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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation *July, 2009*

Fire Fighter Suffers a Fatal Heart Attack During Wildland Fire Operations—Oklahoma

SUMMARY

On February 20, 2009, a 45-year-old male volunteer fire fighter (FF) assisted in fighting an 800-acre wildland (grass) fire. After fighting the fire for approximately 10 hours, the FF was asked to assist with "mop up." While backing up a brush truck to provide water to crew members, the FF collapsed. A crew member yelled for help and moved the gearshift to the park position. The FF was pulled from the brush truck and found to be unresponsive, not breathing, with a weak pulse. Shortly thereafter, his pulse stopped, and an oral airway was placed while cardiopulmonary resuscitation (CPR) was begun. An automated external defibrillator (AED) was retrieved, a shock was delivered, and a pulse returned. An ambulance arrived and began advanced life support treatment. About 30 minutes after he collapsed, a Life Flight helicopter arrived and took over patient care. The FF went into cardiac arrest again and CPR continued for another 32 minutes. Medical Control was contacted and informed of the FF's condition. Medical Control advised the flight crew to pronounce the FF dead, approximately 67 minutes after his collapse. The death certificate and the autopsy, completed by the medical examiner, listed "atherosclerotic and hypertrophic cardiovascular disease" as the cause of death. NIOSH investigators conclude that the physical stress of performing fire extinguishing activities, coupled with the FF's severe underlying atherosclerotic coronary artery disease (CAD), probably triggered a heart attack and his subsequent sudden cardiac death.

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

- Provide preplacement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.
- Incorporate exercise stress tests following standard medical guidelines into a fire department medical evaluation program.
- Phase in a comprehensive wellness and fitness program for fire fighters consistent with National Fire Protection Association (NFPA) 1583, Standard on Health-Related Fitness Programs For Fire Fighters.
- Perform an annual physical performance

(physical ability) evaluation consistent with NFPA 1500, Standard on Fire Department Occupational Safety and Health Program.

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

INTRODUCTION & METHODS

On February 20, 2009, a 45-year-old male volunteer FF suffered a cardiac event and died after fighting a large wildland fire. Despite CPR and advanced life support, the FF died. The United States Fire Administration notified NIOSH of this fatality on February 23, 2009. The affected fire department called NIOSH on February 26, 2009, to provide additional information. On March 9, 2009, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Oklahoma to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Acting Fire Chief
- Retired Fire Chief
- Captain
- FF's spouse

NIOSH personnel reviewed the following documents:

- Fire department policies and operating guidelines
- Fire department training records
- Fire department annual report for 2008
- Fire department incident report
- Dispatch log
- Emergency medical service (ambulance) incident report
- Life Flight medical report
- Death certificate
- Autopsy report

RESULTS OF INVESTIGATION

Incident. On February 20, 2009, the fire department was dispatched to three separate grass fires burning simultaneously near a ranch. Two brush trucks and 4 personnel responded initially. One pumper, one tanker, and a third brush truck with an additional 9 personnel responded shortly thereafter. Units arrived on scene and requested mutual aid. Mutual aid from eight fire departments and a helicopter from the State Division of Forestry eventually assisted in fighting the fires with a total of 17 brush trucks, 3 tankers, and 2 pumpers (see Appendix A for a partial timeline). Two additional fires were intentionally set during the day, making a total of five fires. Four of the fires burned together, with the fifth fire located within one-half mile of the main fire, and eventually consumed approximately 800 acres and threatened numerous homes. The weather conditions included temperatures from 54°F to 70°F, humidity from 21 percent to 50 percent,

and wind speeds from 3 miles per hour to 28 miles per hour [NOAA 2009].

Throughout the day, the FF, wearing Nomex® wildland gear, performed fire extinguishment utilizing a 1-inch booster line from a brush truck (Photograph 1) and assisted in setting back fires. Crew members had food and water available for nourishment and hydration. Fire extinguishment efforts continued until approximately 1817 hours, when most fire units were released. A few units from two fire departments (including the FF's) remained on scene for mop up.

At approximately 2100 hours, a backfire was set to burn an unburned area of grass. At approximately 2200 hours, the backfire was not burning adequately and a decision was made to set another backfire. The FF was told to back up the brush truck to supply the crew with a water source (Photograph 2). As a crew member guided the FF, the FF stopped the brush truck and told the crew member the truck had an electrical short. The crew member looked at the headlights, then back at the FF, who was now leaning against the door. The crew member thought the FF was looking at the steering wheel and the floor. The crew member said something to the FF, but he did not respond at which time the crew member yelled for help. The gearshift was moved to the park position as the FF was pulled out of the truck.

