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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation *May 2010*

Captain Suffers Fatal Heart Attack While Participating in Fire Department Physical Fitness Program – Mississippi

SUMMARY

On October 21, 2009, a 54-year-old male career Captain was jogging alone on a paved trail behind his fire station as a component of the Fire Department's (FD) physical fitness program. The Captain was last seen by crew members at approximately 1630 hours. Approximately 35 minutes later, a civilian found the Captain lying on the trail, unresponsive, and not breathing. The civilian called 911, and a police officer was dispatched. Crew members heard the dispatch and responded to the trail. They found the Captain unresponsive, without a pulse, and not breathing. Crew members began cardiopulmonary resuscitation (CPR) while requesting an ambulance. Despite CPR and advanced life support administered on scene, en route to the hospital's emergency department (ED), and in the ED, the Captain died. The autopsy, completed by the medical examiner, listed "severe coronary artery atherosclerosis with acute plaque change: hemorrhage into an atherosclerotic plaque and rupture of the plaque" as the cause of death. Given the Captain's underlying heart disease, NIOSH investigators conclude that the physical stress of jogging probably triggered a fatal heart attack due to the acute plaque rupture of his right coronary artery.

The NIOSH investigators offer the following recommendations to address general safety and health issues. Had the first recommended measure been in place prior to the Captain's collapse, perhaps his underlying coronary artery disease would have been identified, he would have been referred for treatment, and his sudden cardiac death may have been prevented. The third recommendation may have hastened emergency treatment after the Captain's collapse.

- Ensure fire fighters over the age of 45 with two or more risk factors for CAD have a maximal (symptom-limiting) exercise stress test (EST).
- 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 NFPA 1582.
- Ensure on-duty fire fighters exercise in pairs or within viewing distance of another crew member.

INTRODUCTION & METHODS

On October 21, 2009, a 54-year-old male career Captain suffered sudden cardiac death while exercising during his shift. Despite CPR and advanced life support administered by crew members, the ambulance paramedics, and personnel in the hospital's ED, the Captain died. The United States Fire Administration notified NIOSH of this fatality on October 22, 2009. NIOSH contacted the affected FD to gather additional information on October 26, 2009, and on November 10, 2009, to initiate the investigation. On November 16, 2009, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Mississippi to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Training Officer
- Crew members
- The Captain's spouse

NIOSH personnel reviewed the following documents:

- FD policies and operating guidelines
- FD training records
- FD annual report for 2008
- FD incident report
- Police report
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Autopsy report
- Primary care provider medical records

RESULTS OF INVESTIGATION

Incident. On October 20, 2009, the Captain arrived for duty at Station 3 at approximately 1700 hours for his 24-hour shift. No emergency calls came in during the Captain's shift. At approximately 1630 hours, the Captain left Station 3 to jog on a paved trail in a public park approximately 200 feet behind the fire station. The Captain had been jogging on-duty since the FD began its physical fitness program 12 years ago. He typically jogged at a pace of 5–6 miles per hour (mph) (10–12 minutes to run 1 mile). The temperature was 71 degrees Fahrenheit with 71% relative humidity [NOAA 2009], and the Captain was wearing tennis shoes and an FD-issued T-shirt and shorts. The paved trail covered a little more than one quarter of a mile with some slight uphill and downhill areas.

At approximately 1703 hours, 33 minutes after the Captain left the station, a civilian walking in the park noticed a person lying on the trail. She found him unresponsive and not breathing. She called 911, and a police officer was dispatched. The FD Safety Officer heard the police dispatch and telephoned Station 3 to

alert them of the call; the Captain's crew members (Engine 3) responded to the area, arriving just ahead of the police.

