1000 FREDERICK LANE, MORGANTOWN, WV 26508 • 304.285.5916

42-Year-Career Firefighter-Paramedic Died at Home after Leaving Work Following Transient Chest Pain – Missouri

Executive Summary

A 42-year-old career firefighter-paramedic (FF-P) experienced transient episodes of not feeling well and chest pain during a regularly scheduled 48-hour on-duty shift. The FF-P performed an electrocardiogram (ECG) on himself on both days but did not see any evidence of ischemia. At approximately 1300 hours of the second shift day, he saw an orthopedic physician for a hand injury sustained at work the previous day. Following that appointment, he was told to go home and let the swelling in the hand resolve. The FF-P had no known communications after 1420 hours. On the following morning, the FF-P was found deceased in his bed.

The medical examiner's report listed the cause of death as acute coronary artery thrombus in the right coronary artery with probable dissection complicating severe coronary atherosclerosis. The autopsy also found left ventricular hypertrophy and hyperemic areas in the left ventricle. National Institute for Occupational Safety and Health (NIOSH) investigators concluded that the FF-P died of a myocardial infarction and that symptoms had developed while on duty.

Key Recommendations

NIOSH offers the following recommendations to reduce the risk of heart attacks and sudden cardiac arrest among firefighters at this and other fire departments across the country.

Key Recommendation 1: Ensure that all firefighters are aware of the warning signs of a cardiovascular event and the atypical ways it can present.

For further information, visit the program Web site at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Introduction

During his work shifts on June 06 and the morning of June 07, 2019, the firefighter-paramedic (FF-P) had reported episodes of chest pain and not feeling well, but declined his captain's suggestion to obtain emergent medical evaluation. The FF-P indicated that he would speak to the physician he was scheduled to see the afternoon of June 07, 2019, regarding a hand injury he sustained at work the previous days. Unfortunately, the FF-P did not tell the provider, an orthopedic specialist, about the chest pain that he had experienced and returned home on June 07 after this appointment. On June 08, 2019, at approximately 0933 hours, family members entered the FF-P home and found him deceased in bed. Emergency medical service (EMS) responded to the home and pronounced the FF-P dead at 0951 hours. In August 2020, a contractor for the NIOSH Fire Fighter Fatality Investigation and Prevention Program (the National Institute for Occupational Safety and Health [NIOSH] investigator) conducted a series of telephone interviews to investigate the incident.

During the investigation, the NIOSH investigator interviewed the following people:

- *Chief*
- *Assistant Chief*
- *Deputy Chief – medical officer*
- *Crew member who was working with FF-P*
- *Captain*
- *Orthopedic physician who evaluated the hand injury*

The NIOSH investigator reviewed the following documents:

- *FD records on events during the preceding 24-hour period*
- *FD incident reports for calls throughout the shift*
- *Emergency medical service (ambulance) report*
- *Occupational medical records*
- *Medical records from the orthopedic physician*
- *Autopsy report*

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Fire Department

At the time of the NIOSH investigation, the fire department (FD) consisted of 42 uniformed personnel operating out of 2 fire stations. It serves a population of approximately 22,000 in a geographic area of about 18 square miles.

Membership and Training

Applicants must be at least 18 years of age, have a high school diploma or equivalent, and possess a valid driver's license. Potential members complete an application and are interviewed by a board consisting of firefighters, officers, and the community. A background check is performed on those who pass the first interview, and those who pass the background check are interviewed by the fire chief. Contingent offers are made based on successful completion of a medical evaluation. The FF-P had been with the FD for 21 years.

Preplacement/Periodic/Return to Work Medical Evaluation

The FD requires preplacement medical evaluations for applicants and annual medical evaluations for incumbents. Components of the medical evaluation are the same for both groups except a urine drug screen is performed for candidates. Components of the medical evaluation are consistent with National Fire Protection Association (NFPA) 1582 and include the following:

- *Complete medical history*
- *Electrocardiogram (ECG)*
- *Complete blood count*
- *Urinalysis*
- *Urine drug screen (candidates only)*
- *Audiogram*
- *Vision test*
- *Respirator use questionnaire*
- *Spirometry*
- *Exercise stress test*
- *Chest X-ray*

Firefighters must be medically cleared by their treating physician for return to work following a serious injury or illness by the treating physician.

