



Reserve Fire Fighter Suffers Sudden Cardiac Death While Working on a Fuel Reduction Crew – Arizona

SUMMARY

On June 19, 2004, a 39-year-old male reserve (volunteer) Fire Fighter (FF) assisted in forest fuel load reduction near a residential area. After about 6 hours of carrying and feeding trees and branches into a wood chipper, the FF suddenly collapsed. Crew members notified 911, who dispatched an ambulance and the fire department (FD) to the area. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) on-scene, in the ambulance, and in the local hospital's emergency department (ED), the FF died. The death certificate, completed by the Medical Examiner, and the autopsy, completed by the Forensic Pathologist, listed "atherosclerotic heart disease" as the cause of death. The NIOSH investigator concluded that the FF's sudden cardiac death was due to his underlying atherosclerotic coronary artery disease (CAD) possibly triggered by the physical exertion associated with chipping the wood and carrying the tree branches.

NIOSH investigators offer the following recommendations to prevent similar incidents or to address general safety and health issues:

- *Provide pre-placement and annual medical evaluations to ALL fire fighters to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.*
- *Consider conducting exercise stress tests (EST) for male fire fighters with two or more risk factors for CAD.*
- *Provide fire fighters with medical evaluations and clearance to wear self-contained breathing apparatus (SCBA).*

- *Ensure the District contract physician reviews all return to work clearances.*
- *Use a secondary (technological) test to confirm appropriate placement of the endotracheal (ET) tube during emergency intubations.*

INTRODUCTION & METHODS

On June 19, 2004, a 39-year-old male FF suffered sudden cardiac death while performing wildland fuel reduction operations. Despite CPR and ALS performed by crew members and EMS, and hospital personnel, the FF died. NIOSH was notified of this fatality on June 23, 2004, by the United States Fire Administration. NIOSH contacted the affected FD on June 30, 2004, to obtain further information, and on July 7, 2005, to initiate the investigation. On July 18, 2005, a Safety and Occupational Health Specialist and an Association of Teachers of Preventive Medicine (ATPM) intern from the NIOSH Fire Fighter Fatality Investigation Team traveled to Arizona to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met and/or interviewed the following persons:

The **Fire Fighter Fatality Investigation and Prevention Program** is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Website at www.cdc.gov/niosh/firehome.html or call toll free 1-800-35-NIOSH



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- Fire Chief
- Crew members
- FF's family members

NIOSH personnel reviewed the following documents:

- FD incident report
- FD training records
- FD annual response report for 2004
- FD standard operating guidelines
- Ambulance report
- Hospital records
- Death certificate
- Autopsy report
- Primary care physician records

INVESTIGATIVE RESULTS

On June 19, 2004, the FF arrived at his fire station (Station 1) at 0700 hours. Four fire fighters were scheduled to perform wildland fuel reduction (wood cutting and chipping). The four FFs left the station and arrived at the job site at about 0715 hours. The FF, wearing brush gear with helmet, goggles, and gloves, was assigned as the "Crew Leader" for the chipper operations. The crew began chipping at about 0730 hours, and five additional FFs arrived to assist.

The crew stopped work at about 0830 hours to eat breakfast. About an hour later, the FF complained of "really bad heartburn." The crew chipped during the remainder of the morning, stopping a few times to drink fluids. The temperature by 1100 hours was 72° Fahrenheit and the relative humidity was 19%. The FF's "heartburn" persisted, and at 1230 hours he took a prescription medication (Nexium) for relief.

At about 1409 hours, the FF was feeding the chipper as two FFs pulled brush to him. As they dropped off the branches, one FF turned away. When he turned back around, he realized the FF had collapsed face down onto the rear of the chipper. After realizing the FF was unresponsive, the crew turned the chipper off

and guided the FF off the chipping machine, while another FF unsuccessfully tried to call 911 via mobile radio. He then called 911 via telephone.

The crew assessed the FF and found his breathing to be slow and labored, and he had a weak pulse. His breathing became slower, and the crew began CPR at about 1410 hours. A FF retrieved the medical jump kit, which contained basic medical supplies and oxygen equipment from the truck and assisted the FF's breathing with a bag-valve-mask and oxygen. Engine 311 arrived on the scene at about 1415 hours. Crew members attached an automated external defibrillator (AED) to the FF, which revealed a shockable heart rhythm, and three shocks (defibrillation attempts) were administered. The ambulance arrived on the scene at 1421 hours, the FF was intubated (breathing tube inserted into the trachea), and intravenous (IV) cardiac medications were administered. Bilateral breath sounds and no epigastric sounds were confirmed by auscultation. Condensation was visible in the intubation tube but no secondary confirmation (technology) tests recommended by the American Heart Association were performed. After assessment revealed a non-shockable heart rhythm, the FF was placed onto a backboard and cot, then into the ambulance. The ambulance departed the scene at 1432 hours en route to the hospital ED.

The ambulance arrived at the hospital ED at 1437 hours. Initial evaluation in the ED found the FF to be unresponsive, with no pulse or respirations. Cardiac monitoring revealed asystole (no heart beat) and CPR and ALS continued. A chest x-ray revealed proper endotracheal tube placement and no other abnormalities. Despite CPR for 43 minutes and ALS for 32 minutes, the FF's condition did not improve. He was pronounced dead by the attending physician at 1453 hours, and resuscitation measures were stopped.

Medical Findings. The death certificate, completed by the Medical Examiner, listed "atherosclerotic heart disease" as the cause of death. The autopsy, performed by the Forensic Pathologist on June 21, 2004, included the following findings:



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- Atherosclerotic heart disease:
 - 99% occlusion of left anterior descending coronary artery
 - 99% occlusion of right coronary artery
 - Left ventricular hypertrophy (wall thickness 1.4 centimeters [cm] [normal 0.6cm-1.1cm])¹
- Chronic pyelonephritis, left kidney
- Negative drug and alcohol tests

Microscopic examinations revealed the following:

- Moderate myocyte nuclear hypertrophy
- Increased perivascular fibrosis

Primary care physician (PCP) medical evaluations from 2002 and a family interview revealed two CAD risk factors in addition to male gender: family history of CAD and cigarette smoking. The FF smoked a few cigarettes per day.

The FF had physical examinations for a commercial driver's license in 2002 and 2004. Nothing abnormal was noted during the examinations, and he was cleared to drive a commercial truck. His most recent EKG was normal. The FF was 70 inches tall and weighed 150 pounds, giving him a "normal" body mass index (BMI) of 21.5 kilograms per square meter (kg/m²)². He had complained of indigestion (heartburn) most all day; he had a history of gastroesophageal reflux disease (GERD) (per ED report). According to family members, the FF never complained of chest pain, only heartburn.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation this combination FD consisted of 12 uniformed career personnel and 20 paid-on-call reserves. They serve a year round population of 15,000 (summertime population of 45,000) in a 42 square-mile area with three fire stations. In 2004, the FD responded to 1,210 calls: 51 structure fires, 52 wildland fires, 16 vehicle fires,

22 refuse fires, 40 hazardous materials calls, 29 false alarms, 66 service calls, 174 vehicle accidents, 728 emergency medical calls, and 32 other calls.

Employment, Membership, and Training. The FD requires all career fire fighter applicants to complete an application; be at least 18 years of age; possess a high school diploma or equivalent; possess a valid state driver's license; and have certifications as Fire Fighter 1 (FF1) and Fire Fighter 2 (FF2), Emergency Medical Technician, Hazardous Materials First Responder, and Wildland Red Card at the time of application. The FF candidate must then pass a written test, a practical test, an oral interview, a physical agility test (PAT) (described below), and a medical examination prior to being hired. Career fire fighters work 24 hours on duty, 0800 hours to 0800 hours, and are off duty for 48 hours.

Reserve fire fighter applicants begin as a "red shirt," which means they perform only support duties and no emergency responses. The applicant must pass an oral interview and a PAT prior to being selected as a member. The member must then pass a training program to certify the member as FF1 and FF2, Hazardous Materials First Responder, and a Red Card Wildland fire fighter. The one-semester training program is conducted at a local college.

The reserve fire fighter, in order to advance to the next level as a "blue shirt" fire fighter, must pass an oral interview and work a 24-hour shift with each shift prior to being selected as a "blue shirt reserve." The member is then allowed to work a vacation or sick shift in place of a career FF and may staff other openings as needed.

