Fire Chief Suffers Sudden Cardiac Death at Structure Fire - Texas

Executive Summary

On April 21, 2014, a 52-year-old male volunteer fire chief ("Chief") responded to a single family dwelling fire at 2303 hours. Responding in the fire department's engine, the Chief arrived on scene at 2320 hours. The Chief was acting as incident commander and assisting fire fighters over the course of an hour, when the fire re-ignited. The Chief was pulling 300 feet of 3-inch supply line to the hydrant when he collapsed. A crew member found the Chief unresponsive with a fading pulse. Dispatch was notified as a deputy sheriff (on scene for traffic control) began cardiopulmonary resuscitation (CPR). An ambulance and a life flight helicopter responded and provided advanced life support (ALS) as the Chief was flown to the hospital's emergency department (ED). Despite CPR and ALS for over an hour at the scene, during transport, and in the ED, the Chief died. The death certificate, completed by the county assistant medical examiner listed "atherosclerotic and hypertensive cardiovascular disease" as the cause of death. The autopsy report by the forensic pathology fellow in the county's Institute of Forensic Services concurred, finding severe coronary heart disease (CHD), borderline cardiomegaly (enlarged heart), and left ventricular hypertrophy (LVH). Given the Chief's underlying CHD, NIOSH investigators concluded that responding to the structure fire, assisting with fire scene activities for over an hour, and the physical exertion of pulling the supply hoseline 300 feet probably triggered a fatal cardiac arrhythmia.

Key Recommendations

- *Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments, *to identify fire fighters at increased risk for coronary heart disease)*
- *Ensure exercise stress tests are performed on fire fighters at increased risk for CHD*
- *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 components of NFPA 1582.*

The following recommendations address general safety and health issues:

- *Phase in a mandatory comprehensive wellness and fitness program for fire fighters*
- *Perform a candidate physical performance (physical ability) evaluation for fire fighter candidates*
- *Provide fire fighters with medical clearance to wear a 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

On April 21, 2014, a 52-year-old male volunteer Chief suffered cardiac arrest at a structure fire. NIOSH contacted the affected fire department on April 29, 2014, to gather information and on July 31, 2014, to initiate the investigation. On August 6, 2014, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program travelled to Texas to investigate the incident.

During the investigation, NIOSH personnel interviewed the following people:

- County fire marshal
- Current fire chief
- Chief's spouse

NIOSH personnel reviewed the following documents:

- Fire department standard operating procedures
- Fire department annual report for 2013
- Emergency medical service (ambulance) report
- Life flight (helicopter) report
- Hospital ED report
- Death certificate
- Autopsy report
- Primary care physician records

Investigation

On April 21, 2014, at 2303 hours, the fire department was dispatched to a single family dwelling fire. The Chief responded from his home to the fire department in his privately owned vehicle then rode in the fire engine to the scene, arriving at about 2320 hours. Weather conditions included a temperature of 65 degrees Fahrenheit and relative humidity of 97% [NOAA 2014].

Upon arrival, the Chief found a heavily involved vacant residential structure fire. Over the course of approximately 60 minutes, fire fighters had extinguished the main body of fire. The Chief, still wearing street clothing, acted as incident commander and assisted fire scene operations by straightening hoselines and retrieving equipment including a ventilation fan that he carried to the front porch. As he attempted to start the ventilation fan, the remaining fire in the attic suddenly spread to the entire structure. The Chief and two crew members then pulled 300 feet of 3-inch supply hoseline from the engine to the hydrant. The dry hoseline weighed approximately 40 pounds per 50-foot section. The engine operator radioed the Chief to see if the hoseline was connected to the hydrant. The Chief did not reply. A few seconds later, a crew member found the Chief unresponsive at the hydrant with a fading pulse. At 0031 hours a deputy sheriff on scene began CPR as an ambulance and life flight helicopter were requested.

