



Lieutenant Suffers Sudden Cardiac Death During Structure Fire Operations – Arkansas

Executive Summary

On January 26, 2010, a 52-year-old male volunteer lieutenant (LT) responded to a residential fire. At the scene, the LT, wearing street clothes, assisted in stretching two 1¾-inch hose lines, carried a positive pressure ventilation (PPV) fan to the porch, and started the fan. After replenishing the fan's fuel supply, the LT collapsed. Cardiopulmonary resuscitation (CPR) was begun. The ambulance, already en route to the structure fire, arrived 6 minutes later, and advanced life support was begun. Despite CPR and advanced life support on scene, during transport, and in the hospital's emergency department (ED), the LT died. The death certificate and the autopsy listed "arteriosclerotic cardiovascular disease" as the cause of death. Given the LT's severe underlying heart disease, NIOSH investigators concluded that the physical exertion involved in responding to the call, stretching the fire hoses, and carrying and starting the PPV fan triggered his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. These recommended programs would have restricted the LT from participating in physically demanding emergency response activities.

Provide preplacement and annual medical evaluations to all fire fighters.

Ensure fire fighters are cleared for emergency response activities by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of National Fire Protection Association (NFPA) 1582.

Phase in a comprehensive wellness and fitness program for fire fighters.

Perform a preplacement and an annual physical performance (physical ability) evaluation.

Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

Conduct annual respirator fit testing.

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The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH “Fire Fighter Fatality Investigation and Prevention Program” which examines line-of-duty-deaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency’s reports do not name the victim, the fire department or those interviewed. The NIOSH report’s summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency’s recommendations and is not intended to be definitive for purposes of determining any claim or benefit. 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 & Methods

On January 26, 2010, a 52-year-old male volunteer LT died while assisting at a structure fire. NIOSH was notified of this fatality on January 27, 2010, by the U.S. Fire Administration. NIOSH contacted the affected Fire Department (FD) on February 4, 2010, to gather additional information, and on August 20, 2010, to initiate the investigation. On September 7, 2010, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Assistant Fire Chief
- LT's spouse

NIOSH personnel reviewed the following documents:

- FD training records
- FD annual report for 2009
- FD incident report
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Autopsy report
- Primary care provider medical records

Investigative Results

Incident. On January 26, 2010, at 1159 hours, the FD was dispatched to a residential structure fire. The LT and his spouse (also a fire fighter) were at the fire station and drove an engine (the LT) and a tanker (his spouse), arriving on the scene at 1200 hours. Nine additional fire fighters, including the Fire Chief and Assistant Chief (AC) responded directly to the scene. Fire fighters found a single-story, unoccupied residential structure with fire involving the living room and a hallway.

The LT placed the engine in pump gear and stretched two 200-foot preconnected 1¾-inch hose lines to the front door. The AC then operated the pump on the engine as fire fighters began interior fire suppression. Per protocol, an ambulance responded to the fire scene in standby mode.

The LT retrieved and carried a PPV fan (weighing about 60 pounds) from the engine to the front porch. The LT then started the fan using a pull rope starter. After about 5 minutes the fan ran out of fuel, and the LT retrieved a 2-gallon fuel can from the yard and restarted the fan. The LT stepped off the porch and walked approximately 15 feet when he collapsed (1215 hours). Crew members assessed the LT and found him unresponsive, not breathing, and without a pulse; dispatch was notified as CPR was begun. The advanced life support ambulance staffed with paramedics already en route to the fire scene for staging was notified of the LT's collapse and upgraded their response. They arrived on scene at 1221 hours.

Paramedics found the LT unresponsive, not breathing, without a pulse, and with CPR in progress. A cardiac monitor revealed ventricular fibrillation, and a shock was delivered without

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Investigative Results (cont.)

change in the LT's condition. An intravenous line was placed, and cardiac resuscitation medications were administered. The LT's heart rhythm remained in ventricular fibrillation, and two additional shocks were delivered. The ambulance departed the scene at 1236 hours en route to the ED. Paramedics made an unsuccessful intubation attempt while en route to the ED.