Wellness/Fitness Programs

The Fire Department has a fitness program that is part of its collective bargaining contract that requires participation in physical fitness training and provides time for it on duty days. The FF-P reportedly

worked out with his crew on an intermittent basis, going through periods where he emphasized resistance training and periods where he did minimal exercise.

Investigation

On June 06, 2019, at 0700 hours, a 42-year-old career FF-P began his regularly scheduled 48-hour shift. He was the company officer (acting captain) of the engine that day. The engine responded to a fire alarm sounding call at 1115 hours. During this call, firefighters wore full-turnout gear and searched the structure for hazards before resetting the alarm. This incident was resolved and the engine crew returned to station. At 1215 hours, as he was climbing onto the fire engine for an animal rescue call, the FF-P felt a "pop" in his hand. The call did not require any action from the engine crew.

Around 1245 hours, while the crew was eating lunch, the FF-P went to the bay and retrieved an ECG from the ambulance and preformed a 12-lead ECG on himself. He called another FF to review the ECG with him, but neither of them saw any ECG abnormalities beyond sinus tachycardia. The FF-P explained that before lunch he had chest pain that radiated to the jaw and then disappeared. The other FF suggested going to hospital to get checked, but the FF-P declined. He indicated that the chest pain was gone, he had just passed his stress test during his annual medical exam in March and was simply checking the ECG because the sensation was so curious. After their conversation was interrupted, there was no further reports of chest pain and they did not discuss further. At 1641 hours, the engine responded to a medical call for a stroke and assisted EMS with patient care. On return from the medical call, the remainder of the crews evening at the fire station was uneventful.

On June 07, 2019, at 0613 hours, the FF-P and his crew responded to a medical call for a person with a stroke who was wedged in the bathroom. At 0728 hours the company responded to a report of a gas line being struck, resulting in free-flowing gas. The FF-P assisted in searching approximately 4–5 homes adjacent to the gas leak and assessing gas levels in homes using a four-gas meter. At the time of dispatch for the gas leak, it was already warm and humid; (approximately 80°F with 67% relative humidity [RH] [Weather Underground]), and the FF-P was wearing bunker gear.

Around 0900 hours, the FF-P and crew began departmental training with thermal imaging cameras in an indoor air-conditioned training center. At about 1030 hours, the FF-P began feeling ill and experienced chest pain, and without telling others, he left training and went to the ambulance bay to have paramedics at the station run an ECG. As the rest of his crew was getting ready to leave training, the captain asked where the FF-P was, and he was told that he was in the ambulance bay. The captain quickly went to check on the FF-P, who told him he had had chest pain that was radiating to his neck both this morning and yesterday. He stated further that the symptoms were now gone and he was 100% okay, and that he just wanted to have the paramedics look at his ECG. The paramedics reviewed the ECG but could not identify any abnormalities. The captain urged the FF-P to go to the hospital to get a complete evaluation, but he refused. The FF-P told the captain that he had just passed his exercise stress test and that he had a doctor's appointment after lunch for his hand injury and that he would get his symptoms checked at that appointment. The captain told the FF-P he could not respond to a call until he had a medical evaluation of this chest pain. They left for their home station and stopped at the grocery store for food.

The FF-P's hand was swollen from the injury he sustained the previous day. Because the swelling was significant enough to prevent him from donning his gloves, he had an appointment to have this injury

evaluated by an orthopedic physician contracted by the city's Worker's Compensation department at 1300 hours on June 7, 2019. An X-ray of his hand obtained during the visit did not show a fracture, so the physician prescribed over-the-counter nonsteroidal anti-inflammatory medication and sent the FF-P home with instructions on how to reduce the swelling. The FF-P was instructed to return for a follow-up evaluation of his hand before his next duty shift in four days. The FF-P did not discuss his chest pain with the orthopedic physician. During the visit, his pulse was 96 beats per minute (bpm) and his blood pressure was 144/96 millimeters of mercury (mmHg).

