



Fire Fighter Collapses and Suffers Sudden Cardiac Death After Responding to a Vehicle Fire – Kentucky

SUMMARY

On March 25, 2004, a 45-year-old male volunteer fire fighter (FF) responded to a roadside vehicle fire. As his engine company exited the fire station, the call was cancelled. The engine was backed into the fire station and, as the FF began to exit the apparatus, he suddenly collapsed. Despite cardiopulmonary resuscitation (CPR), defibrillation, and advanced life support (ALS) performed by crew members, emergency medical technicians (EMTs), paramedics, and hospital emergency department (ED) personnel, the FF died. The autopsy, completed by the Coroner, listed “a cardiac event (arrhythmia) due to hypertensive and atherosclerotic cardiovascular disease” as the cause of death. NIOSH investigators concluded that the physical stress of responding to the alarm, donning turnout gear, and underlying atherosclerotic coronary artery disease (CAD) all contributed to the FF’s sudden cardiac death.

The first five recommendations below are preventive measures recommended by NIOSH and other fire service groups to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among FFs. The final recommendation addresses a procedural safety issue.

- 1. Provide pre-placement and periodic medical evaluations to ALL FFs consistent with National Fire Protection Association (NFPA) 1582 or equivalent to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.**
- 2. Ensure that FFs are cleared for duty by a physician knowledgeable about the physical demands of fire fighting and the various components of NFPA 1582, and that the results of the exam are discussed with the FF.**
- 3. Consider conducting exercise stress tests for male FFs above the age of 45 years with two or more risk factors for CAD.**
- 4. Phase in a mandatory wellness/fitness program for FFs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.**
- 5. Perform an annual physical performance (physical ability) evaluation to ensure FFs are physically capable of performing the essential job tasks of structural fire fighting.**
- 6. Use a secondary (technological) test to confirm appropriate placement of the endotracheal (ET) tube during emergency intubations.**

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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INTRODUCTION AND METHODS

On March 25, 2004, a 45-year-old male FF suffered sudden cardiac death after responding to his fire station during an alarm. Despite CPR and ALS performed by crew members, ambulance service personnel, and hospital ED personnel, the FF died. NIOSH was notified of this fatality on March 26, 2004, by the United States Fire Administration. NIOSH contacted the affected Fire Department on March 26, 2004, to obtain further information, and on April 16, 2004, to initiate the investigation. On November 3, 2004, a Safety and Occupational Health Specialist and an Occupational Nurse Practitioner from the NIOSH Fire Fighter Fatality Investigation Team traveled to Kentucky to conduct an on-site investigation of the incident.

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

- The Fire Chief
- Crew members on duty with the FF
- The FF's wife

During the site visit, NIOSH personnel reviewed the following records:

- FD incident reports
- FD training records for this FF
- FD annual response report for 2003
- FF's past medical records
- Ambulance report for this incident
- Death certificate
- Autopsy report

INVESTIGATIVE RESULTS

Incident. On March 25, 2004, the Fire Department (FD) was dispatched to an unknown type of fire beside a roadway at 0746 hours. The FF received the call on his pager and responded from his home. The Shift Lieutenant (LT) and Engine 102, staffed

with four FFs, responded, arriving at the scene at 0750 hours. Engine 101, staffed with four FFs (including the deceased) responded at 0753 hours but was cancelled just as the apparatus pulled out of the station onto the ramp. With this information, the Engineer returned Engine 101 to the station's apparatus bay. As the apparatus stopped, the FF opened his door (the driver's side crew cab) and collapsed, falling out of the apparatus onto the floor (0755 hours). As the Engineer got out of the apparatus, he saw the FF and yelled for a FF/EMT to assist him.

Witnesses thought the FF was having a seizure. His arms and legs were flailing, his teeth and fists were clenched, his eyes were open with pupils dilated, he was gurgling, and he had a hematoma (bruise) on his forehead. The Engineer radioed Dispatch for a paramedic unit to respond to a possible seizure. A FF/EMT on duty at the station inserted a nasopharyngeal airway, at which time the FF stopped flailing, stopped breathing, and became pulseless. The FF/EMT checked for vital signs, and finding them negative, began CPR. Crew members connected a semi-automatic external defibrillator (SAED) to the FF. The SAED advised to shock, and one shock (defibrillation attempt) was delivered. The SAED reanalyzed with no shock advised and since the FF had no pulse, CPR was resumed. The FF was transferred onto a stretcher, placed into the ambulance, and transported to the hospital at 0804 hours.