The ambulance arrived at the ED at 1240 hours. Advanced life support continued, including three additional defibrillation attempts and intubation, without change in the LT's condition. At 1259 hours, approximately 45 minutes after his collapse, the attending physician pronounced the LT dead, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy listed "arteriosclerotic cardiovascular disease" as the cause of death. On autopsy, the LT had evidence of previous heart attacks (1998, 2008), five-vessel coronary artery bypass grafts (CABG) (1998), and angioplasty with stent placement (2008). Specific findings are listed in Appendix A.

The LT was 66 inches tall and weighed 185 pounds, giving him a body mass index of 29.9 kilograms per meters squared (kg/m²). A body mass index 25.0–29.9 kilograms per meter squared is considered overweight [CDC 2010]. The LT had known coronary artery disease (CAD) in addition to multiple CAD risk factors including hypertension, hypercholesterolemia, and family history of CAD. In 2008 significant heart failure was diagnosed with a left ventricular ejection fraction (LVEF) of 25%–30% (normal is \geq 55%). At this time his left ventricle had reduced anterior-

septal wall motion and no movement of his posterolateral wall. An implantable cardioverter-defibrillator (ICD) was recommended by the cardiologist, but medical records available to NIOSH showed no physician visits after November 2008 and no indication that an ICD was placed. He was prescribed antihypertensive medications, antiplatelet medications, a diuretic for heart failure, a lipid-lowering medication, and fish oil. Weeks and months prior to this incident, the LT had no medical complaints and had not performed some physically exerting activities.

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Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of three fire stations with 24 uniformed volunteer personnel that served 5,000 residents in a geographic area of 40 square miles. In 2009, the FD responded to 274 calls including 54 fire calls and 220 first responder calls.

Membership and Training. The FD requires new fire fighter applicants to complete an application, be 18 years of age (21 years to drive fire apparatus), and have a valid State driver's license. The applicant is voted on at a general meeting. New members must complete a medical questionnaire and identify any health problems that would preclude them from performing interior structural fire fighting duties. Members precluded from interior structural fire fighting may perform support functions and training, depending upon their level of physical ability. The FD also has a Junior Fire Fighter Program that allows the junior fire fighter to train and perform support activities until reaching the age of 18. Arkansas does not require minimum training levels for volunteer fire fighters. The LT was certified as a Fire Fighter, Driver/Operator, Incident Commander, Wildland Fire Fighter, Fire Investigator, Fire Inspector, and First Responder. He also was certified in hazardous materials operations and incident command. He had 8 years of fire fighting experience.

Preplacement and Periodic Medical Evaluations. The FD does not require preplacement or periodic (annual) medical evaluations for members. No annual SCBA medical clearance or annual SCBA facepiece fit test are required. Members injured on duty are not required to obtain physician clearance for return to duty.

Health and Wellness Programs. The FD has no formal wellness/fitness program, and no exercise equipment is available in the fire station. No annual physical ability test is required.

Discussion

Atherosclerotic Coronary Artery Disease (CAD).

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 older than 45, male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2010; NHLBI 2010]. The LT had several of these risk factors (age older than 45, male gender, family history of CAD, hypercholesterolemia, and hypertension). In addition, the LT had documented CAD as evidenced by two heart attacks, CABG surgery, and angioplasty with stent placement.

The 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.

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. The LT did not have a heartbeat on which to conduct an EKG, cardiac enzymes were not tested, and no thrombus was identified at autopsy. However, occasionally (16%–27% of the time) postmortem examinations do not reveal the coronary artery thrombus/plaque rupture during acute heart attacks [Davies 1992; Farb et al. 1995]. The

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Discussion (cont.)

LT suffered either a primary heart arrhythmia (discussed below) or sudden cardiac death from an acute heart attack without a thrombus being present at autopsy.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Siscovick et al. 1984; Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks in fire fighters have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The LT had responded to the alarm, stretched two hose lines, carried a ventilation fan to the porch, and started the fan twice. These activities expended about 8 METs, which is considered moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Given the LT's underlying CAD and heart failure, the stress of performing duties at the structure fire probably triggered an arrhythmia, resulting in sudden cardiac death.