At 2210 hours, Dispatch was notified that a fire fighter was down. An ambulance and a Life Flight helicopter were dispatched. At 2211 hours, the FF was assessed and found to be unresponsive, not breathing, and with a weak pulse. The pulse soon stopped and CPR began as oxygen was administered and an AED was applied. One defibrillation (shock) was administered at 2212 hours, but subsequent cardiac monitoring/analysis did not reveal a shockable heart rhythm. CPR continued as an oral airway was inserted and rescue breathing began.

Photo1. The FF using a booster hose to extinguish a very smoky grass fire

Photo 2. Location of the FF's collapse

A heartbeat returned at 2216 hours at a rate of 120 beats per minute and the FF had a blood pressure of 110 millimeters of mercury by palpation. The ambulance arrived at 2221 hours and the FF was placed into the ambulance. Crew members found the FF had a pulse and was breathing on his own. An intravenous line was placed and monitoring continued. At approximately 2235 hours, the FF stopped breathing and an unsuccessful endotracheal intubation attempt was made. An oropharyngeal airway was placed and rescue breathing was restarted.

The Life Flight helicopter arrived at 2243 hours and paramedics assumed patient care. A cardiac monitor was placed, revealing ST-segment elevation (indicating a heart attack). Cardiac medications were administered via intravenous line. At 2247 hours the FF went into asystole and additional cardiac resuscitation medications were administered as CPR resumed. The FF was intubated and tube placement was confirmed by secondary technological testing (end tidal carbon dioxide testing) [AHA 2000]. At 2251 hours, his heart rhythm changed to ventricular fibrillation and the FF received his second defibrillation (shock). His heart rhythm reverted to asystole. Advanced life support continued for an additional 26 minutes when Medical Control at the local hospital emergency department was contacted and advised of the situation. Since there was no positive change in the FF's condition, Medical Control recommended that the FF be pronounced dead. At 2317 hours the FF was pronounced dead and resuscitation efforts were discontinued.

Medical Findings. The death certificate and autopsy, completed by the medical examiner, listed "atherosclerotic and hypertensive cardiovascular disease" as the cause of death. Findings from the autopsy included severe coronary artery atherosclerosis, prior heart attacks, an enlarged heart (cardiomegaly), concentric left ventricular hypertrophy (LVH), and a carboxyhemoglobin level < 5% (insignificant). Specific findings from the autopsy report are listed in Appendix B.

The FF was 71 inches tall and weighed 240 pounds, giving him a body mass index (BMI) of 33.5 kilograms per square meter (kg/m^2). A BMI greater than 30.0 kg/m^2 is considered obese [CDC 2009]. The FF's risk factors for CAD included male gender, high blood pressure, smoking, and obesity. According to his wife, the FF was diagnosed with high blood pressure in 1997 but was not prescribed a blood pressure-lowering medication. The FF had not visited a primary care physician since that time. He did not report heart-related symptoms (chest pain, chest pressure, angina, shortness of breath on exertion, etc.) to his family or the fire department.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the volunteer fire department consisted of one fire station with 13 uniformed personnel and served a population of 1,200 residents in a geographic area of 26 square miles.

In 2008, the fire department responded to 118 calls: three structure fires, 37 wildland fires, four vehicle fires, one tank battery fire, 11 motor vehicle accidents, 53 medical calls, one fire alarm, six other calls, and two cancelled calls.

Membership and Training. The fire department requires all new FF applicants to be at least 16 years of age, have a valid state driver's license, pass a criminal background check, be a resident of the fire district or live nearby, attend three consecutive meetings, and pay the membership dues. Members between 16 and 18 years of age are restricted to support activities. Apparatus operators must be at least 18 years of age. New members receive monthly training on fire fighting subjects and are offered training at the local vocational-technical school and state fire college. There is no state minimum requirement for fire fighter certification. The FF had served 3 years as a volunteer fire fighter and had been trained/certified in Volunteer Fire Fighter Practices, Wildland Fire Fighting, Apparatus Operator, First Responder, National Incident Management System, and Hazardous Materials Awareness.

Preplacement and Periodic Medical Evaluations. Preplacement and periodic medical evaluations, annual SCBA medical clearance, annual physical ability tests, and medical clearance for return to duty are not required by the fire department.

Health and Wellness Programs. The fire department does not have a wellness/fitness program and exercise (strength and aerobic) equipment is not available in the fire station.

