2019
08

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 4, 2019

41-Year-Old Captain Suffers Fatal Heart Attack After Participating in a Multi-Unit Training Drill—Indiana

Executive Summary

On September 27, 2017, at approximately 2000 hours, a 41-year-old male career Captain (CAPT) staged for a multi-unit training scenario in an abandoned restaurant. The CAPT was the officer of a 4-person ladder truck and responded along with two engines and a battalion chief. The CAPT and his crew performed forcible entry and began a primary search (on air). They were then assigned to meet up with the engine crew and take over their hoseline. The CAPT and another firefighter advanced the hoseline about 10 feet to extinguish the simulated fire. The training drill lasted approximately 20–25 minutes (min). Following the drill, crews cleaned up and then met for a debriefing.

After the debriefing the CAPT went to use the bathroom while others went in to view the building without smoke obscuring visibility. The CAPT returned from the bathroom and told an on-site paramedic that his arm was numb. After further questioning he affirmed that he was having pressure in his chest and stated that he did not feel well. The paramedic and the Assistant Chief (serving as Safety Officer) escorted the CAPT to the engine. The paramedic began an assessment, provided oxygen to the CAPT, and requested that an ambulance be dispatched. The CAPT indicated that he was feeling dizzy, leaned forward, lost consciousness, and collapsed. On-scene personnel retrieved an automatic external defibrillator from the engine, attached it to the CAPT, and delivered a shock. The ambulance was dispatched at 2124 hours and medics arrived on scene about 1 min later. Advanced life support was provided on scene, including defibrillation (x8), cardiac medications, and assisted ventilation. The ambulance left the scene at 2205 hours and arrived at the emergency department at 2212 hours. The emergency department staff continued resuscitation efforts for approximately 20 min. The CAPT was pronounced dead at 2231 hours.

The death certificate and the Medical Examiner's report listed the cause of death as "intracoronary thrombus (myocardial infarction) due to severe, occlusive arteriosclerotic cardiovascular disease". The autopsy found a thrombus (clot) in the left anterior descending coronary artery and severe atherosclerosis in multiple coronary arteries. The heart had thickened ventricles (hypertrophy), was heavier than normal, and had microscopic changes indicative of hypertensive cardiovascular disease. National Institute for Occupational Safety and Health investigators concluded that the physical exertion associated with the training activity triggered a heart attack in an individual with underlying cardiovascular disease.

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.

41-Year-Old Captain Suffers Fatal Heart Attack After Participating in a Multi-Unit Training Drill—Indiana

- *Ensure firefighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment (PPE) and self-contained breathing apparatus (SCBA) used by firefighters, and the various components of National Fire Protection Association (NFPA) 1582.*
- *Adopt a mandatory comprehensive wellness and fitness program for firefighters.*

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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Introduction

On September 27, 2017, a 41-year-old Captain (CAPT) suffered a fatal heart attack after leading his ladder crew through a training drill. The U.S. Fire Administration notified National Institute for Occupational Safety and Health (NIOSH) of this fatality on September 28, 2017. On May 20, 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:

- *Fire Chief*
- *Assistant Chief of Special Operations and Training*
- *Union Leadership*
- *Battalion Chief (BC) in charge of training drill*
- *Crew members who worked with the CAPT*
- *Wife of CAPT*

The NIOSH investigator reviewed the following documents:

- *Fire Department (FD) incident reports for fire calls*
- *FD report for medical call (provided initial care)*
- *EMS (ambulance) report*
- *Hospital emergency department (ED) records*
- *Occupational medical records*
- *Personal physician records*
- *Death certificate*
- *Autopsy report*
- *Training Lesson Plan and Master Scenario Events List*

Investigation

On September 27, 2017, at approximately 0700 hours (hrs), the CAPT reported for work as the officer of a 4-person ladder truck. The ladder was stationed in a firehouse with one engine. After completing

morning chores, the CAPT led the station in daily training that lasted approximately 1¾ to 2 hours (hrs). The training consisted of large diameter hose training, portable hydrants, and using the deck gun.