Heart Failure. The LT was diagnosed with moderate to severe congestive heart failure due to his ischemic heart disease and heart attacks in September 2008. With treatment his heart failure improved from an LVEF of 25% to 30% by November 2008. Despite the improvement, this degree of heart failure is strongly associated with an increased risk of ventricular arrhythmias and sudden cardiac death [Moss et al. 2002]. As a result, his cardiologist appropriately recommended an ICD [Zipes et al. 2006].

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the LT was found to have left ventricular

hypertrophy (LVH) and an enlarged heart. Both LVH and cardiomegaly increase the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure (hypertension), a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The LT had both a history of hypertension and CAD consistent with chronic cardiac ischemia.

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 (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria. The LT had known CAD (heart attacks, CABG, angioplasty with stent placement) and congestive heart failure. Either of these conditions should have precluded the LT from emergency response duties [NFPA 2007a].

After the LT's heart attack in 2008, the LT's cardiologist advised him to "avoid labor and vigorous activity unless cleared by the cardiologist; no fire fighting." However, no restrictions were mentioned during his last visit to his cardiologist in November 2008. From November 2008 until his death it appears the LT was restricted from interior fire suppression duties but not other emergency response activities. Perhaps if the LT was restricted from emergency response activities that involved moderate or strenuous physical activity, his death could have been prevented.

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Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. These recommended programs would have restricted the LT from participating in physically demanding emergency response activities.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2007a]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, the FD is not legally required to follow this standard. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments to implement.

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians (EMTs) from the local EMS (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 FD, City, or State. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the City, the State, and physician

volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Ensure that fire fighters are cleared for emergency response activities 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]. According to this guideline, the FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty. The physician should review job descriptions and essential job tasks required for all FD positions and ranks to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. Although no specific medical clearance for return to duty was identified in the records obtained by NIOSH, in 2008, his cardiologist recommended he avoid fire fighting. From 2008 to 2010, the LT did not perform fire suppression duties, but he participated in emergency response that involved moderately strenuous activities.

Recommendation #3: Phase in a comprehensive wellness and fitness program for fire fighters.

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

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Recommendations (cont.)

Programs for Fire Fighters, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; NFPA 2008; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce coronary artery disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than \$1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007].

Given the FD'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 #4: Perform a preplacement and an annual physical performance (physical ability) evaluation.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage

in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b].

Recommendation #5: Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's 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 2010]. Arkansas does not operate an OSHA-approved State plan nor other State-regulated workplace safety and health program. However, NIOSH investigators recommend voluntary compliance with this standard to ensure all members have been medically cleared to wear an SCBA.

Recommendation #6: Conduct annual respirator fit testing.

The OSHA respiratory protection standard requires employers whose employees are required to use a respirator (e.g., an SCBA) to have a formal respiratory protection program, including annual fit testing [29 CFR 1910.134]. As mentioned previously, Arkansas does not operate an OSHA-approved State plan; therefore, the FD is not required to follow OSHA standards [OSHA 2010]. Nevertheless, NIOSH investigators recommend voluntary compliance with this standard to ensure proper fitting personal protective equipment to improve safety and health.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Health, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

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Appendix A

Autopsy Findings

Cardiac

- Severe arteriosclerotic cardiovascular disease
 - Severe to complete focal narrowing of the native main coronary arteries
 - Prior coronary artery bypass graft surgery (1998)
 - Severe to complete focal narrowing of all four graft ostia
 - Well-healed infarction involving the left ventricle
 - No evidence of recent thrombus (blood clot in the coronary arteries)
 - Cardiac chambers slightly (dilated) enlarged
- Cardiomegaly (enlarged heart) (heart weighed 520 grams [g]; predicted normal weight is 358 g; between 271 g and 473 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Cardiac chambers slightly (dilated) enlarged
- Normal cardiac valves

Other

- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Carboxyhemoglobin (blood test for carbon monoxide exposure) <5% (normal for smokers; toxic level is 15%–35% saturation [Winek 1976])
- Negative blood tests for drugs and alcohol

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