The ambulance arrived at 0042 hours to find the Chief in cardiac arrest with CPR in progress. Cardiac monitoring revealed asystole (no heart beat); CPR continued. The Chief was placed into the ambulance as an intravenous line was inserted, cardiac resuscitation medications were administered, and an intubation tube was placed with oxygen administered. Correct tube placement was verified by tube condensation, bilateral breath sounds, and capnography [Neumar 2010]. The ambulance departed the scene at 0109 hours en route to the landing zone, arriving at 0110 hours as the life flight helicopter landed. The Chief was moved into the helicopter where ALS continued. The helicopter departed the scene at 0117 hours. En route to the hospital's ED, cardiac monitoring revealed asystole, CPR continued, and the Chief's clinical status remained the same. The helicopter arrived at the hospital at 0134 hours, and the Chief was transferred to the ED. Inside the ED, ALS and CPR continued for 7 minutes when the Chief was pronounced dead by the attending physician; resuscitation efforts were discontinued.

Medical Findings

The death certificate, completed by the county assistant medical examiner, listed "atherosclerotic and hypertensive cardiovascular disease" as the cause of death. The autopsy report, completed by the forensic pathology fellow, also found severe coronary heart disease (CHD), borderline cardiomegaly, and LVH. Pertinent findings from the autopsy are listed in Appendix A. The Chief was potentially exposed to fire smoke during the exterior fire suppression efforts and did not wear SCBA. No carboxyhemoglobin levels were measured in the ED or at autopsy.

The Chief's risk factors for CHD included: age > 45, male gender, hypertension, hyperlipidemia, type II diabetes mellitus, and obesity. The Chief was being followed by his primary care physician for diabetes (diagnosed in 2000), hypertension (diagnosed prior to 2008), and hyperlipidemia (diagnosed in 2010). He was prescribed a lipid-lowering medication and three diabetes medications. His most recent primary care physician visit in January 2014 revealed a normal blood pressure of 120/80 millimeters of mercury; his latest lipid values (August 2013) included cholesterol of 178 milligrams per deciliter (mg/dL) (normal is 100–199), triglycerides of 238 mg/dL (normal is 0–149), high density lipoprotein (HDL) of 39 mg/dL (normal is >39), low density lipoprotein (LDL) of 91 mg/dL (normal is < 130), glucose of 156 mg/dL (normal is 65–99), and hemoglobin A1c of 8.9 (normal is <5.7). His lipid and glucose levels were not well controlled despite the daily regimen of medications. His physician recommended a weight loss program with regular exercise.

The Chief was 71 inches tall and weighed 245 pounds at his last primary care physician visit in January 2014, giving him a body mass index of 34.2 kilograms per meter squared. A body mass index > 30.0 kilograms per meter squared is considered obese [CDC 2014]. The Chief did not participate in an exercise program but had lost 40 pounds over the past 4 years. The Chief reported no cardiac signs or symptoms prior to this incident.

Fire Department

At the time of the NIOSH investigation, the fire department consisted of one fire station with 12 volunteer uniformed personnel serving 1,000 residents in a geographic area of 100 square miles. In 2013, the fire department responded to 50 calls.

Membership, Training, and Experience

The fire department requires new fire fighter applicants to be 18 years of age, have a valid state driver's license, and pass a vote by the fire department membership. The successful applicant must attend 4 hours training per month and 50% of the emergency responses and meetings during the 6-month probationary period. The Chief was trained as a fire fighter, fire officer, driver/operator, and hazardous materials technician. He had 36 years of fire fighting experience.

Preplacement and Annual Medical Evaluations/Return to Work Medical Evaluations

Neither preplacement nor annual medical evaluations are required by the fire department. Members injured on duty are evaluated by their primary care physician, but return to duty medical clearance is not required. Neither medical clearance to wear a respirator nor annual SCBA facepiece fit test is required.

Fitness/Wellness Programs

Physical agility tests are not required for candidates but are required annually for all emergency service district members. The fire department does not have a wellness/fitness program. Exercise equipment, however, is available in the fire station. The Chief did not use the exercise equipment at the fire station.

DISCUSSION

Sudden Cardiac Events

In the United States, atherosclerotic CHD 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 CHD, smoking, hypertension, high blood cholesterol, diabetes, and obesity/physical inactivity [Greenland et al. 2010; AHA 2014; NHLBI 2014]. The Chief had four modifiable CHD risk factors (high blood pressure, high blood cholesterol, diabetes, and obesity).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2013]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion. Heart attacks typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques [Libby 2013].