In the afternoon the CAPT and his crew performed a light workout, consisting largely of stretching and light calisthenics. The CAPT and his crew regularly exercised together, but on this day, they did a light workout because they had heard that the training drills were strenuous.

At 1701 hrs, the ladder truck was dispatched to assist an ambulance crew on a medical emergency. About 5 minutes (min) into the response they were notified that their assistance was not needed, and they returned to quarters.

The station crew had dinner together at approximately 1800 hrs. At around 1940 hrs, apparatus, including the CAPT and his ladder truck, left the station to stage in a parking lot for a multi-unit training drill that was scheduled to begin at 2000 hrs. The training scenario was designed by the training academy and was held in an abandoned restaurant. The training site had been used for the previous 2 shift days. The training scenario did not include live fire, but a fog unit was used to obscure vision. It was a warm day (76 degrees Fahrenheit [°F]) with temperatures at the start of the drill approximately 59°F (72% humidity, no wind) [Weather Underground no date].

Individual units dispatched from the staging area were staggered to simulate apparatus arriving at different times and from different stations. The CAPT and his truck crew were the last apparatus dispatched (at approximately 2019 hrs) and staged on the Delta side of the building. The BC assumed incident command and assigned the ladder crew to perform forcible entry through two exterior steel doors. As the ladder crew entered the building, they went on air and began a primary search for possible victims. The CAPT did a 360 walk around and then joined his crew on the 2nd floor. As the drill continued, the engine crew that deployed the initial attack line (1¾ inches) exited the building due to low air alarms. The Incident Commander (IC) instructed the ladder crew to take the hoseline and attack the fire. The CAPT and one of his firefighters found the hoseline and advanced it approximately 10 feet (ft) to the fire (glowing light) and extiquished the fire. The low air alarm bells on the ladder crew were ringing as they exited the building. It is estimated that they worked inside the building for approximately 10–15 min.

After the drill was completed, the crew of the ladder truck crew cleaned up, returned their tools to the truck, and exchanged their air bottles. They then met with other crews on the Alpha side of the building for a debriefing. At the debriefing, the company officer for each apparatus gave a report on the situation they encountered and the actions they took. During the debriefing, the CAPT gave an uncharacteristically short report and was kneeling on one knee much of the time. After the debriefing the CAPT asked the Safety Officer if the bathrooms were still operational. The IC had released crews to go view the building so that they could better understand the layout of the buildng without the fog obscuring visibilility. As crews went to into the building, the CAPT went to the bathroom just inside the enterance. The CAPT returned from the bathroom and told an on-site paramedic that his arm felt numb. He showed no sign of distress and stated that he felt fine. The paramedic assessed his radial pulse and had difficulty finding it. After a short period of time, the CAPT stated that he was having difficulty catching his breath. He affirmed that he felt pressure in his chest. The paramedic and the Safety Officer escorted the CAPT to an engine in front of the building (about 20 ft away). The Safety

41-Year-Old Captain Suffers Fatal Heart Attack After Participating in a Multi-Unit Training Drill—Indiana

Officer summoned another paramedic and radioed dispatch to send an ambulance. The paramedic provided oxygen to the CAPT, gave him aspirin, and assessed breath sounds (clear; 24–30 breaths/min). The CAPT indicated that he was feeling dizzy. He then leaned forward and collapsed to the ground. The paramedic assessed his carotid artery and found a rapid, weak pulse. The CAPT was moved to his left side and started to show seizure-like activity. The paramedic reassessed the CAPT after about 30 seconds and found that he was pulseless and not breathing. The CAPT was placed on his back and compressions were initiated. While the paramedic and firefighters initiated cardiopulmonary resuscitation (CPR), other firefighters retrieved the automatic external defibrillator (AED) from the engine. The AED pads were placed on the CAPT's chest, he was analyzed, and a shock was advised and delivered (x2).

