2019
15

Death in the line of duty...

National Institute for Occupational Safety and Health NIOSH

A report from the NIOSH Fire Fighter Fatality Investigation and Prevention Program December 1, 2019

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

Executive Summary

On May 07, 2019, a 67-year-old volunteer Lieutenant (LT) complained of pain in his pectoralis muscle after completing departmental rapid intervention team training. The LT initially denied that the pain could be related to cardiac issues and refused to be evaluated, but as symptoms of increasing pressure and shortness of breath appeared, the LT agreed to be evaluated by paramedics in the station. The LT was escorted into the station by a fellow firefighter who requested that the paramedics evaluate the LT. The paramedic in the room asked the LT to sit down while he notified dispatch (2125 hours) that there was a walk-in. The LT was now pale and he suffered a syncopal episode within a minute of being seated and had to be lowered to the floor with the help of two other members. Another paramedic entered the room as the firefighter was being lowered to the floor. Paramedics evaluated for a pulse, and finding none, initiated cardiopulmonary resuscitation. After approximately one minute, the LT briefly regained consciousness and fought efforts to provide care. Approximately 30 seconds later, he lost consciousness and had no pulse. The cardiac monitor revealed pulseless electrical activity (PEA). Advanced cardiac life support (ACLS) protocols were continued. The LT was intubated and received cardiac medications, but he never had a shockable rhythm. The LT was transferred to a nearby emergency department where ACLS protocols were continued for approximately 20 minutes to no avail. The LT never regained an organized cardiac rhythm and cardiac ultrasound revealed no cardiac activity. The LT was pronounced dead at 2203 hours.

The Medical Examiner's report listed the cause of death as "hypertensive atherosclerotic cardiovascular disease", and offered the opinion that this likely resulted in a myocardial infarction (heart attack). The autopsy found 75% luminal narrowing of the left main artery due to atherosclerotic plaque. There was no intracoronary thrombosis (blood clot) noted. National Institute for Occupational Safety and Health (NIOSH) investigators concluded that the physical activity associated with the training drill triggered a sudden cardiac event in an individual with undiagnosed underlying cardiovascular disease.

Key Recommendations

NIOSH, as a federal agency whose focus is prevention, offers the following recommendations to lower the risk of sudden cardiac events and other incapacitating medical conditions among firefighters at this and other fire departments across the country.

- Phase in a comprehensive wellness and fitness program for all firefighters.
- Ensure that all firefighters are aware of the warning signs of a cardiovascular event and the atypical ways it can present.

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

NIOSH also provides the following as a general recommendation for the fire service:

In addition to fire department fitness-wellness programs and occupational medical exams, firefighters can enhance their heart health and overall health by following a heart-healthy lifestyle away from the firehouse and having regular checkups with their family doctor.

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

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15

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Introduction

On May 7, 2019, a 67-year-old voluteer Lieutenant (LT) collapsed after rapid intervention team (RIT) training and suffered sudden cardiac death despite immediate resuscitative efforts. The U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this fatality on May 22, 2019. On August 8, 2019, a contractor for the NIOSH Fire Fighter Fatality Investigation and Prevention Program (the NIOSH investigator) conducted an on-site investigation of the incident.

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

- Deputy Chief
- Battalion Chief (BC), Health Safety Officer
- Firefighters who participated in training and rendered care
- Paramedics who provided care
- Wife of the LT

The NIOSH investigator reviewed the following documents:

- Fire Department (FD) incident reports for calls throughout the shift
- Law enforcement report of fatality
- EMS (ambulance) report
- Hospital emergency department (ED) records
- Occupational medical records
- Death certificate
- Autopsy report

Investigation

On May 7, 2019, at 1900 hours, a 67-year-old volunteer LT reported to the fire station for departmental training along with 8 other members of his station. The training drills were designed to increase knowledge of skills needed to locate, package, and remove a downed firefighter as part of a rapid intervention crew (RIC).