Physical Agility Test (PAT). All applicants are required to wear full protective clothing consisting of turnout coat, turnout pants, hood, gloves, SCBA, and helmet while taking the PAT. Applicants may not run at any time during the PAT. The PAT consists of the following eight timed tasks:



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1. Stair climb
2. Advance 1¾-inch charged hoseline 75 feet
3. Equipment carry 85 feet
4. Raise and extend a 24-foot ladder
5. Perform forcible entry evolution
6. Perform victim search
7. Victim drag 35 feet
8. Ceiling breach and pull

The travel distance between events is 85 feet and the total time to completion is 10 minutes, 20 seconds.

State fire fighter certification (FF1 and FF2) is voluntary for all fire fighters. There is no annual recertification requirement. The FF was certified as a Fire Fighter 2, Driver/Operator, Emergency Medical Technician, and a Hazardous Materials First Responder. He was a “blue shirt” fire fighter but had been taken off the line due to his hip injury. He had 14 years of fire fighting experience and had been a member of two other FDs in the past.

Pre-placement Physical Examination. A pre-placement physical examination is required by this FD for career and hazardous materials technician applicants only. The contents of the examination are as follows:

- Complete medical history
- Physical examination
- Vital signs
- Vision screening
- Audiogram
- Urinalysis
- Urine drug screen

A District-contracted physician performs the medical examinations and forwards the clearance for duty decision to the Fire Chief.

Periodic Evaluations. Annual medical evaluations are required for career and hazardous materials technician members; their frequency is based on age. The medical evaluations are given every 3 years for members up through age 29; every 2 years for members age 30

– 39; and every year for members over age 40. The components are the same as the pre-placement medical evaluation. The same District-contracted physician performs the medical evaluations and forwards the clearance for duty decision to the Fire Chief, who makes the final determination regarding clearance for duty. Annual SCBA clearance is not required.

An annual PAT and the US Forest Service pack test for Wildland Red Card certification are required for career and “blue shirt reserve” members. The FD requires participation in a fitness program where the FD pays half of the membership dues at a local fitness club. The FD requires 1 hour of exercise per day. A return-to-duty medical clearance is required from the fire fighter’s PCP for duty-related injuries and for illnesses that prevent fire fighters from performing their duty for three shifts. The clearance is provided to the Fire Chief, who reviews it and makes a final determination regarding return to work.

DISCUSSION

Coronary Artery Disease and the Pathophysiology of Sudden Cardiac Death. In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.³ Risk factors for its development include age over 45, male gender, family history of CAD, smoking, high blood pressure (systolic >140 mmHg or diastolic > 90 mmHg), high blood cholesterol (total cholesterol > 240 mg/dL), obesity/physical inactivity, and diabetes.^{4,5} The FF had three of these risk factors (male gender, family history, and smoking).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.⁶ However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.⁷ 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.⁸ This sudden blockage is primarily due to blood clots (thrombosis) forming on top of ath-



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erosclerotic plaques. The sequence of events of the FF's death is consistent with, but not diagnostic of, a heart attack. Heart attacks are confirmed/diagnosed by any of the following: autopsy findings (thrombus formation), blood tests (cardiac isoenzymes), or EKG findings. The autopsy did not reveal a thrombus, the FF died prior to the cardiac isoenzymes becoming positive, and the FF did not have a heart rhythm on which to conduct an EKG. Therefore, based on the clinical scenario, the FF probably had a heart attack, but this cannot be definitively stated.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.⁹⁻¹² The FF worked for about 6 hours carrying and chipping brush prior to his collapse. This activity is considered moderate physical exertion.^{13,14} The physical stress of chipping brush and his underlying atherosclerotic CAD contributed to this fire fighter's cardiac arrest and sudden death.

Occupational Medical Standards for Structural Fire Fighters and Use of Exercise Stress Tests to Screen for CAD. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the National Fire Protection Association (NFPA) developed NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments*.¹⁵ NFPA 1582 recommends, for informational purposes only, screening asymptomatic fire fighters with two or more CAD risk factors for obstructive CAD by an EST. NFPA defines these CAD risk factors as: family history of premature (first degree relative < age 60) cardiac event, hypertension (diastolic blood pressure > 90 mmHg), diabetes mellitus, cigarette smoking, and hypercholesterolemia (total cholesterol > 240 mg/dL).¹⁵ This guidance is similar to recommendations from the American College of Cardiology/American Heart Association (ACC/AHA) and the Department of Transportation (DOT) regarding EST in asymptomatic individuals.^{16,17}