Establishing a recent (acute) heart attack requires any of the following: characteristic electrocardiography (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, the Chief did not have a heart rhythm to conduct an EKG, cardiac enzymes were not tested, and no coronary artery thrombus was identified at autopsy. Given that heart attacks can occur without a coronary thrombus, it is possible that the Chief had a heart attack [Davies 1992; Farb et al. 1995]. However, his lack of angina at the fire scene suggests a cardiac arrhythmia was the more likely cause of his sudden cardiac death, although diabetics have a higher risk of silent heart attacks [NHLBI 2011].

Primary Arrhythmia
Primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation) was probably responsible for the Chief’s sudden cardiac death. Risk factors for arrhythmias include cardiac disease, heart attack, sleep apnea, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [AHA 2012; Mayo Clinic 2014]. The Chief had undiagnosed CHD, cardiomegaly, and LVH in addition to type II diabetes mellitus and possible sleep apnea. He was referred for a sleep study but medical records provided to the NIOSH investigator suggested a sleep study was never performed.

Cardiomegaly/Left Ventricular Hypertrophy
On autopsy, the Chief was found to have LVH and a borderline cardiomegaly. These conditions increase 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 hypertension, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The Chief had both hypertension and undiagnosed cardiac ischemia.

Physiological Stress of Firefighting
In addition to medical conditions, sudden cardiac death has been linked to heavy physical exertion [Albert et al. 2000; Patterson et al. 2013]. Among fire fighters, sudden cardiac events 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’s activities at the fire scene would have expended about 8 metabolic equivalents (METs), which is considered moderate physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

In summary, NIOSH investigators conclude the Chief’s sudden cardiac death was probably due to an arrhythmia associated with his CHD. The arrhythmia could have been triggered by the physical exertion associated with his fire ground activities.

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 2013a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Chief's underlying CHD was not identified until after this incident. Recommendations on whether to screen asymptomatic individuals for CHD using exercise stress tests (EST) are varied. The following paragraphs summarize the positions of widely recognized organizations on this topic. Had an EST been performed, perhaps the Chief's CHD could have been identified, leading to further evaluation and treatment.

NFPA

NFPA 1582, a voluntary industry standard, recommends an EST performed "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2013a]. 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) EST as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (i.e., symptom-limiting) EST with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known CAD
- one 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). Given the Chief's age and modifiable risk factors (hypercholesterolemia, hypertension, and diabetes mellitus), NFPA 1582 would have recommended a symptom-limiting EST.

American College of Cardiology/American Heart Association (ACC/AHA)

The ACC/AHA has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA guideline states that the evidence to conduct stress tests in asymptomatic individuals 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 coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

Given the Chief's public safety position, the ACC/AHA criteria suggest an EST may have been appropriate for the Chief.

U.S. Department of Transportation
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% CHD event risk over the next 10 years

Given the Chief's history of diabetes mellitus, age, and multiple risk factors for CHD, the U.S. Department of Transportation would have recommended an EST for a commercial truck driver with a similar profile [Blumenthal et al. 2007].

U.S. Preventive Services Task Force (USPSTF)
The 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."

Diabetes Mellitus
NFPA 1582 provides guidance for fire department physicians to follow when treating diabetic fire fighters [NFPA 2013a]. The standard states that fire fighters with diabetes mellitus that is controlled by diet, exercise, or oral hypoglycemic agents should be restricted from duty unless the member meets all of the following criteria:

(1) If on oral hypoglycemic agents, has had no episodes of severe hypoglycemia (defined as requiring assistance of another in the preceding year)

(2) Has achieved a stable blood glucose as evidenced by HA_1C level less than 8 during the prior 3-month period

(3) Has a dilated retinal exam by a qualified ophthalmologist or optometrist that shows no higher grade of diabetic retinopathy than microaneurysms

(4) Has normal renal function on the basis of a calculated creatinine clearance greater than 60 milliliters per minute and absence of proteinuria

(5) Has no autonomic or peripheral neuropathy

(6) Has normal cardiac function without evidence of myocardial ischemia on cardiac stress testing (to at least 12 METs) by EKG and cardiac imaging [NFPA 2013a]

The Chief had diabetes mellitus, had not achieved the recommended HA_1C level, and had not performed an EST. Therefore, according to NFPA 1582, he should have been restricted from fire fighting duties.

Recommendations

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments*, to identify fire fighters at increased risk for CHD.

Discussion: 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 2013a]. 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 fire department comply with this recommendation. However, the fire department is not legally required to follow the NFPA standard or the Wellness/Fitness Initiative.

Applying this recommendation involves economic repercussions and may be particularly difficult for smaller fire departments to implement. However, it is likely to be cost-effective [Gaetano et al. 2007]. To overcome the financial obstacle of medical evaluations, the fire department 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, by personal insurance, by a physician volunteer, or paid for by the fire department, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the fire department, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Ensure exercise stress tests are performed on fire fighters at increased risk for CHD.

Discussion: 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 CHD risk factors [Gibbons et al. 2002; IAFF, IAFC 2008; NFPA 2013a]. The Chief was over the age of 45 and had persistent CHD risk factors. A symptom-limiting exercise stress test may have identified his more recent condition, possibly leading to further evaluation and treatment.

Recommendation #3: 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.

Discussion: 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* [IAFF, IAFC 2008; NFPA 2013a]. According to these guidelines, the fire department 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 fire department 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. It is unknown if this Chief's personal physician was aware of NFPA 1582.

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

Discussion: Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters*, the IAFF/IAFC *Fire Service Joint Labor Management Wellness/Fitness Initiative*, the National Volunteer Fire Council *Health and Wellness Guide*, and in *Firefighter Fitness: A Health and Wellness Guide* [IAFF, IAFC 2008; NFPA 2008; USFA 2009; 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 [Pelletier 2009; Baicker et al. 2010]. Fire service health promotion programs have been shown to reduce coronary artery disease 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; Poston et al. 2013]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl et al. 2013].

The fire department does not offer a wellness/fitness program but exercise equipment is available in the fire station. Given the fire department’s structure, the National Volunteer Fire Council program would be applicable [USFA 2009], but NIOSH would recommend a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #5: Perform a candidate physical performance (physical ability) evaluation for fire fighter candidates.

Discussion: NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* requires the fire department to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2013b]. Members who engage in emergency operations must be qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2013b].

Recommendation #6: Provide fire fighters with medical clearance to wear SCBA as part of the fire department’s medical evaluation program.

Discussion: The Occupational Safety and Health Administration (OSHA) revised respiratory protection standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans [OSHA 2014]. Texas does not operate an OSHA-approved state plan; therefore, the fire department is not required to ensure all members have been medically cleared to wear an SCBA. However, NIOSH investigators recommend voluntary compliance with this recommendation to improve fire fighter health and safety.

Recommendation #7: Conduct annual respirator fit testing.

Discussion: 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]. Therefore, each member should have his or her own SCBA facepiece, or the fire department would have to ensure enough facepieces of each size were made available on each fire apparatus. As mentioned previously, Texas does not operate an OSHA-approved state plan; therefore, the fire department is not required to follow OSHA standards [OSHA 2014]. Nevertheless, NIOSH investigators recommend voluntary compliance with this standard to ensure proper fitting personal protective equipment to improve safety and health.

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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) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Health, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Disclaimer

Appendix A
Autopsy Findings

- Heart disease
  - Borderline cardiomegaly (enlarged heart): heart weighed 525 grams (g) (predicted normal weight is 410 g (ranges between 312 g and 543 g as a function of sex, age, and body weight) [Silver and Silver 2001]
  - Coronary artery atherosclerosis
    - Severe (70%) focal narrowing of the left main coronary artery
    - Moderate (50%) focal narrowing of the proximal left anterior descending coronary artery
    - Severe (70%) focal narrowing of the mid left anterior descending coronary artery
    - Severe (99%) focal narrowing of the distal left anterior descending coronary artery
    - Severe (80%) focal narrowing of the left circumflex coronary artery
    - Severe (99%) focal narrowing of the right coronary artery
    - No evidence of recent coronary artery thrombus (blood clot)
  - Hypertensive cardiovascular disease
  - Concentric left ventricular hypertrophy
      - Left ventricle and septum thickened at 1.8 centimeter [cm] (normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997])
    - Microscopic: myocyte hypertrophy, perivascular and interstitial fibrosis
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for illicit drugs and alcohol were negative
- Blood tests for carbon monoxide poisoning (carboxyhemoglobin) were not conducted

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