Crew members found the Captain unresponsive, not breathing, and without a pulse. Dispatch was notified, and an ambulance and the FD (Rescue 1, Deputy Chief, and Fire Chief) were dispatched at 1719 hours. Crew members began CPR and retrieved an automated external defibrillator (AED) and oxygen equipment. The AED advised not to shock. Rescue 1 paramedics arrived at 1724 hours and began advanced life support including cardiac monitoring, intravenous (IV) line placement, and intubation. Proper intubation placement was confirmed by breath sounds and verified by capnography [AHA 2000]. The cardiac monitor revealed asystole (no heart beat), and IV medications were administered. The ambulance arrived on the scene at 1729 hours, and advanced life support treatment continued. The Captain was moved to the ambulance, which departed at 1739 hours en route to the hospital's ED.

The ambulance arrived at the hospital's ED at 1751 hours, at least 45 minutes after his collapse. Inside the ED, resuscitation efforts continued without change in the Captain's clinical condition. At 1800 hours, the Captain was pronounced dead by the attending physician, and resuscitation efforts were stopped.

Medical Findings. The death certificate and the autopsy report, both completed by the medical examiner, listed "complication of coronary artery atherosclerosis" as the cause of death. Autopsy findings showed severe narrowing of all three major coronary arteries, and an acute ruptured plaque completely occluding the right coronary artery. More complete autopsy findings are listed in Appendix A.

The Captain had a history of high blood cholesterol although the exact date of diagnosis was not available to NIOSH investigators. He was prescribed a statin, a cholesterol-lowering medication, in 2008; his cholesterol levels in October 2009 remained elevated. The Captain also had a history of high blood pressure (hypertension). The exact date of diagnosis was not available to NIOSH investigators. He was prescribed an antihypertensive medication, and his blood pressure reading was slightly elevated in October 2009.

As part of the FD annual medical evaluation, the Captain had a "Graded Exercise Stress Test (GXT) - Bicycle Ergometer" test in 2008 and 2009. (These tests had been performed since 1994.) The FD contractor performing this test had subjects pedal on the bicycle at 50 revolutions per minute. Pedal resistance was increased by 0.5 kilogram (kg) each minute until the subjects reached 85% of their maximal age-predicted heart rate, at which point the test was stopped. The contractor used a 12-lead electrocardiogram (EKG) to monitor the subjects' heart rate, and once the test was completed, to look for signs of cardiac ischemia. If ischemia was found, subjects were referred to their primary care physician for follow-up. In addition to pulse, blood pressure was measured every minute during the test and for 5 minutes during the test recovery phase.

In 2008, the Captain exercised for 4 minutes on the GXT Bicycle Ergometer when he reached 84% of his maximum heart rate, and the test was stopped. He had no chest pain, normal blood pressure response, and no ischemic changes on his EKG. Given his weight of 175 pounds, his estimated aerobic capacity (VO_2) was 20.6 milliliters per kilogram per minute (mL/kg/min) or 5.9 metabolic equivalents (METS) [ACSM 2007]. In 2009, the Captain exercised for 5 minutes when he reached 87% of this maximum heart rate, and the test was stopped. Again, he had no chest pain, normal blood pressure response, and no ischemic changes on his EKG. At this time his weight was 167 pounds, and his estimated VO_2 was 24.8 mL/kg/min or 7.1 METS [ACSM 2007]. In 2008 and 2009, the Captain was "medically cleared under 29 CFR 1910.156, 29 CFR 1910.134, 29 CFR 1910.120 regulations, and NFPA 1582 guidelines" [NFPA 2007a].

Prior to this incident the Captain never reported angina; in June 2008, he had episodes of heartburn that were unrelieved by antacid medications. A scope (esophagogastroduodenoscopy) diagnosed nonerosive gastritis and gastroesphogeal reflux disease (GERD). The symptoms eventually resolved with Nexium®, a medication that reduces stomach acid secretions.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the career FD consisted of three fire stations with 49 uniformed personnel. It served a population of 27,000 residents in a geographic area of 43 square miles.

Employment and Training. The FD requires all new fire fighter applicants to be 21 years of age, have a valid State driver's license, pass a background check, pass a drug screen, pass a physical ability entrance test (PAET) (Appendix B), pass a general aptitude test, and complete an oral interview by a panel that includes FD members and a police officer prior to being ranked. The candidate must then pass a preplacement medical evaluation and a psychological evaluation prior to being hired. New hires are assigned to day shift during the 8–12 week minimum standards training program for fire fighters. Once the member passes this training program, he/she is placed on a regular duty shift of 24 hours on duty/48 hours off duty, from 1700 hours to 1700 hours. The member then attends the 6-week State Fire Academy to be trained to the NFPA 1001 Fire Fighter I and II level. The member receives emergency medical technician (EMT) training at a local community college. The State requires career fire fighter candidates to meet the State Minimum Standards and Certification Board guideline, which is the National Fire Protection Association (NFPA) 1001, *Standard for Fire Fighter Professional Qualifications* [NFPA 2008]. The Captain was certified as a Fire Fighter II, Driver/Operator, EMT, Fire Officer

II, HazMat Technician, Fire Service Instructor II, Fire Inspector, Technical Rescue Specialist, and Incident Safety Officer. He had 22 years of fire fighting experience.

Preplacement Medical Evaluations. The FD requires a preplacement medical evaluation for all fire fighter candidates regardless of age. This evaluation includes the following components:

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

These evaluations are performed by a physician contracted with the City. Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for wearing a respirator and fire fighting duties and forwards this decision to the City's personnel director and the FD. The Captain had a preplacement medical evaluation in 1987.

Periodic Medical Evaluations. Annual medical evaluations have been required for all members since 1998. This evaluation includes the following components:

- Complete medical history
- Physical examination (including vital signs)
- Complete blood count with lipid panel
- Pulmonary function test
- Audiogram
- Vision screen
- Urinalysis
- Resting EKG
- Submaximal cycle ergometer test (described in detail on page 4)

These evaluations are performed by a mobile medical clinic. Once this evaluation is complete, a physician traveling with the clinic determines medical clearance for respirator use and fire fighting duties, and forwards this decision to the City's personnel director and the FD.

Return to duty clearance is required for duty-related injuries. The member's primary care physician provides the fire fighter clearance for duty based on NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2007a]. If members are off duty for 48 hours (2 shifts) continuously for an illness, medical clearance from their primary care physician is required.

Health and Wellness Programs. The FD has a mandatory wellness/fitness program; exercise (strength and aerobic) equipment is available in the fire stations. Health maintenance programs are available from the City. Self-contained breathing apparatus (SCBA) mask fit tests are performed annually. Semiannual physical ability tests are required for all fire fighters. Fire fighters must perform at least 20 sit-ups, 10 push-ups, and either run 1.5 miles within 16.5 minutes (VO2 of 35.7 mg/kg/min or 10 METs) or walk 3 miles within 45 minutes (VO2 of 14.2 mg/kg/min or 4 METs). The Captain's results are as follows:

DATE	SIT-UPS	PUSH-UPS	RUN
11-14-06	35	20	11:07
05-29-07	35	25	10:25
11-27-07	40	20	11:42
05-27-08	35	20	12:00
01-30-09	35	20	14:39
06-02-09	35	20	13:10

DISCUSSION

Atherosclerotic Cardiovascular Disease. In the United States, atherosclerotic coronary artery disease (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 over 45, male gender, family history of CAD, smoking, high blood cholesterol, high blood pressure, obesity/physical inactivity, and diabetes [AHA 2009]. The Captain had five of these risk factors (age over 45, male gender, family history of CAD, high blood cholesterol, and high blood pressure) and severe CAD on autopsy.

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. The Captain had an acute plaque rupture completely occluding his right coronary artery, establishing that he had an acute heart attack.

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 fire suppression and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The Captain had run an unknown number of laps around the jogging track. Assuming his typical pace of approximately 10 minutes per mile (the

pace required for the physical ability test), the Captain would have expended at least 10 METs in the 35 minutes he was unobserved, which is considered heavy physical activity [Ainsworth et al. 1993]. Given the Captain's underlying CAD, the strenuous physical activity probably triggered a heart attack resulting in his sudden cardiac death.

Left Ventricular Hypertrophy. The autopsy revealed left ventricular hypertrophy (LVH). LVH increases the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure, a heart valve problem, or chronic cardiac ischemia (coronary artery disease) [Siegel 1997]. The Captain's hypertension and chronic cardiac ischemia were most likely responsible for his LVH.

Occupational Medical Standards for Structural Firefighting. 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]. NFPA 1582 recommends that all fire fighters receive annual medical evaluations. As part of this medical evaluation, fire fighters should receive a submaximal stress EKG test (85% of the fire fighter's maximal heart rate) as a measure of aerobic capacity. For asymptomatic fire fighters over age 45 (55 for women) with two or more risk factors for CAD (e.g., the Captain), NFPA 1582 recommends a cardiology evaluation with a symptom limiting (maximal) imaging stress test. This recommendation is consistent with the recommendation of the American Heart Association and the American College of Cardiology (AHA/ACC) [Gibbons et al. 2002]. According to the records reviewed by the NIOSH investigator, neither a cardiology evaluation nor an imaging maximal stress test was recommended to the Captain by the FD contract clinic or the Captain's primary care physician. Either may have identified his underlying CAD, resulting in further evaluation and treatment and the likely prevention of his sudden cardiac death.

RECOMMENDATIONS

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had the first recommended measure been in place prior to the Captain's collapse, perhaps his underlying coronary artery disease could have been identified, he would have been referred for treatment, and his sudden cardiac death may have been prevented. The third recommendation may have hastened emergency treatment after the Captain's collapse.

Recommendation #1: Ensure fire fighters over the age of 45 with two or more risk factors for CAD have a maximal (symptom-limiting) exercise stress test (EST).

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 two or more CAD risk factors [IAFF,

IAFC 2008]. Although the Captain had a submaximal cycle ergometer test to measure his aerobic capacity, this test is not the same as the diagnostic exercise stress test recommended by NFPA 1582 or the ACC/AHA [Gibbons et al. 2002; NFPA 2007a]. The FD contract clinic and/or the Captain's primary care physician should have recommended a maximal EST because the Captain was over the age of 45 and had more than two CAD risk factors.

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 a physician who is officially responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty. The FD 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. The FD physician should also be familiar with the personal protective equipment the fire fighter wears during various types of emergency operations, and the medical guidance contained in NFPA 1582. If the FD does not have a physician on staff or on contract, the fire fighter's personal physician should be advised of these guidelines.

Recommendation #3: Ensure on-duty fire fighters exercise in pairs or within viewing distance of another crew member.

Members should exercise in pairs or at least within viewing distance of another crew member. If a medical emergency occurs, the other crew member can alert EMS or dispatch. Another option would be for exercising members to carry a PASS device and/or portable radio. PASS devices are portable, lightweight units that, when activated, emit a 95-decibel alarm. The device, which can be manually activated, automatically activates if no motion is detected for approximately 30 seconds [NFPA 2007b].

Portable radios have the advantage of allowing affected members to specify the problem and their exact location. The disadvantages are that a radio is a little larger and heavier, and a radio will not automatically alert anyone if the member suddenly collapses. At the time of this report, the FD requires members to carry portable radios that have a panic button.

REFERENCES

ACSM (American College of Sports Medicine) [2007]. Metabolic equations for gross VO2 in metric units. [http://www.acsm.org/AM/Template.cfm?Section=Exam_Information&Template=/CM/HTMLDisplay.cfm&ContentID=13024]. Date accessed: March 2010.

AHA [2000]. Advanced cardiovascular life support: section 3: adjuncts for oxygenation, ventilation, and airway control. Circ 102(8)(Suppl):I-95–I-104.

AHA [2009]. AHA scientific position, risk factors for coronary artery disease. Dallas, TX: American Heart Association [http://www.americanheart.org/presenter.jhtml?identifier=4726]. Date accessed: March 2010.

Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr., Montoye HJ, Sallis JF, Paffenbarger RS Jr. [1993]. Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc 25(1):71–80.

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.

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.

Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL 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 (Committee on Exercise Testing). [http://content.onlinejacc.org/cgi/content/short/40/8/1531]. Date accessed: March 2010.

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: March 2010.

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.

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 [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.

Mittleman MA, Maclure M, Tofler GH, Sherwood JB, Goldberg RJ, Muller JE [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Engl J Med 329(23):1677–1683.

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

NFPA [2007b]. Standard on personal alert safety systems (PASS). Quincy, MA: National Fire Protection Association. NFPA 1982.

NFPA [2008]. Standard for fire fighter professional qualifications. Quincy, MA: National Fire Protection Association. NFPA 1001.

NIOSH [2007]. NIOSH alert: preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2007-113.

NOAA [2009]. Quality controlled local climatological data; hourly observations table; Jackson International Airport, Jackson, MS. National Oceanic and Atmospheric Administration. [http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N]. Date accessed: December 2009.

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

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

Siscovick DS, Weiss NS, Fletcher RH, Lasky T [1984]. The incidence of primary cardiac arrest during vigorous exercise. N Engl J Med 311(14):874–877.

Tofler GH, Muller JE, Stone PH, Forman S, Solomon RE, Knatterud GL, Braunwald E [1992]. Modifiers of timing and possible triggers of acute myocardial infarction in the Thrombolysis in Myocardial Infarction Phase II (TIMI II) Study Group. J Am Coll Cardiol 20(5):1049–1055.

Willich SN, Lewis M, Lowel H, Arntz HR, Schubert F, Schroder R [1993]. Physical exertion as a trigger of acute myocardial infarction. N Engl J Med 329(23):1684–1690.

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

Appendix A

Autopsy Findings

- Severe atherosclerotic CAD
  - — Total (100%) focal narrowing of the right coronary artery
  - — Severe (80%) focal narrowing of the left anterior descending coronary artery
  - — Moderate (70%) focal narrowing of the circumflex coronary artery
  - — Acute myocardial infarction (heart attack) of the posterior wall due to acute plaque rupture in the right coronary artery
  - — Evidence of a separate posterior wall heart attack 10–14 days prior to his death
- Left ventricular hypertrophy (LVH)
  - — Left ventricular and interventricular septum walls thickened (2.0 cm, 1.7 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]
- Normal heart size (390 grams)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Negative blood tests for drugs and alcohol
- Final pathologic diagnosis: "severe coronary artery atherosclerosis with acute plaque change: hemorrhage into an atherosclerotic plaque and rupture of the plaque" as the cause of death

REFERENCES

Armstrong WF, Feigenbaum H [2001]. Echocardiography. In: Braunwald E, Zipes DP, Libby P, eds. Heart disease: a text of cardiovascular medicine. 6th ed. Vol. 1. Philadelphia, PA: W.B. Saunders Company, p. 167.

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

Silver MM, Silver MD [2001]. Examination of the heart and of cardiovascular specimens in surgical pathology. In: Silver MD, Gotlieb AI, Schoen FJ, eds. Cardiovascular pathology. 3rd ed. Philadelphia, PA: Churchill Livingstone, pp. 8–9.

Appendix B

Physical Ability Entrance Test

The fire fighter candidate must pass the following components within the time specified:

- 35 bent knee sit-ups in less than 2 minutes
- 65-foot ladder climb without stopping
- 50-foot rescue crawl while wearing a 50-pound vest
- Run 1.5 miles in less than 13 minutes