Paramedics met the ambulance en route and ALS procedures were begun (intravenous line [IV] established and intubation was performed, but without secondary tests to confirm tube placement). The SAED performed multiple analyses but advised no further shocks. Multiple doses of ALS medications were administered by IV, but failed to alter the rhythm. The FF



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continued in a non-shockable rhythm until he arrived 21 minutes later in the hospital's ED (0825 hours).

Upon arrival at the hospital, the FF had no heart beat (asystole) and no respiration. Intubation was checked by auscultation with breath sounds heard throughout the lungs and absent over the abdomen. Advanced life support medications were continued in the emergency room without results until time of death at 0835 hours (per death certificate), although there appears to be an error in the ED records, which put cessation of efforts at 1140 hours.

Medical Findings. The autopsy, completed by the Coroner, listed, "A cardiac event (arrhythmia) due to hypertensive and atherosclerotic cardiovascular disease" as the cause of death. Significant findings included the following:

- Cardiomegaly (an enlarged heart) weighing 560 grams (normal is less than 400 grams)¹
- Dilated right ventricle
- Scar of white fibrous tissue interlacing with brown myocardium (evidence of a remote [old] myocardial infarction [heart attack])
- Moderate to severe coronary artery atherosclerosis (left and right)
- Possible thrombus in the right coronary artery

The FF had the following risk factors for coronary artery disease (CAD): family history, male gender, high blood pressure, high blood cholesterol, diabetes mellitus, physical inactivity and obesity (Body Mass Index [BMI] of 31 kilograms/meter²). A BMI above 30 kg/m² indicates obesity². At the time of death, the FF was prescribed an oral agent for diabetes mellitus, a statin for high blood cholesterol, a calcium-channel blocker and a beta-blocker for angina and hypertension, and

nitroglycerin (as needed) for angina.

The FF was first diagnosed with CAD in June 1990, when he went to the emergency room for chest pain. He was diagnosed with an acute inferior MI and an emergent cardiac catheterization showed two possible clots in both the right coronary artery (RCA) and right posterior descending artery. He was successfully treated with an intracoronary "clot-busting" agent, but his left ventricular function remained impaired (left ventricle ejection fraction [LVEF] was "moderately" reduced). One year later, the FF underwent a thallium exercise stress test (EST). Using the Bruce Protocol, he exercised 9 minutes (8.6 metabolic equivalents [METS]) and stopped due to fatigue after reaching 85% of his target heart rate (165 beats per minute [bpm]). His electrocardiogram (EKG) was negative for ischemia changes, and his thallium scan showed no evidence of reversible myocardial ischemia.

In December 1992 another episode of chest pain resulted in emergent cardiac catheterization and subsequent angioplasty. The angioplasty reduced a 70%-80% stenosis in the RCA to 20%. At this time his LVEF was estimated to be 40% (normal is at least 50% or higher). The RCA lesion reoccluded four years later.

The FF took annual ESTs, all of which were normal until January 1997 when a heart rhythm disturbance was found (bigeminy premature ventricular contractions). An echocardiogram later that year found mild hypertrophy of the left ventricle and moderate left atrial enlargement with diffuse hypokinesis possibly related to ischemia. The LVEF was still estimated at 40%-45%. He was cleared for duty as a FF in August 1997. Cardiac evaluations in 1999 (EST and echocardiogram), 2000 (cardiac catheterization), and 2003 (EST and echocardiogram) had similar



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findings, except the 2003 echocardiogram showed diminished LVEF (35%) and the 2003 EST only achieved a heart rate of 136 BPM (the target rate was 149 BPM).

