, Hanrath P [1996]. Functional, angiographic and intracoronary Doppler flow characteristics in symptomatic patients with myocardial bridging: Effect of short-term intravenous beta-blocker medication. J Am Coll Cardiol *27*(7):1637–1645.

Shah PK [1997]. Plaque disruption and coronary thrombosis: new insight into pathogenesis and prevention. Clin Cardiol *20*(11 Suppl2):II-38–44.

Soni MG, Carabin IG, Griffiths JC, Burdock GA [2004]. Safety of ephedra: lessons learned. Toxicology Letters *150*(1):97–110.

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.

Teragawa H, Fukuda Y, Matsuda K, Hirao H, Higashi Y, Yamagata T, Oshima T, Matsuura H, Chayama K [2003]. Myocardial bridging increases the risk of coronary spasm. Clin Cardiol *26*(8):377–383.

Theoharides TC [1997]. Sudden death of a healthy college student related to ephedrine toxicity from a ma huang-containing drink. J Clin Psy *17*(5):437–439.

USFA [2004]. Health and wellness guide. Emmitsburg, MD: Federal Emergency Management Agency; United States Fire Administration. Publication No. FA-267.

USPSTF [2004]. U.S. Prevention Services Task Force. Screening for coronary heart disease: Recommendation Statement. Ann Intern Med *140*(7):569–572.

van Brussel BL, van Tellingen C, Ernst MP, Plokker HW [1984]. Myocardial bridging: a cause of myocardial infarction? Int J Cardiol *6*(1):78–82.

References (cont.)

Vasan RS, Bahl VK, Rajani M [1989]. Myocardial infarction associated with a myocardial bridge. Int J Cardiol *25*(2):240–241.

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), 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

- Myocardial bridging of the left anterior descending coronary artery
- Coronary artery atherosclerosis
  - Moderate (50%) focal narrowing of the left main and left anterior descending coronary arteries
  - Mild (25%) focal narrowing of the right coronary artery
  - Mild (25%) focal narrowing of the circumflex coronary artery
- Normal cardiac valves
- No evidence of a coronary artery thrombus (blood clot)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative