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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 2009

Fire Fighter Suffers Fatal Heart Attack While Fighting Residential Fire – New Jersey

SUMMARY

On March 9, 2008, a 62-year-old male volunteer fire fighter (FF) was dispatched to a residential fire. On-scene, he assisted crew members in pulling 200 feet of uncharged 1¾-inch hoseline while wearing full turnout gear and self-contained breathing apparatus (SCBA) and carrying a 10-pound flat-head axe. The FF used the axe to strike the front door to gain entry. Once inside, the hoseline was charged, and the FF and two crew members crawled through the dwelling to locate the fire. The fire was extinguished shortly thereafter, and the FF and crew members checked void spaces for hidden fire. Finding none, the crew began to ventilate by opening windows in adjacent rooms. Suddenly, the FF collapsed. Crew members called a mayday and pulled the FF outside where the on-scene ambulance crew began its assessment. Finding the FF unresponsive, without a pulse, and not breathing, the crew began cardiopulmonary resuscitation (CPR). Despite CPR and advanced life support administered on-scene, en route to the hospital, and at the hospital, the FF died. The death certificate, completed by the township registrar, and the autopsy, completed by the assistant state medical examiner, listed "atherosclerotic and hypertensive cardiovascular disease" as the cause of death. Given the FF's underlying atherosclerotic coronary artery disease (CAD), the stressful environmental conditions and the physical stress of performing fire fighting training duties triggered a heart attack or a cardiac arrhythmia, resulting in his sudden cardiac death.

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the FF's collapse, his sudden cardiac death may have been prevented.

- ***Provide preplacement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.***
- ***Conduct symptom-limiting exercise stress tests on some fire fighters based on their risk for coronary heart disease.***
- ***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.***
- ***Phase in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.***
- ***Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the Fire Depart-***

ment's annual medical evaluation program.

- ***Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.***

INTRODUCTION & METHODS

On March 9, 2008, a 62-year-old male volunteer FF suffered sudden cardiac death after performing forcible entry, fire suppression, and ventilation at a residential fire. Despite CPR and advanced life support administered by crew members, the ambulance crew, paramedics, and personnel in the hospital's emergency department, the FF died. The United States Fire Administration notified NIOSH of this fatality on March 10, 2008. NIOSH contacted the affected Fire Department to gather additional information on March 19, 2008, and on November 14, 2008, to initiate the investigation. On November 24, 2008, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to New Jersey to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Assistant Chief
- Training Captain
- Township Fire Marshal
- Family members of the FF

NIOSH personnel reviewed the following documents:

- Fire Department policies and operating guidelines
- Fire Department training records
- Fire Department annual report for 2007
- Fire Department incident report
- Police report
- Witness statements
- Fire Department medical evaluation protocols
- Emergency medical service (ambulance) incident report
- Paramedic incident report
- Hospital emergency department records
- Death certificate
- Autopsy report
- Primary care provider medical records

RESULTS OF INVESTIGATION

Incident. On March 9, 2008, the Fire Department (Companies 1, 2, and 4), an ambulance, and a police officer were dispatched to a residential fire at 1450 hours. Engine 1 (apparatus operator, lieutenant, and four fire fighters, including the FF), responded, arriving at 1453 hours. Fire fighters found a ranch-style single family dwelling of ordinary construction, measuring 1,300 square feet. White smoke was emitting from the eaves on the "D" side, and darker smoke was emitting from the attic vent. Other companies began to arrive at this time (approximately 1454 hours).

The FF and two crew members, wearing full turnout gear and SCBA, pulled 200 feet of uncharged 1¾-inch hoseline to the front door of the residence. The FF, also carrying a 10-pound flat-head axe, gained forcible entry. Once the hoseline was charged, the FF and crew members advanced the hoseline into the residence. They crawled into the residence due to the intense heat and thick smoke. They crawled

through the residence where they found fire in the area of the kitchen. They extinguished the fire in about 10 minutes.

The FF and his crew members then searched for fire spread in void spaces and hidden spaces, including the attic. Finding none, the crew began horizontal ventilation by opening windows in adjacent rooms. After being on scene approximately 17 minutes, the FF suddenly collapsed.

A mayday call was radioed, and the FF was pulled from the dwelling. The ambulance crew (composed of two emergency medical technicians) responded to the porch area, began their assessment, and requested that the police officer bring oxygen equipment from his cruiser. The ambulance crew found the FF unresponsive, with no pulse, and not breathing. They began CPR as oxygen was administered. The police officer then retrieved an automated external defibrillator (AED) from his cruiser. The AED was applied, and two shocks were delivered with no change in the FF's clinical condition. The FF was placed into the ambulance, which departed the scene at 1519 hours en route to the hospital's emergency department. En route a paramedic unit met the ambulance (1529 hours) and took over patient care.

Paramedics assessed the FF, finding him unresponsive, without a pulse, not breathing, and with CPR in progress. He was intubated with proper tube placement determined by bilateral breath sounds. Secondary technology tests recommended by the American Heart Association were not performed [AHA 2000]. A cardiac monitor was applied, revealing asystole. An intravenous line was placed and cardiac resuscitation medications were administered. The ambulance continued to the hospital as advanced life support and CPR continued with no change in the FF's condition. The ambulance arrived at the hospital at 1558 hours.

Inside the emergency department, a heart rhythm and pulse returned for about 10 minutes, allowing a 12-lead electrocardiogram (EKG) to be conducted. The EKG revealed atrial fibrillation with a rapid ventricular response at 100 beats per minute. Marked ST segment elevation in the inferior leads (II, III, F) confirmed an acute heart attack. The EKG also revealed reciprocal changes (ST segment depression) in the FF's precordial leads (V2-V5). Despite this heart rhythm and pulse, the FF could not maintain a blood pressure, and he was not stable enough to undergo cardiac catheterization. Resuscitation efforts continued until 1710 hours, when the FF was pronounced dead by the attending physician.

Medical Findings. The death certificate, completed by the township registrar, and the autopsy, completed by the assistant state medical examiner, listed "atherosclerotic and hypertensive cardiovascular disease" as the cause of death. Pertinent findings from the autopsy are listed in Appendix A.

The FF was 65 inches tall and weighed 171 pounds, giving him a body mass index (BMI) of 28.5. A BMI of 25.0 to 29.9 kilograms per meters squared is considered overweight [CDC 2008]. The FF's risk factors for CAD included male gender, age over 45, high blood pressure, high cholesterol, and smoking. In 1985, the FF suffered a silent heart attack (diagnosed by EKG changes). In 2003, the FF was diagnosed with chronic obstructive pulmonary disease, hyperlipidemia, and hypertension. Lipid-lowering and antihypertensive blood-pressure lowering medications were prescribed. In 2004, his primary care physician recommended an imaging cardiac stress test (cardiolite), but it appears this test was not performed. In 2005, a second lipid-lowering medication was added to his prescribed medications followed by a second antihypertensive medication in 2006. In 2007, this second antihypertensive medica-

tion was discontinued but a third lipid-lowering medication was added. His blood pressure and blood lipids remained under good control with the medications. A 2007 visit to his primary care physician revealed clear, but decreased, lung sounds. He was referred to a cardiologist in 3 months for a carotid ultrasound (March 10, 2008) and a stress test (March 17, 2008), but the FF died prior to the appointments.

The FF had not reported heart-related symptoms (chest pain, chest pressure, angina, shortness of breath on exertion, etc.) to his physicians, his family, or the Fire Department. On the day prior to this incident, the FF carried wood into his home for the fireplace and performed odd jobs around the house.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the volunteer Fire Department consisted of one fire station with 32 uniformed personnel that served a population of 2,500 residents in a geographic area of 15 square miles.

In 2007, the Fire Department responded to 157 calls: 30 fires, 19 hazardous condition calls, 5 emergency medical calls, 3 overpressure/rupture/explosion/overheat calls, 75 false alarms, 13 good intent calls, 9 service calls, and 3 severe weather calls.

Membership and Training. The Fire Department requires all new fire fighter applicants to be 18 years of age, have a valid state driver's license, pass a preplacement medical evaluation (described below), and obtain a background check prior to being selected for membership. New members are placed on probation for 6 months and must attend training. New members are placed in the Fire Fighter 1 program at the county fire training academy. Members must complete the program within 1 year of joining the Fire Department. The State requires initial Fire Fighter I certification but no annual recertification. The FF, a former Fire Chief, was certified as a Fire Officer I, Fire Fighter I, Driver/Operator, Rescue, Extrication, HazMat Awareness, and had 31 years of fire fighting experience.