At 1419 hours, the captain sent the FF-P a text message asking about the appointment, and he responded that he had sprained his hand and that they didn't find anything on his chest pain. A crew member sent a text to the FF-P at 1529 hours, but that text went unanswered. A family member was unable to reach the FF-P that evening or the following morning. On June 08, 2019, she went to his home at approximately 0933 hours and found him unresponsive on the bed. EMS was called to the home and the FF-P was pronounced dead by the responding paramedic at 0951.

Medical Findings

The medical examiner's report identified the cause of death as acute coronary thrombus with probable dissection complicating severe coronary atherosclerosis. There was severe atherosclerosis in the proximal portion of the right coronary artery reducing patent vessel area by 90%. In addition, further down the right coronary artery there was a blood clot that nearly blocked the entire vessel with hemorrhage into the epicardial fat tissue around it which represented a probable dissection. There was atherosclerosis in the left main coronary artery resulting in 75% blockage of the vessel interior. The heart weighed 510 grams and the medical examiner noted left ventricular hypertrophy (1.5 centimeters [cm]) and biventricular dilation. Cut sections of the myocardium revealed multiple ill-defined hyperemic areas, buildup of blood or congested area in front of an area of severe narrowing of the blood vessel interior, in the left ventricle and interventricular septum.

The FF-P received a medical evaluation for the fire department in March 2019. The medical evaluation noted hyperlipidemia, low testosterone, obstructive sleep apnea, tobacco use, and obesity. His only prescribed medication was injectable testosterone. A submaximal exercise stress to 85% of age-predicted maximal heart did not reveal any signs of ischemia, but the FF-P did have an exaggerated blood pressure response to the test. The FF-P exercised to 11 METs (metabolic equivalents) and had an estimated peak MET level of 14.5 based on the test duration (12 METs are the minimum recommended standard for aerobic fitness for firefighting based on NFPA guidelines). The medical evaluation also noted that the FF-P reported good compliance with continuous positive airway pressure (CPAP) usage and that the physician counseled the FF-P about the importance of addressing the modifiable risk factors, including the importance of weight loss, control of his lipids and blood glucose, tobacco cessation, and the need to regularly engage in moderate exercise. The physician also reviewed the exercise stress test and cautioned the FF-P that the test was used as a fitness tool and not a definitive coronary artery disease screening tool. This type of testing is the most basic of all different types of testing, is done on asymptomatic individuals, and is not a workup for coronary artery disease. The FF-P was 5'9" and weighed 236 pounds, giving him a body mass index (BMI) of 34.8 kilograms per cubic meter (kg/m^2). Cardiovascular disease risk factors along with standard risk categories are provided in Table 1.

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Table 1. Cardiovascular (CVD) Risk Factors (RFs)

Risk Factor	Interpretation	Category Guidelines
Systolic BP[1]	Normal Elevated Stage 1 Hypertension Stage 2 Hypertension	< 120 mmHg 120–129 mmHg 130–139 mmHg ≥ 140 mmHg
Diastolic BP[1]	Normal Elevated Stage 1 Hypertension Stage 2 Hypertension	< 80 mmHg > 80 mmHg 80–89 mmHg ≥ 90 mmHg
Total Cholesterol[2]	Desirable Borderline High High	< 200 mg/dL 200–239 mg/dL ≥ 240 mg/dL
HDL[2]	Low High (Desirable)	< 40 mg/dL ≥ 60 mg/dL
LDL[2]	Optimal Above normal Borderline high High	< 100 mg/dL 100–129 mg/dL 130–159 mg/dL > 160 mg/dL
Triglycerides[3]	Normal Hypertriglyceridemia Severe hypertriglyceridemia	> 175mg/dL 175–499mg/dL ≥ 500mg/dL
Blood Glucose[4]	Normal Prediabetes Diabetes	< 100 mg/dL 100–125 mg/dL ≥ 126 mg/dL
BMI[5]	Underweight Normal weight Overweight Obesity	< 18.5 kg/m^2 18.5–24.9 kg/m^2 25–29.9 kg/m^2 ≥ 30 kg/m^2

Note: References for Table 1: [1]Whelton et al. 2017; [2]Kratz et al. 2004; [3]Grundy et al. 2019; [4]ADA 2014; [5]CDC 2020.