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

The drill was conducted in the fire station and was designed to simulate a collapsed building with wire entanglements. Groups of 3 firefighters performed the drill together. One firefighter stayed at the window to assist with removing the victim, while two firefighters entered the prop through a simulated window. The two firefighters who entered the window followed a charged hose line for about 10 feet to the entrapment section. One firefighter remained at the entrance to the entrapment prop while the other navigated his way through the prop (about 6 feet), then proceeded through a narrow tunnel (about 3 feet), and then continued along the hose line for another 15 feet until they found a rescue mannequin (60 pounds). The firefighter radioed that he had found the victim and was returning and made his way back to the entrapment prop. The firefighter who had remained at the entrapment prop entrance met the firefighter who was returning with the rescue mannequin in the entanglement prop and and then both firefighters dragged the mannequin to the window, where the 3 firefighters in the crew assisted in passing the mannequin out the window.

The firefighters estimated that it took 6–10 minutes to complete each evolution depending on how long it took to navigate the entrapment section. Firefighters critiqued the performance of fellow firefighters and discussed different approaches to the obstacles so the duration of the evolutions seemed to get shorter each time the drill was performed. There were 3 groups of 3 firefighters, and each group performed the drill two times. The LT was in the third group. The first time he performed the evolution he was stationed at the window, the second time that he performed the drill, he entered the window and then remained at the entrance of the entanglement section while the other firefighter continued on the course and retrieved the mannequin. The LT then met the firefighter and helped return the mannequin to the window where it was lifted and removed. The entire training drill lasted about 2 hours. This included the safety briefing, 6 evolutions, short debriefing after each group went through the course, a period of rehab and formal critique after everyone finished their first evolution, and time to clean up the area after training.

After the drills had ended, some firefighters put air bottles on an apparatus to go to another station to fill them, and some members met in a small office area to enter their training time. The LT asked two fellow firefighters what would cause his pectoral muscles to hurt. As he asked, he had his thumbs in his underarm area and was rubbing his chest. One of the firefighters asked if the pain could be cardiac-related. The LT responded that it was not cardiac, it was muscular and it had been happening after his workouts. The firefighters asked more about his workout and he described a heavy, upper body workout routine that involved calisthenics, including push-ups, hand weights and a rowing machine. Another firefighter entered the room and heard part of the conversation, and he too asked if the pain could be cardiac. Again, the LT strongly denied the possibility and insisted it was muscular. He had no other pain and no signs of distress. After multiple suggestions to go into the station and have the paramedics there do an evaluation, and consistent assurances from the LT that the pain was muscular, everyone left the station (several members had already left).

As one of the last firefighters was walking to his car in back of the station, he saw the LT leaning over with his hands on his knees and spitting. The firefighter went to the LT and asked again for him to come into the station and have the paramedics do an evaluation. The LT agreed and walked a short distance into the dayroom and was seated at the table. At this point he was diaphoretic and was in some distress. The firefighter who had escorted him into the station asked the paramedic in the dayroom to

do an evaluation; the paramedic agreed and said he needed to call it in as a "walk-in." The paramedic notified dispatch at 2125 hours and the other paramedic in the station heard this radio transmission and came to the dayroom. A set of vitals was obtained and the LT had a slow heart rate (40 beats per minute) and rapid breathing (20 breaths per minute). As the paramedic was making the call, the LT slumped in his chair. The firefighter and paramedic helped ease him to the floor. The call was upgraded to a cardiac arrest call and firefighters who had just left the station heard the call and returned to assist with care. Another set of vitals was obtained immediately as the LT was helped to the floor. An electrocardiogram (EKG) revealed the LT had a heart rate of 45 beats per minute; his respiration rate was 10 breaths per minute.

Within moments of being assisted to the floor the LT became unresponsive, pulseless, and apneic. At 2128 hours, cardiopulmonary resuscitation (CPR) was initiated and the LT was provided oxygen via bag-valve mask (BVM). After approximately one minute of CPR, the LT regained responsiveness and a pulse, and stated that he was fine and wanted help removing the mask. After about 30 seconds, the LT then became unresponsive, pulseless and apneic. CPR was provided with the Lucas® mechanical chest compression device. The EKG revealed pulseless electrical activity (PEA). The LT received his first round of epinephrine at 2128 hours and was intubated at 2133 hours. The ambulance left the scene at 2143 hours and continued cardiac life support protocols en route with no change in status.

The ambulance arrived at the ED at 2147 hours. The rhythm continued to be PEA. CPR was continued, ventilation was confirmed, two more rounds of epinephrine were administered and bicarbonate was given but the LT remained in PEA. Cardiac ultrasound revealed that there was no cardiac activity. At 2203 hours, the LT was pronounced dead.