Preplacement Medical Evaluation. The Fire Department currently requires a preplacement medical evaluation for all new members, regardless of age. Components of this evaluation are determined by the Fire Department. Components of this evaluation are listed below:

- History
- Vital signs
- Physical examination
- Vision screen
- Audiogram
- Pulmonary function test
- OSHA respirator clearance

These evaluations are performed by a city-contracted physician, who determines medical clearance for firefighting duties.

Periodic Medical Evaluation. Periodic (annual) medical evaluations are not currently required by the Fire Department. However, the Fire Department will begin a periodic medical evaluation program later in 2009, pending budgetary allowance from the township.

An annual SCBA facepiece fit test is required for interior structural fire fighters. Members injured on duty must be evaluated by their primary care physician and give the results to the city Fire Commissioner, who makes the final determination regarding return to duty.

Health and Wellness Programs. The Fire Department does not have a wellness/fitness program, and no exercise (strength and aerobic) equipment is available in the fire station. Health maintenance programs are not available from the city. The Fire Department will begin an annual physical ability test in 2009 as part of its training program. Members who do not pass this test will be placed on restricted duty until they can pass the test. Members who cannot pass the test are assigned duties that do not involve fighting fires.

DISCUSSION

In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age over 45, male gender, family history of CAD, smoking, high blood cholesterol, high blood pressure, obesity/physical inactivity, and diabetes [AHA 2008]. The FF had five of these risk factors (age over 45, male gender, smoking, high blood cholesterol, and high blood pressure) and significant atherosclerotic 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 FF had autopsy findings consistent with an old heart attack (the silent heart attack in 1985) and both EKG and autopsy findings that confirmed a recent heart attack.

Establishing the occurrence of a recent heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In the FF's case, the EKG performed in the hospital confirmed the occurrence of an acute (abrupt onset) heart attack.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks [Siscovick et al. 1984; Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993]. 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 FF had responded to the structure fire and, while wearing full turnout gear and SCBA, helped pull 200 feet of uncharged 1¾-inch hoseline to the front door of the residence. The FF, also carrying a 10-pound flat-head axe, gained forcible entry. The FF then advanced a charged hoseline as he crawled through the dwelling. These activities expended at least 10 metabolic equivalents (METs), which is considered moderate to heavy physical activity [Gledhill and Jamnik 1992]. Given the FF's underlying CAD, the physical stress of conducting fire suppression duties probably triggered his heart attack, resulting in his 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 NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides medical requirements for candidates and current fire fighters.

NFPA 1582 considers CAD a Category A condition for candidates, that is, "a medical condi-

tion that will preclude a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the member or others" [NFPA 2007a]. For members, the standard states that CAD compromises a member's ability to safely perform many of the essential job tasks of structural firefighting, specifically wearing SCBA and advancing water-filled hoselines [NFPA 2007a]. The standard states that the physician shall report the applicable job limitations to the fire department if any one of the following is present:

1. Current angina pectoris even if relieved by medication
2. Persistent significant stenosis in any coronary artery (greater than 70% lumen diameter narrowing) following treatment
3. Lower than normal left ventricular ejection fraction as measured by radionuclide scan, contrast ventriculography, or echocardiography
4. Maximal exercise tolerance of less than 42 milliliters of oxygen per minute per kilogram or less than 12 METs
5. Exercise-induced ischemia or ventricular arrhythmias observed by radionuclide stress test during an evaluation reaching at least a 12-MET workload
6. History of myocardial infarction, angina, or coronary artery disease with persistence of modifiable risk factor(s) for acute coronary plaque rupture (e.g., tobacco use, hypertension despite treatment or hypercholesterolemia with cholesterol greater than or equal to 180, or low density lipoproteins greater than or equal to 100 despite treatment, or glycosylated hemoglobin greater than 7 despite exercise and/or weight reduction) [NFPA 2007a]

Given the FF's silent heart attack in 1985 (confirming his CAD), he should have had a subsequent fire fighter fitness for duty medical evaluation. The heart attack and his persistent smoking and hyperlipidemia indicate he should have been restricted from full fire suppression duties.

Screening Tests for Cardiac Disease – Stress Tests. Although stress testing asymptomatic individuals for CAD is somewhat controversial, it is recommended for a 62-year-old male with five risk factors for CAD [Gibbons et al. 2002; Blumenthal et al. 2007; NFPA 2007a]. A stress test was recommended to the FF in 2004 by his primary care physician, but medical records suggested the test was never performed. According to NFPA 1582, the FF should not only have had an imaging stress test, but these tests should have been occurring on a regular basis. If a recent stress test had been performed, perhaps the FF's worsening cardiac condition could have been identified, and he would have been referred for further evaluation and treatment. The FF had regular primary care physician visits and a stress test was scheduled, but the FF died eight days prior to the test.