The FD's medical evaluation for the fire department in March 2019 also revealed that he used smokeless tobacco regularly and did not engage in regular physical activity (defined as 150–300 min/week moderate intensity or 75–150 min/week high intensity exercise [HHS 2019]). His BMI of 34.8 was considered obese and his elevated blood sugar of 110 milligrams per deciliter (mg/dL) was

indicative of a pre-diabetic state. His blood pressure of 116/86 placed him in the Stage I Hypertension category via the diastolic value. The FD's total cholesterol of 251 mg/dL and low-density lipoprotein (LDL) ("bad") cholesterol level of 179 mg/dL were both in the high range. His high-density lipoprotein (HDL) ("good") cholesterol and triglycerides, 41 mg/dL and 157 mg/dL respectively, were within normal limits. Based on his age and risk factors, the American Cardiology Association/American Heart Association (ACC/AHA) Atherosclerotic Cardiovascular Disease (ASCVD) risk calculator indicated that the FF-P had a 6.9% 10-year risk of heart attack or stroke.

In addition to annual medical evaluations, the FD also provides coronary artery calcium (CAC) scans to screen for coronary artery disease on a periodic basis. The FF-P had the CAC done in 2009 and 2014. In 2009 he had no detectible calcium in his coronary arteries, but in 2014 a small focus of calcific plaque formation was found in the right coronary artery with a calcium score of 2 [Kapoor et al. 2020]. The calcium score of 2 put the FF-P (then 37 years old) at low risk of significant coronary artery disease, but it did place him in the 84th percentile for someone his age.

Discussion

Sudden Cardiac Events

Sudden cardiac events are most often caused by myocardial infarction (heart attack) or cardiac arrest (fatal arrhythmias). In the United States, atherosclerotic coronary heart disease (coronary artery disease) is the most common risk factor for cardiac arrest and sudden cardiac death [Myerburg and Castellanos 2008]. Risk for the development of atherosclerosis is grouped into nonmodifiable and modifiable risk factors. Nonmodifiable risk factors include age older than 45, male sex, and family history of coronary artery disease. Modifiable risk factors include diabetes mellitus, smoking, high blood pressure (hypertension), unhealthy blood cholesterol levels, obesity and physical inactivity [ACC/AHA 2018]. The American Cardiology Association/American Heart Association (ACC/AHA) Atherosclerotic Cardiovascular Disease (ASCVD) risk calculator can be used to provide a 10-year estimate of risk of a cardiac event based on age and number and severity of risk factors. Based on this risk calculator, the FF-P had a 6.9% 10-year risk of heart attack or stroke.

Coronary Artery Disease

Coronary artery disease refers to atherosclerotic plaque in the coronary arteries and the complications of the plaque. 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. Plaque buildup that restricts blood flow and prevents sufficient oxygen delivery to the myocardium causes ischemia and often causes chest pain (angina), particularly with exertion. Heart attacks or myocardial infarctions 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 a ruptured atherosclerotic plaque [Libby 2013]. Heart attacks and sudden cardiac death can be triggered by heavy physical exertion [Albert et al. 2000; Mittleman et al. 1993; Willich et al. 1993], including snow shoveling [Franklin et al. 2001] and firefighting activity, including an alarm response and training [Kales et al. 2003, 2007; NIOSH 2007; Smith et al. 2019].

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Establishing the occurrence of an acute heart attack requires any of the following: characteristic ECG changes, elevated cardiac enzymes, coronary artery thrombus/plaque rupture, or evidence of myocardial damage at autopsy. The FF-P performed an ECG on himself because of symptoms of transient chest pain, but he did not see any abnormalities. Because he did not seek medical care for chest pain, a physician did not read his ECG. The autopsy found severe atherosclerosis in the right coronary artery (90% narrowing) and a clot (thrombus) resulting in near occlusion of blood flow.