Throughout this time period (1997-2003) the FF was cleared for full fire fighting duties. Only one restriction of 1-week duration was found in the records, dated April 2001. Other return to work certificates may have been completed, but no mention was made in the physician's or fire department's records. The FF was also diagnosed with hypertension in 1991 and diabetes mellitus in 2001. According to his wife and fellow crew members, the FF did not report any chest pain or other symptoms suggestive of angina in the days prior to this incident.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this combination FD consisted of 49 uniformed personnel (9 career and 40 volunteer). The FD served a population of 25,000 in an area of 25 square miles. There was one fire station.

In 2003, the FD responded to 406 calls: 12 structure fires, 12 vehicle fires, 6 rubbish fires, 3 wildland fires, 6 other fires, 176 medical calls, 39 false alarms, 31 mutual aid calls, 18 hazmat responses, 31 other hazardous calls, and 72 other calls.

Training. The FD requires all career FF/EMT applicants to be at least 21 years of age; possess a valid state driver's license; pass a written exam, a physical ability test, an oral interview, and a background check; have previous firefighting experience and a state 150-hour FF certificate; and possess a current state EMT certificate prior to being selected. The member must then pass an illicit drug screening. The member has 1 year after being hired to obtain a state 400-hour FF certificate. Career FFs work the following schedule: 24 hours on duty, 48 hours off duty,

0730 hours to 0730 hours.

The FD requires volunteer FF applicants to pass an oral interview and a dexterity test prior to being selected. The member must also present proof of a current physical examination from the primary care physician. The member then begins a 6-month training program, including the state Fire Fighter I program, which accounts for 125 hours of the 150-hour minimum for state volunteer FF certification. Training occurs twice weekly for 6 months, after which, training occurs once a week. At the end of the 6-month period, the member must pass the written Fire Fighter I exam and a skills test to become a full member. The FD requires a minimum of 20 hours of training for a member to ride fire apparatus.

The state requires 100 hours of training annually for career FF recertification, and 20 hours annually for volunteer FF recertification. Paramedics, EMTs and First Responders must recertify every 2 years according to state guidelines.

The FF, certified as a Fire Fighter II, was at the Hazardous Materials Operations Level II and had 7 years of fire fighting experience.

Pre-placement Physical Examination. A pre-placement physical examination is required by this FD for all career applicants. The pre-placement physical examination is encouraged but not required for volunteer FF applicants. The contents of the examination are as follows:

- A complete medical history
- Physical examination
- Vital signs
- Vision screening
- Audiogram
- Blood analysis: lipid panel and complete blood count
- Urine dipstick



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- Urinalysis
- Chest x-ray
- EKG
- Hepatitis B screening
- Tuberculosis (TB) skin test
- Pulmonary function test (spirometry)

Periodic Medical Evaluations. Annual medical evaluations are required by this FD for career FFs only. The components of the evaluation are the same as the pre-placement physical examination. The periodic medical evaluations are encouraged for volunteer FFs, but the volunteer is responsible for these expenses.

A “return-to-duty” medical clearance is required for illnesses and injuries that prevent FFs from performing their duty. The member’s primary care physician provides the Fire Chief with restrictions, if any, following any illness or injury affecting job performance. Annual self-contained breathing apparatus fit tests are required.

Fitness/Wellness Programs. Exercise (strength and aerobic) equipment is located in the fire station. A physical agility test is not required for current fire department members. No wellness/fitness programs are in place.

DISCUSSION

Coronary Artery Disease (CAD) Risk Factors 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 coronary artery disease, smoking, high blood pressure (systolic >140 millimeters of mercury [mmHg] or diastolic > 90 mmHg), high blood cholesterol (total

cholesterol > 240 milligrams per deciliter [mg/dL]), obesity/physical inactivity, and diabetes.^{4,5} The FF had most of these risk factors.

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 the top of atherosclerotic plaques. The FF had an extensive history of coronary artery disease including a prior MI. On autopsy, he had moderate to severe atherosclerotic CAD and a possible thrombus in one coronary artery. This possible thrombus, plus his extensive history, suggests his sudden cardiac death was due to another heart attack. The term “possible” is used because autopsy findings (thrombus formation), blood tests (cardiac isoenzymes), or ECG findings are required to confirm a heart attack.