RECOMMENDATIONS

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the FF's collapse, his sudden cardiac death may have been prevented.

Recommendation #1: Provide preplacement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform duties without present-

ing a significant risk to the safety and health of themselves or others.

Guidance regarding the content and frequency of these 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 2000]. However, the Fire Department is not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [NFPA 2007b; USFA 2004].

To overcome the financial obstacle, 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 EMTs from the local emergency medical 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 Fire Department. Sharing the financial responsibility for these evaluations between fire fighters, the Fire Department, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Conduct symptom-limiting exercise stress tests on some fire fighters based on their risk for coronary heart disease.

Although conducting exercise stress tests on asymptomatic fire fighters is somewhat controversial, the NFPA, the IAFF/IAFC, and the ACC/AHA all recommend stress tests for fire fighters with multiple CAD risk factors [Gibbons et al. 2002; IAFF, IAFC 2000; NFPA 2007a]. The exercise stress test could be conducted by the fire fighter's personal physician or the city contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the city physician, who should be responsible for decisions regarding medical clearance for firefighting duties.

Recommendation #3: 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.

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 2000]. 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 as required by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2007b]. The physician should review job descriptions and essential job tasks required for all Fire Department positions and ranks, in order 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.

Recommendation #4: Phase in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the National Volunteer Fire Council (NVFC)'s Health and Wellness Guide [IAFF, IAFC 2000; USFA 2004; NFPA 2008]. 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 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD 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 recent study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007].

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

Recommendation #5: Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.

NFPA 1500 recommends that Fire Department members who engage in emergency operations be annually evaluated and certified by the Fire Department as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007b]. One model currently in use in Kansas City, Kansas, incorporates the physical ability evaluation into the training program. Each task may or may not be a timed event; however, each fire fighter must be capable of performing the tasks to be cleared for full fire fighting duties.

Recommendation #6: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the Fire Department's annual medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans [OSHA 2008]. New Jersey operates an OSHA-approved State plan for the public sector; therefore, public sector employers (including volunteer/paid fire departments) are required to comply with OSHA standards.

Recommendation #7: Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

To reduce the risk of improper intubation, the American Heart Association and the International Liaison Committee on Resuscitation published recommendations in the Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care [AHA 2000]. These guidelines recommend confirming tube placement by primary and secondary methods. Primary confirmation is the five-point auscultation: left and right anterior chest, left and right midaxillary, and over the stomach. Secondary confirmation requires a technology test, either an end-tidal carbon dioxide detector or an esophageal detector device. In this incident, the FF had bilateral breath sounds confirmed by auscultation and chest rise; however, secondary confirmation was not performed. We are not able to assess whether the endotracheal tube was misplaced or whether this issue contributed to the FF's death. We raise this only to ensure that future advanced life support resuscitation efforts follow AHA guidelines.

1Code of Federal Regulations. See CFR in references.

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INVESTIGATOR INFORMATION

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Mr. Tommy Baldwin (M.S.) 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 (M.D., M.P.H.) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Appendix A: Autopsy Findings

- Atherosclerotic and hypertensive CVD
  - — Moderate (85%) focal narrowing of the right coronary artery
  - — Minimal (20%) focal narrowing of the left anterior descending coronary artery
  - — No evidence of recent thrombus (blood clot in the coronary arteries)
  - — Areas of pallor (acute infarct) in the posterior septal to lateral left ventricle and in the apical left ventricle
  - — Myocardial scarring and thinning (suggestive of old/remote heart attack)

- Cardiomegaly (enlarged heart) with heart weighing 525 grams [g]. (Normal ranges between 261 g and 455 g as a function of gender, age, and body weight) [Silver and Silver 2001]
- Left ventricular hypertrophy
  - Left ventricle walls thickened (2.5 centimeters [cm]); normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]; normal by echocardiographic measurement is 0.6–1.1 cm) [Armstrong and Feigenbaum 2001]
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for carbon monoxide, cyanide, drugs, and alcohol were all negative

Microscopic examination of cardiac tissue revealed marked myocyte hypertrophy and interstitial fibrosis.

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