The ambulance was dispatched at 2124 hrs and arrived on scene about a minute later (it was returning to quarters from another call and was only about a block away). The ambulance crew found the CAPT unresponsive with CPR in progress. The ambulance crew switched the CAPT to a cardiac monitor. The CAPT was in ventricular fibrillation (VFIB). Manual defibrillation was administered. After the 2nd shock, the CAPT had what appeared to be a normal rhythm for about 5–10 seconds. The CAPT's rhythm then changed back to VFIB. The CAPT was defibrillated 8 times with the last 2 defibrillations being double sequential defibrillations per Medical Command. A nasopharyngeal airway was obtained and oxygen was provided by bag-valve-mask (BVM). The CAPT's airway was suctioned as needed. Attempts to insert a laryngoscope or oropharyngeal airway were unsuccessful due to jaw clenching. The nasopharyngeal airway was not providing adequate ventilation and so a cricothyrotomy was performed, which resulted in placement of an endotracheal tube that provided good end-tidal (exhaled) carbon dioxide (CO_2) throughout resuscitation efforts. Intraosseous (IO) access was gained in the tibia and the CAPT received 11 rounds of epinephrine and multiple doses of amiodarone, as well as sodium bicarbonate and magnesium. The ambulance left the scene at 2205 hrs. While the CAPT was being transported to the emergency department (ED), his rhythm changed to pulseless electrical activity (PEA).

The ambulance arrived at the ED at 2212 hrs. The CAPT was still in PEA and his pupils were dilated bilaterally and fixed. Advanced life support (ALS) measures continued; the CAPT was given 5 more rounds of epinephrine in the ED. The CAPT never regained a pulse and his rhythm changed to asystole. Bedside cardiac ultrasound confirmed that there was no cardiac activity. The CAPT was pronounced dead at 2231 hrs.

Medical Findings

The CAPT complained of cardiac symptoms after completing the training drills and was being treated by a paramedic when he suffered a cardiac arrest. The CAPT received immediate treatment from an on-scene paramedic and an ALS ambulance that arrived on-scene about 2 min after he collapsed. The paramedics performed resuscitation efforts for about 40 min in the field and then transported the CAPT to the ED where resuscitation efforts continued for approximately 20 min in the ED.

The Medical Examiner's report identified the cause of death as a thrombus in the left anterior descending (LAD) coronary artery (myocardial infarction) due to severe, occlusive arteriosclerosis.

The CAPT's heart weighed 540 grams and had left ventricular wall thickening (LVH) of 2.1 centimeters (cm). See Appendix A for a more detailed description of autopsy findings.

The CAPT received required yearly medical evaluations ("firefighter physicals") as a member of the fire department (FD). His last medical evaluation was in June of 2017. At that time his blood pressure was 129/76 millimeters of mercury (mmHg) (< 120/80 is normal, 120–129 is pre-hypertension, ≥ 130 systolic [or ≥ 80 diastolic] is high blood pressure/hypertension) [Whelton et al. 2018]. Blood work ordered prior to the visit indicated the CAPT had high (225) total cholesterol (< 200 is normal), high (123) "bad" low-density lipoprotein (LDL) cholesterol (< 100 is normal), high (250) triglycerides (< 150 is normal), a normal level (52) of "good" high-density lipoprotein (HDL) cholesterol (> 40 is normal, > 60 is optimal/best), and high-normal (100) blood sugar (< 100 is normal) (all results in mg/dL) [ADA 2019; Mayo Clinic 2019a].

The CAPT also had an exercise stress test (EST) during this physical using the Bruce Treadmill protocol. He exercised for 9:01 min and reached a peak heart rate of 166 (93% of his age-predicted heart rate max), giving him an estimated aerobic capacity of 10 metabolic equivalents (METs). These results were a noticeable decrease from the previous year's exercise performance of 10:01 min and 12.8 METs.

The CAPT had coronary artery calcium (CAC) scanning done in 2013 and in 2017 as part of a local program where a cardiologist's office provides this service voluntarily for any firefighter. In 2013, the CAPT had no detectible calcium in his arteries (score of 0). In 2017, the CAPT had a calcium score of 101.2. This value falls in the range of moderate plaque buildup but was particularly concerning given the CAPT's young age (his calcium score was higher than about 99% of men his age) [Mayo Clinic 2019b].