Heart Attack Symptoms

An individual who is experiencing a heart attack may experience a range of signs and symptoms. The American Heart Association provides a partial list, including [AHA 2021]:

- *Uncomfortable pressure, squeezing, fullness or pain in the chest*
- *Pain or discomfort in one or both arms, the back, neck, jaw, or stomach*
- *Shortness of breath*
- *Sweating (diaphoresis)*
- *Nausea or vomiting*
- *Dizziness or lightheadedness*

The signs and symptoms of a heart attack vary greatly in how they present and in their severity; some individuals experience the sensation of "an elephant on their chest"; some people experience shortness of breath or fatigue; and in some individuals, sudden cardiac death is the first sign of a myocardial infarction. There is evidence that the symptoms of a heart attack vary by age and gender [AHA 2021]. Although women are more likely than men to have heart attack symptoms other than classical chest pain, men may also experience symptoms such as pain or discomfort in the neck, jaw, either shoulder or arms, upper back, and abdomen. Heart attack symptoms may also include shortness of breath, nausea or vomiting, sweating; lightheadedness, or dizziness [Mehta et al. 2016]. Some of the variability in the signs and symptoms occur because of the location of the blockage of the coronary vessel(s). The FF-P reported "not feeling well" and having episodes of chest pain that radiated to his neck/jaw for 2 days before being found deceased. The symptoms were classic symptoms of a heart attack and were concerning enough that he performed an ECG on himself and asked paramedics to perform and evaluate an ECG. However, it appears that because of the transient nature of the episode and how well he felt when he was not experiencing chest pain, because he did not see ECG abnormalities that he thought explained the chest pain, and perhaps because of a false sense of assurance because of a submaximal exercise test that had been performed during his annual medical evaluation, the FF-P did not seek medical help.

Symptoms of a heart attack are widely varied, and there are many symptoms that may be mistaken for or attributed to other problems. Unfortunately, there are too many cases where firefighters do not seek medical attention despite symptoms that indicate it is appropriate to do so. Table 2 presents NIOSH investigative reports from 2009 to 2018 where the symptoms that preceded the sudden cardiac event would not have been considered "classic symptoms." In many cases, the symptoms were plausibly attributed to a cause other than cardiac problems.

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Report	Brief Description
F2009-16	A 42-year-old lieutenant died of a cardiac arrhythmia after completing live fire training drills and reporting weakness and shortness of breath that he blamed on his recent cold. Symptoms seemed relatively mild and did not affect his drill performance.
F2010-03	A 43-year-old career firefighter suffered sudden cardiac death after completing overhaul. He complained of extreme back pain and then loss of vision.
F2010-34	A 56-year-old male career firefighter/paramedic died of a sudden cardiac event after rescue training. He had complained of chronic chest pain over the previous couple of weeks that he attributed to a cold.
F2013-10	A 44-year-old volunteer fire chief died of cardiac arrest while functioning as incident commander of a brush fire, showing symptoms of coughing and sweating. The chief said he was getting over a cold. Coughing escalated to gasping for air and vomiting, sweating profusely.
F2014-04	A 53-year-old male career fire chief died of heart attack after responding to grass fire and complaining of symptoms of indigestion with excessive burping and heart burn.
F2014-05	A 57-year-old career FF died of a heart attack after responding to an alarm that required him to climb 5 flights of stairs. He had symptoms of burping and blamed it on indigestion.
F2015-10	A 54-year-old male career firefighter experienced a cardiac event after fighting a residential fire, and complaining of shoulder pain that spread to his back. He explained that it felt like a “pulled muscle.” He later complained of shortness of breath.
F2015-12	A 44-year-old male career captain responded to CO call, played basketball for 30 minutes, and then complained of leg pain and leg cramping before experiencing sudden cardiac death.
F2018-01	A 47-year-old male career FF died of cardiac arrest after a light workout, with no symptoms, but reported back pain from incident where he “torqued his back” during medical response call during the same shift.
F2018-05	A 44-year-old female career FF died of sudden cardiac arrest after reporting a burning sensation in her throat that she attributed to breathing in cold air during a physical ability test. The burning sensation intensified and was accompanied with heavy sweating and eventually chest pain and shortness of breath.

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The Occupational Medical Standards for Structural Firefighters

Nearly half of all firefighter duty-related deaths are caused by sudden cardiac death. Firefighting results in multiple cardiovascular changes that could lead to plaque rupture or arrhythmogenic changes in individuals with underlying cardiovascular disease [Smith et al. 2016]. Research suggests that the vast majority of duty-related sudden cardiac deaths occur in firefighters who have atherosclerosis, cardiomegaly/left ventricular hypertrophy, or both [Geibe et al. 2008; Kales et al. 2003; Smith et al. 2018; Yang et al. 2013]. In fact, a study that relied on autopsy data and was able to verify the presence of atherosclerosis and structural heart changes (specifically cardiomegaly and left ventricular hypertrophy) found that over 80% of cardiac fatalities had both types of heart disease [Smith et al. 2018].