DISCUSSION

Cardiovascular Disease. In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age over 45, male gender, family history of CAD, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2009]. The FF had four known risk factors (age over 45, male gender, high blood pressure, and obesity) and had severe CAD at autopsy.

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 EKG changes, elevated cardiac enzymes, or coronary artery thrombus. Although the FF did not have a coronary artery thrombus at autopsy, the paramedics from Life Flight reported seeing an ST-segment elevation (a heart rhythm consistent with a heart attack) in their cardiac monitor. Therefore, it is likely the FF had an acute heart attack.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks [Siscovick et al. 1984; Tofler et al. 1992; Willich et al. 1993; Mittleman et al. 1993]. The FF had participated in wildland fire suppression utilizing a booster hoseline and setting backfires. This is considered light to moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992]. 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]. Given the FF's underlying CAD, the physical stress involved in performing wildland fire suppression and setting backfires in a smoky environment probably triggered his heart attack, resulting in cardiac arrest and sudden cardiac death.

Cardiomegaly/LVH. On autopsy, the FF was found to have concentric LVH and an enlarged heart. The FF's history of untreated high blood pressure, the pattern of his LVH (concentric), and the microscopic changes of the heart muscle are all consistent with hypertensive cardiovascular disease and chronic ischemia from underlying atherosclerotic CAD [Antman et al. 2008].

However, the microscopic examination of the FF's heart tissue did not yield results consistent with this diagnosis [Hughes 2004].

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 minimum medical requirements for candidates and current fire fighters. Of particular importance is the use of exercise stress tests to identify fire fighters with CAD and at risk for sudden cardiac death. NFPA 1582 recommends performing an exercise stress test "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (e.g., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known to have CAD
- two or more risk factors for CAD (in men more than 45 years old and women more than 55 years old)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (diastolic blood pressure greater than 90 mm Hg), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old). This exercise stress test recommendation is similar

to that recommended by the American College of Cardiology/American Heart Association (ACC/AHA) and the U.S. Department of Transportation (DOT) [Gibbons et al. 2002; Blumenthal et al. 2007].

Because this FF did not have his cholesterol level checked, it is unclear if he met the NFPA or the ACC/AHA criteria for an exercise stress test. If a stress test was indicated and had one been performed, perhaps the FF's underlying cardiac condition would have been identified, and he would have been referred for further evaluation and treatment. This may have prevented his sudden cardiac death.

Physical Fitness Programs for Structural Fire Fighters. NFPA 1583, Standard on Health-Related Fitness Programs for Fire Department Members, establishes the minimum requirements for the development of a health-related fitness and exercise program and health promotion for fire department members involved in emergency operations [NFPA 2008]. Members must be cleared annually for participation in a fitness assessment by the fire department physician and be required to participate in a periodic fitness assessment under the supervision of the fire department health and fitness coordinator [NFPA 2008]. The fitness assessment includes (1) aerobic capacity, (2) body composition, (3) muscular strength, (4) muscular endurance, and (5) flexibility. The exercise and fitness program shall include (1) education, (2) individualized participation, (3) warm-up and cool-down exercise guidelines, (4) aerobic exercise, (5) muscular strength and endurance, (6) flexibility exercise, (7) healthy back exercise, and (8) safety and injury prevention [NFPA 2008].

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the fire department 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 [NFPA 2007b].

RECOMMENDATIONS

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

Recommendation #1: Provide preplacement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000; NFPA 2007a]. These guidelines help to determine fire fighters' medical abil-

ity to perform duties without presenting a significant risk to the safety and health of themselves or others. However, fire departments are not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small, volunteer fire departments to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [USFA 2004; NFPA 2007b].

To overcome the financial obstacle of medical evaluations, fire departments 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 emergency medical service (vital signs, height, weight, visual acuity, and electrocardiogram [EKG]). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the fire department, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the fire department, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters. Medical evaluations should occur prior to performing fire suppression duties and/or other physically demanding duties including training.

Recommendation #2: Incorporate exercise stress tests following standard medical guidelines into a fire department medical evaluation program.

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters older than 45 with two or more CAD risk factors [IAFF, IAFC 2000; Gibbons et al. 2002; NFPA 2007a]. The exercise stress test could be conducted by the fire fighter's personal physician or the fire department contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the fire department physician, who should be responsible for decisions regarding medical clearance for fire fighting duties. Because this FF did not have his cholesterol level checked, it is unclear if he met the NFPA or the ACC/AHA criteria for an exercise stress test.

Recommendation #3: Phase in a comprehensive wellness and fitness program for fire fighters consistent with NFPA 1583, Standard on Health-Related Fitness Programs For Fire Fighters.