The CAPT received the results of his firefighter medical evaluation, which noted moderate plaque burden and moderately high risk of developing symptomatic heart disease (e.g., chest pain/angina, shortness of breath, heart attack, or sudden cardiac arrest). The report recommended that the CAPT aggressively treat his high blood pressure, lose weight to decrease his body mass index (BMI), be attentive to cholesterol levels and follow up with his primary care physician. The CAPT exercised regularly with his crew and joined fellow firefighters in an attempt to eat healthier in the firehouse.

Regarding other risk assessment for cardiovascular health, the CAPT was 75 inches tall and weighed 405 pounds giving him a BMI of 50.9 (≥ 30.0 is considered obese; ≥ 40 is severely obese) [NHLBI no date-a]. He was a previous smoker. Based on his age and other risk factors, the American Cardiology Association (ACC) 10-year Heart Risk calculator indicated that the CAPT had a 5.6% risk of heart attack or stroke within the next 10 years (0.7% risk if all risk factors were optimal) [AHA/ACC 2018; NFPA 2018].

Fire Department

At the time of the NIOSH investigation, the FD consisted of approximately 350 uniformed personnel operating out of 18 fire stations. It serves a population of approximately 250,000 in a geographic area of 110 square miles.

41-Year-Old Captain Suffers Fatal Heart Attack After Participating in a Multi-Unit Training Drill—Indiana

Employment and Training

Applicants must be between 21–36 years of age, have a high school diploma or equivalent, and be a U.S. citizen. Applicants take a written aptitude (civil service exam) and must pass a candidate physical ability test (CPAT). The highest ranked candidates then undergo an initial interview. A criminal background check is performed after successful completion of the interview process. Successful applicants are then offered conditional employment and must pass a medical evaluation before they are hired. New members attend training and are probationary firefighters for 1 year. The CAPT had been with the FD for 19 years and had been a CAPT for 9 years.

Preplacement/Annual Physicals and Return to Work Medical Clearance

The FD requires preplacement medical evaluations for applicants. Components of this include:

- Complete medical history
- Electrocardiogram (EKG)
- Complete blood count
- Urinalysis
- Urine drug screen
- Audiogram
- Vision test
- Respirator use questionnaire
- Spirometry (pulmonary function tests)
- Exercise stress test
- Chest x-ray.

The FD requires an annual firefighter medical evaluation for all members that contains the same items as the preplacement medical evaluation, except that a urine drug screen is not performed. Firefighters complete a respiratory questionnaire and a respiratory fit test as part of their annual evaluation, which is provided by a contract health care provider. Firefighters are required to obtain return to work medical clearance following a serious injury or illness. If the injury occurs off-duty, the firefighter must provide a clearance note from the treating physician. If the injury occurs on-duty, the contract health care provider provides the return to work clearance.

Wellness/Fitness Programs

The FD offers wellness programming through the city Employee Assistance Program. The FD has exercise equipment in all stations and encourages firefighters to work out during the day. It is generally up to the officer in charge to determine when firefighters work out. The FD has embraced many

components of the wellness/fitness initiative but does not require that firefighters engage in a physical fitness program.

Discussion

Sudden Cardiac Events

Sudden cardiac events are most often caused by heart attack or cardiac arrest (fatal arrhythmias). In the U.S., 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 male sex, age > 45 (> 55 if female), and family history of coronary artery disease. Modifiable risk factors include diabetes, smoking, high blood pressure, unhealthy blood cholesterol levels, and obesity/physical inactivity [AHA 2016; NHLBI no date-b]. The CAPT had one non-modifiable risk factor (male sex); was only 41 years old, so age was not a major risk factor; and he did not have a known family history of premature cardiovascular death. The CAPT had four known modifiable risk factors (high blood pressure, which was being treated; smoking; high cholesterol; and obesity). A structurally enlarged heart (cardiomegaly or LVH) is also found in many people 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 non-linear, often abrupt fashion. Plaque buildup that restricts blood flow and prevents sufficient oxygen delivery to the heart muscle (myocardium) causes ischemia and often produces chest pain (angina), particularly with exertion. Heart attacks or myocardial infarctions typically occur with the sudden and complete blockage (occlusion) of one or more coronary arteries that have not developed a collateral blood supply. This sudden blockage is primarily due to blood clots forming on top of a ruptured atherosclerotic plaque [Libby 2013]. Heart attacks and sudden cardiac death can be triggered by heavy physical exertion such as snow shoveling, and firefighting activities, including responding to alarms and training [Albert et al. 2000; Franklin et al. 2001; Kales et al. 2003, 2007; Mittleman et al. 1993; NIOSH 2007; Smith et al. 2019; Willich et al. 1993]. The triggering of a heart attack by physical exertion is far more likely in people who do not regularly engage in strenuous activities [Mittleman et al. 1993].