Medical Findings

The Medical Examiner's report identified the cause of death as hypertensive atherosclerotic cardiovascular disease. The heart was normal size (350 grams). There was atherosclerosis in the left main coronary artery resulting in 75% lumen stenosis (i.e., the diameter of the artery was narrowed by 75%). There was no thrombus noted and there were no focal lesions in the myocardium (heart muscle). The autopsy revealed granular kidneys, consistent with nephrosclerosis, which is often found in individuals with long standing hypertension (i.e., target-organ damage).

The FF received a medical evaluation for the fire department in September of 2018. Cardiovascular disease risk factors are provided in Table 1. The LT was a non-smoker, physically active (defined as 150–300 min/week moderate intensity or 75–150 min/week high intensity exercise [HHS 2019]), not obese, and had normal blood sugar (no diabetes). His blood pressure was elevated; although his total and low-density lipoprotein (LDL) ("bad") cholesterol levels were normal, further analysis revealed unhealthy levels of high-density lipoprotein (HDL) ("good") cholesterol and triglycerides. Based on his age and risk factors, the American Cardiology Association/American Heart Association (ACC/AHA atherosclerotic cardiovascular disease (ASCVD) risk calculator estimated that the FF had a 19.8% 10-year risk of heart attack or stroke.

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

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

References for table 1: [1]Whelton et al. 2017; [2]Kratz et al. 2004, Mayo Clinic 2019a; [3]Grundy et al. 2018; [4]ADA 2014; [5]CDC 2020.

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

Fire Department

At the time of the NIOSH investigation, the FD consisted of approximately 200 uniformed personnel operating out of 6 fire stations. It serves a population of approximately 88,000 in a geographic area of about 22 square miles.

Membership and Training

The FD actively recruits for new members. Applicants must be at least 18 years of age, have a high school diploma or equivalent, and possess a valid driver's license. They must also live within the city or be with 2.5 miles or 5 minutes. Potential members complete an application and a background check is performed. The FD hosts an orientation for potential candidates who have cleared the background check that includes rules, regulations and expectations. Potential members are then invited to make a commitment to the FD. Applicants who affirm they want to join are required to pass a medical evaluation provided by the City. New members receive departmental training based on the State's curriculum and are certified as Firefighter I. New members are then required to become familiar with department policies and procedures, equipment and apparatus, and to attend on-going training. The FF had been with the FD for 13 years and was actively involved.

Preplacement, Periodic, and Return to Work Medical Evaluations

The FD requires preplacement medical evaluations for applicants. Components of the medical evaluation include the following:

- Complete medical history
- EKG
- Complete blood count
- Urinalysis
- Urine drug screen
- Audiogram
- Vision test
- Respirator use questionnaire
- Spirometry
- Exercise stress test
- Chest x-ray

The FD provides periodic medical evaluations that include the same components listed above. Firefighters must be medically cleared by their primary care physician for return to work following a serious injury or illness by the treating physician.

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

Wellness/Fitness Programs

The Fire Department does not offer a formal wellness program. There is exercise equipment in fire stations and the FD for members to use. The LT was an avid exerciser and worked out almost every day.

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 non-modifiable and modifiable risk factors. Non-modifiable risk factors include older age (> 45 for men, > 55 for women), male sex, and family history of coronary artery disease. Modifiable risk factors include diabetes, smoking, high blood pressure (hypertension), unhealthy cholesterol levels, and obesity/physical inactivity [AHA 2016; CDC 2020]. The LT had 2 non-modifiable risk factors (male sex, age over 45) but had not been diagnosed with any modifiable disease risk factors. A structurally enlarged heart (cardiomegaly or left ventricular hypertrophy) is also common among many individuals who die of sudden cardiac events [Tavora et al. 2012].

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 (heart muscle) causes ischemia and often 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].

Establishing the occurrence of an acute heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, coronary artery thrombus/plaque rupture, or evidence of myocardial damage at autopsy. In this case, there was no definitive evidence of a heart attack, but the autopsy identified severe atherosclerosis (75% stenosis) in the left main (main blood supply for left ventricle/pumping chamber), and tissue damage may not be clearly visible in infarcts < 24 hours old [Siegel 1997].