To reduce the risk of sudden cardiac events or other incapacitating conditions among firefighters, the NFPA developed 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2018]. Regarding cardiovascular disease (CVD) screening for asymptomatic firefighters, NFPA 1582 recommends basing the decision for exercise stress testing (EST) on the firefighter's 10-year Heart Risk score (which is based on age, lipids, and other cardiovascular risk factors) [ACC/AHA 2018; NFPA 2018]. Heart Risk should be calculated each year beginning at age 40, and firefighters whose risk is 10% to < 20% should receive a symptom-limiting EST (with or without imaging) to at least 12 METs [NFPA 2018]. The FF-P in this investigation had regular medical evaluations, including an exercise stress test (ESTs may be listed in medical records as submaximal exercise testing with ECG). The FF-P did well on the EST but was counseled to modify diet, abstain from tobacco use, and increase his exercise to control his cardiovascular disease risk. He had a 10-year risk score of 6.8% at his last occupational medical evaluation in March of 2019.

NIOSH offers the following recommendations to reduce the risk of heart attacks and sudden cardiac arrest among firefighters at this and other fire departments across the country.

Recommendations

Recommendation #1: Ensure that all firefighters are aware of the warning signs of a cardiovascular event and the atypical ways it can present.

Discussion: Most firefighters are familiar with the classic symptoms of a heart attack. FDs could include a review of the wide variety of classic and atypical heart attack symptoms at required departmental training. FD training may include the American Heart Association's "What are the warning signs of heart attack?" fact sheet in addition to other heart attack resource materials [AHA 2015]. Personnel should have a high level of suspicion that symptoms in the chest, upper abdomen, shoulder, back, and neck can be related to cardiac issues. Even if these symptoms can be attributed to other possible causes, it does not mean they are not related to cardiac issues. All potential cardiac symptoms should be evaluated in an emergent manner.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical Line-of-Duty Deaths (LODD) Investigations Team, located in Cincinnati, Ohio. Denise L. Smith, Ph.D., led the investigation and authored the report. Dr. Smith is Professor of Health and Human Physiological Sciences, and Director of the First Responder Health and Safety Laboratory at Skidmore College, where she holds the Tisch Family Distinguished Professorship. She is also a member of the NFPA Technical Committee on Occupational Safety and Health. Dr. Smith was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical LODD Investigations Team, during this investigation.

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Appendix A
Autopsy Findings

Coronary arteries

- Severe atherosclerosis in proximal segment of right coronary artery with luminal narrowing of 90%
- Right coronary artery has near occluding thrombus with surrounding hemorrhage into the subepicardial fat tissue (a layer of fat between the heart muscle and the pericardium, the fibrotic sac that surrounds the heart) representing probable dissection
- Left anterior descending and left circumflex coronary artery demonstrate moderate atherosclerosis with 40% narrowing

Structural

- Cardiomegaly (heart weighed 510 grams)
- Left ventricular hypertrophy (left ventricular thickness of 1.5 cm)
- Biventricular dilation
- Multiple ill-defined hyperemia areas in left ventricle

Microscopic

- Left ventricle demonstrates enlarged myocytes with “box car” nuclei

Toxicology

- Negative for drugs of abuse

Author’s Discussion

The determination of cardiomegaly (enlarged heart) is based on the predicted heart weight of 405 grams for a male of 236 pounds, according to research in Silver and Silver [2001].

The determination of left ventricular hypertrophy (abnormally thickened muscle of the left ventricle) is based on postmortem studies by Kitzman et al. [1988] that predicts an average value of 1.23 cm with a range 1.07 cm–1.39 cm for a male of this FF’s age and body habitus.

References

Kitzman DW, Scholz DG, Hagen PT, Ilstrup DM, Edwards WD [1988]. Age-related changes in normal human hearts during the first 10 decades of life. Part II (maturity): a quantitative anatomic study of 765 specimens from subjects 20 to 99 years old. Mayo Clin Proc *63*(2):137–146.

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