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initia-

tive, and in the NVFC's Health and Wellness Guide [IAFF, IAFC 2000; USFA 2004; NFPA 2008]. These guidelines provide information to reduce risk factors for cardiovascular disease and improve cardiovascular capacity. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, reducing the number of work-related injuries, and reducing the number of work-related lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A recent study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future non occupational healthcare costs [Kuehl 2007]. Given this fire department's structure, the NVFC program might be the most appropriate model. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #4: Perform an annual physical performance (physical ability) evaluation consistent with NFPA 1500, Standard on Fire Department Occupational Safety and Health Program.

NFPA 1500 recommends fire department members who engage in emergency operations be annually evaluated and certified by the fire department as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007b]. This is recommended to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.

Recommendation #5: Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the fire department's medical evaluation program.

The Occupational Safety and Health Administration (OSHA)'s Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using

respiratory protection [29 CFR[1] 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans. Oklahoma does not operate an OSHA-approved state plan; therefore, public sector employers (including volunteer/paid fire departments) are not required to comply with OSHA standards. Nonetheless, for safety reasons, we recommend voluntary compliance with this OSHA standard.

[1]Code of Federal Regulations. See CFR in references.

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INVESTIGATOR INFORMATION

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Tommy Baldwin, MS, led the investigation and coauthored 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. Thomas Hales, MD, MPH, provided medical consultation and coauthored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Heath, and vice chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

APPENDIX A

TIMELINE OF EVENTS

February 20, 2009

- 1026 hours: Three fires are reported
- 1028 hours: Fire department alerted
- 1029 hours: Caller advised fires are spreading rapidly
- 1036 hours: Fire department responding
- 1119 hours: Dispatch advises fire has jumped the highway
- 1204 hours: Mutual aid requested
- 1210 hours: Mutual aid grass truck (E253) responding
- 1214 hours: Mutual aid grass truck (E260) responding
- 1218 hours: E253 arrives
- 1220 hours: E260 arrives
- 1244 hours: Caller advised the fire is getting close to a structure
- 1305 hours: Requested mutual aid from two additional fire departments
- 1306 hours: Mutual aid responding
- 1315 hours: Mutual aid engine responding
- 1318 hours: Mutual aid tanker responding
- 1321 hours: Caller advised the fire is getting close to her house
- 1334 hours: Mutual aid engine (E252) responding
- 1343 hours: Mutual aid chief (261) responding
- 1346 hours: E252 arrived
- 1351 hours: Chief 261 arrived
- 1416 hours: Fire jumped the highway
- 1419 hours: Caller advised the fire is getting close to her house
- 1433 hours: Ambulance en route for standby
- 1518 hours: Mutual aid grass truck (E254) responding
- 1524 hours: E254 arrived
- 1549 hours: Caller advised the fire is near his house
- 1614 hours: Paged additional mutual aid
- 1705 hours: Caller advised another fire has been set
- 1713 hours: Fire jumped the highway again
- 1726 hours: Mutual aid tanker (E259) responding
- 1738 hours: E259 arrived
- 1817 hours: Mutual aid units released
- 2210 hours: Ambulance requested for fireman down
- 2211 hours: Life Flight requested
- 2212 hours: AED placed into service
- 2215 hours: Ambulance en route
- 2216 hours: FF's pulse returned

- 2221 hours: Ambulance arrived
- 2242 hours: Life Flight arrived

Appendix B

Autopsy Findings

- Coronary artery disease
  - — Severe (95%–100%) focal narrowing of the left anterior descending coronary artery
  - — Severe (95%–100%) focal narrowing of the right coronary artery
  - — Moderate (50%) focal narrowing of the circumflex coronary artery
  - — Mild (25%) focal narrowing of the left main coronary artery
  - — No evidence of a thrombus (blood clot) in the coronary arteries
  - — Patchy areas of transmural fibrosis in the anterior and posterior walls which are consistent with old (remote) heart attacks
- Cardiomegaly (enlarged heart)(heart weighed 700 grams [g]; predicted normal weight is 406 g (ranges between 308 g and 536 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Concentric left ventricular hypertrophy
  - — Left ventricular wall thickened (2.3 cm; normal by autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]; normal by echocardiographic measurement is 0.6–1.1cm) [Armstrong and Feigenbaum 2001]
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative
- Carboxyhemoglobin (blood test for carbon monoxide exposure) < 5% saturation (a level considered insignificant by the medical examiner)
- Resuscitation injuries (bilateral rib fractures, sternal fracture)

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