Establishing the occurrence of an acute heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus/plaque rupture. In this case, the CAPT had a thrombus in a major coronary artery (the LAD) at autopsy, and the autopsy revealed that the firefighter had severe and complicated plaque in multiple coronary blood vessels.

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 dangerous arrhythmias

in individuals with underlying heart disease [Smith et al. 2016]. Research suggests that the vast majority of firefighter duty-related sudden cardiac deaths have coronary atherosclerosis, an enlarged heart, 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 atherosclerotic coronary artery disease and structural heart enlargement (specifically cardiomegaly and LVH) found that over 80% of firefighter cardiac deaths 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 on the firefighter's 10-year Heart Risk score (which is based on age, cholesterol, 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 CAPT had a 10-year risk score of 5.6% at his last firefighter medical evaluation in June of 2017, which by itself would not have indicated an EST. However, he was not able to achieve 12 METs on the treadmill test as a measure of aerobic capacity for firefighting tasks.

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 firefighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment (PPE) and self-contained breathing apparatus (SCBA) used by firefighters, and the various components of NFPA 1582.

Discussion: According to NFPA 1582, the FD should require that physicians are familiar with the physical demands of firefighting and the risks that firefighters encounter and should guide, direct, and advise members with regard to their health, physical fitness, and suitability for duty [NFPA 2018]. The physician should review job descriptions and essential job tasks required for all FD positions to understand the physiological and psychological demands of firefighting and the environmental conditions under which firefighters perform, as well as the PPE/SCBA they must wear during various types of emergency operations.

Recommendation #2: Phase in a mandatory comprehensive wellness and fitness program for firefighters.

Discussion: Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve aerobic capacity is found in NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters* [NFPA 2015], and the 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 work days [Aldana 2001; Stein et al. 2000].

41-Year-Old Captain Suffers Fatal Heart Attack After Participating in a Multi-Unit Training Drill—Indiana

Health promotion programs designed for firefighters have been shown to reduce their cardiovascular risk factors and improve their physical fitness levels, with mandatory programs showing the greatest benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005].

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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. Wendi Dick, MD, MSPH, provided medical consultation and contributed to the report. Dr. Dick is Lead for the Cardiac and Medical LODD Investigations Team in Cincinnati.

41-Year-Old Captain Suffers Fatal Heart Attack After Participating in a Multi-Unit Training Drill—Indiana

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41-Year-Old Captain Suffers Fatal Heart Attack After Participating in a Multi-Unit Training Drill—Indiana

Appendix A
Autopsy Findings

Coronary arteries

- Intracoronary thrombus, proximal LAD artery with severe occlusive coronary atherosclerosis
- Complete occlusive coronary atherosclerosis, first marginal branch

Structural

- Hypertensive heart disease
- Cardiomegaly (heart weighed 540 grams)
- LVH (left ventricular thickness of 2.1 cm)
- Cardiac chambers moderately dilated
- No evidence of healed myocardial injury

Microscopic

- Focal coronary thrombus with focal severe coronary atherosclerosis
- Hypertrophic myocytes
- Focal subacute ischemic changes with repair in anterior left ventricle

Toxicology

- Negative for drugs of abuse

Author's Discussion:

Predicted normal heart weight 479 grams (ranges between 363 and 633 grams as a function of sex and body weight based on greatest weight reported), according to research in Silver and Silver [2001].

Left ventricular thickness of 2.1 cm is high on the basis of postmortem studies by Kitzman et al. [1988] (normal range 1.07 cm–1.39 cm, average 1.23 cm).

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, PMID: 3276974.

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