Because the FF had two NFPA CAD risk factors (family history and smoking), one might expect NFPA 1582 to recommend an EST. However, neither the ACC/AHA nor the DOT recommend EST in asymptomatic individuals under the age of 45, regardless of the number of CAD risk factors. Given this conflicting guidance, it is unclear if an EST would have been indicated in this case. In addition to EST, NFPA 1582 also recommends a mandatory comprehensive wellness/fitness program that should include smoking cessation, dietary education, and exercise. Although the FD had a mandatory wellness/fitness program, this requirement only applied to blue shirt and full-time members. The FF was a blue shirt member. It is unclear if a wellness/fitness program alone would have prevented the FF's death at this time.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to prevent similar incidents or to address general safety and health issues:

Recommendation #1: Provide pre-placement and annual medical evaluations to ALL fire fighters to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

Guidance regarding the content and frequency of pre-placement and periodic medical evaluations and examinations for structural fire fighters can be found in NFPA 1582,¹⁵ in the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) *Wellness/Fitness Initiative*,¹⁸ and the National Volunteer Fire Council (NVFC) *Health and Wellness Guide*.¹⁹ The pre-employment/placement medical examination should include a baseline chest x-ray and a baseline resting EKG for all fire fighters. However, the FD is not legally required to follow any of these standards.



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Applying NFPA 1582 involves economic issues. These economic concerns go beyond the costs of administering the medical program; they involve the personal and economic costs of dealing with the medical evaluation results. NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, Chapter 8-7.1 and 8-7.2²⁰ and the NVFC *Health and Wellness Guide*¹⁹ address these issues.

The physical evaluation could be conducted by the FF's PCP or the District-contracted physician. If the evaluation is performed by the FF's PCP, the results must be communicated to the District physician, who makes the final determination for clearance for duty.

Recommendation #2: Consider conducting exercise stress tests for male fire fighters over the age of 45 years with two or more risk factors for coronary artery disease.

NFPA 1582 and the IAFF/IAFC *Wellness/Fitness Initiative* recommend EST for fire fighters with two or more CAD risk factors.^{15,18} The American Heart Association (AHA) states EST may be indicated for individuals over 45 years of age with two or more risk factors for CAD.¹⁶ The EST could be conducted by the fire fighter's personal physician or the District contract physician. If the fire fighter's personal physician conducts the test, the results should be communicated to the appropriate FD representative.

Recommendation #3: Provide fire fighters with medical evaluations and clearance to wear SCBA.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees who use respiratory protection.²¹ This includes fire fighters who utilize SCBA while performing their duties. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved State plans. Arizona is a state-plan

state; therefore, public sector employers are required to comply with OSHA standards. We have provided the FD with a copy of the OSHA-approved respiratory protection clearance form and recommend the FD provide SCBA clearance medical evaluations to the District contract physician.

Recommendation #4: Ensure the District contract physician reviews all return to work clearances.

NFPA 1582 requires the FD physician to review and approve medical evaluations conducted by a physician or medical provider other than the FD physician.¹⁵ The FD should set protocols regarding length of time absent from duty and/or medical conditions that require the FD physician to evaluate a member.¹⁵

Currently, the primary care physician provides medical clearance for return to work in this FD. The FD should ensure the District contract physician reviews all return to work clearances to ensure continuity and increased safety and health.

Recommendation #5: Use a secondary (technological) test to confirm appropriate placement of the endotracheal (ET) tube during emergency intubations.

To reduce the risk of improper intubation, the American Heart Association and the International Liaison Committee on Resuscitation published recommendations in the Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care.²² These guidelines recommend confirming tube placement by primary and secondary methods. Primary confirmation is the 5-point auscultation: left and right anterior chest, left and right midaxillary, and over the stomach. Secondary confirmation requires a technology test, either an end-tidal carbon dioxide detector or an esophageal detector device. In this incident, the FF had bilateral breath sounds and no epigastric sounds by auscultation, and the tube became visibly fogged. However, according to records obtained by the NIOSH investigator, no



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secondary confirmation test was performed. In no way should this recommendation imply that improper placement of the ET contributed to the FF's death. We raise this issue only to ensure that future ALS resuscitation efforts follow AHA guidelines.

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