Heart Attack Symptoms

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

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 2016]:

- 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", others may experience shortness of breath or fatigue, and in some individuals, sudden cardiac death is the first sign of a myocardial infarction. Some of the variability in the signs and symptoms occur because of the location of the blockage. There is also evidence that the symptoms of a heart attack vary by age and gender [AHA 2016]. Although the most common symptom in women is some type of chest pain, pressure or discomfort in the chest, it is not always severe or even the most prominent symptom. Women are more likely than men to have heart attack symptoms that are different than chest pain, such as neck, jaw, shoulder, upper back or abdominal discomfort; shortness of breath; pain in one or both arms; nausea or vomiting; sweating; lightheadedness or dizziness [Mayo Clinic 2019b].

Importantly, symptoms of a heart attack are widely varied, and many symptoms may be mistaken for other problems. Table 2 presents recent investigative reports 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.

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

Table 2. NIOSH firefighter fatality investigation reports involving sudden cardiac events

Report	Brief Description
F2009-16	A 42-yr old Lieutenant died of a cardiac arrhythmia after completing live fire training drills and reporting weakness and shortness of breath which he blamed on his recent cold. Symptoms seemed relatively mild and did not affect his drill performance.
F2010-03	A 43-yr old career firefighter sudden cardiac death after completing overhaul. He complained of extreme back pain and then loss of vision.
F2010-34	56-yr old male career firefighter/paramedic died of a sudden cardiac event after rescue training while complaining of chronic chest pain over the past couple weeks that he attributed to a cold.
F2013-10	A 44-yr 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	53-yr 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	57-yr 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	54-yr 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	44-yr old male career captain responded to CO call, played basketball for 30 min, and then complained of leg pain and leg cramping before experiencing sudden cardiac death.
F2018-01	47-yr 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	44-yr old female career FF died of sudden cardiac arrest after reporting a burning sensation in her throat which 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.

Source: NIOSH FFFIPP http://www.cdc.gov/niosh/fire/investigations/investigations.html

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

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 firefighter duty-related sudden cardiac deaths 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 (coronary heart disease) 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 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, blood pressure, cholesterol, and other CVD 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 had a 10-year risk score of 19.8% at his occupational medical evaluation in September of 2018.

NIOSH, as a federal agency whose focus is prevention, offers the following recommendations to lower the risk of sudden cardiac events and other incapacitating medical conditions among firefighters at this and other fire departments across the country.

Recommendations

Recommendation #1: Phase in a comprehensive wellness and fitness program for firefighters.

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* [NFPA 2015], and the International Association of Fire Fighters; Fairfax, VA: International Association of Fire Chiefs (IAFF/IAFC) *Fire Service Joint Labor Management Wellness-Fitness Initiative* [IAFF and IAFC 2018]. 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 workdays [Aldana 2001; Stein et al. 2000]. Health promotion programs for firefighters have been shown to reduce coronary heart disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005].

Recommendation #2: 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 aware of classic symptoms of a heart attack. FDs could include a review of classic symptoms and the wide variety of symptoms at required departmental training.

67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

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 could be attributed to other possible causes does not mean they are not related to cardiac issues.

NIOSH also provides the following as a general recommendation for the fire service:

In addition to fire department fitness-wellness programs and occupational medical exams, firefighters can enhance their heart health and overall health by following a heart-healthy lifestyle away from the firehouse and having regular checkups with their family doctor.

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67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

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67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

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67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac/Medical Fatality Component, 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/ Medical Fatality Component, during this investigation. Wendi Dick, MD, MSPH, provided medical consultation and contributed to the report. Dr. Dick is Medical Officer for the Cardiac/Medical Fatalities Component in Cincinnati.

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67-Year-Old Volunteer Lieutenant Suffers Sudden Cardiac Death Following Training—Florida

Appendix A
Autopsy Findings

Coronary arteries

- 75% stenosis in left main coronary artery
- Other coronary arteries unremarkable
- No thrombus identified in coronary arteries

Structural

- Heart weight = 350 grams
- Myocardium is firm with no focal lesions

Additional

- Granular kidneys, consistent with nephrosclerosis, suggesting hypertension