Atherosclerosis in a coronary artery may cause ischemic heart disease, which occurs when the blood flow within a coronary artery is limited to the point where the oxygen needs of the heart muscle cannot be met. Chronic ischemic heart disease causes hypertrophy of the heart muscle and cardiomegaly. All of these factors, independently and in combination (ischemia, cardiomegaly, or myocardial infarction), increase the risk of cardiac arrhythmia and sudden cardiac death. The FF had a reduced LVEF. A depressed LVEF is also a predictor of sudden cardiac death, particularly when found with CAD.⁹

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.¹⁰ Fire fighting activities



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are strenuous and often require FFs to work at near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and persist through the course of fire suppression activities.¹¹⁻¹³ Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.¹⁴⁻¹⁷ The FF had just responded to the fire station, donned his turnout gear, and gotten into the apparatus prior to his collapse. Although this would be considered light physical exertion,^{18,19} the increase in heart rate due to responding to the alarm, and his significant underlying atherosclerotic CAD may have triggered his heart attack and sudden death.

Use of Exercise Stress Tests (EST) to Screen for CAD. To reduce the risk of heart attacks and sudden cardiac arrest among FFs, the National Fire Protection Association (NFPA) has developed the NFPA 1582 guideline *Comprehensive Occupational Medicine Program for Fire Departments*.²⁰ To screen for CAD, NFPA 1582 recommends an EST for asymptomatic FFs with two or more risk factors for CAD (family history of premature [first degree relative less than age 60] cardiac event, hypertension [diastolic blood pressure greater than 90 mmHg], diabetes mellitus, cigarette smoking, and hypercholesterolemia [total cholesterol greater than 240 mg/dL]).²⁰ This recommendation is similar to those of the American Heart Association/American College of Cardiology (AHA/ACC) and the Department of Transportation (DOT) regarding EST in asymptomatic individuals.^{21,22}

Since the FF had three of the risk factors, an EST would have been recommended by NFPA 1582. The FF's last EST, in November 2003, was nondiagnostic; his heart rate only advanced to 136 BPM but the target rate was 149 BPM. Although

no chest pain or ST segment changes were noted and the cardiologist stated that he remained stable from a clinical standpoint with no new problems identified, if the FF had exercised to the target heart rate, signs of worsening CAD may have been identified.

As noted above, growth of atherosclerotic plaques can occur in an abrupt pattern.⁷ It is entirely possible that this FF's plaque abruptly grew after the November 2003 EST. In this scenario, his progressive CAD would not have been identified even with a symptom-limiting EST. In either case, a mandatory comprehensive wellness/fitness program, including weight reduction, dietary education, and exercise would have benefited this FF.

Other Issues. The FF had cardiomegaly (enlarged heart) with a dilated right ventricle and left ventricular hypertrophy. Both hypertrophic and dilated cardiomyopathies are associated with sudden cardiac death. It is possible that these cardiomyopathies contributed to this FF's sudden cardiac death, but his untimely death is much more likely due to an MI-induced heart arrhythmia.

NFPA 1582 has identified, "Medical conditions that potentially interfere with a member's ability to safely perform essential job tasks."²⁰ This fire fighter was diagnosed with many conditions that should have restricted his fire fighting duties. These conditions include: 1) current angina pectoris, 2) coronary artery disease with a reduced LVEF, 3) cardiac hypertrophy, and 4) poorly controlled diabetes mellitus. Had the fire department or the FF's medical provider required a maximal EST to 12 METS, as recommended by NFPA 1582, or had the FF's medical provider restricted his fire fighting duties, the FF may not have died at this time.



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RECOMMENDATIONS

The first five recommendations are preventive measures often recommended by fire service groups to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among FF. The final recommendation addresses safety issues unique to this event.

Recommendation #1: Provide pre-placement and periodic medical evaluations to ALL FFs consistent with NFPA 1582 or equivalent to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

We applaud the efforts of the fire department for implementing a comprehensive medical evaluation and examination program for its career members. Since volunteers also serve in immediately dangerous to life and health (IDLH) environments, they need a similar evaluation to ensure they will not become suddenly incapacitated due to a medical condition. Guidance regarding the content and frequency of pre-placement and periodic medical evaluations and examinations for structural FFs can be found in NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments*,²⁰ and in the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) Wellness/Fitness Initiative.²³ Despite our recommendation to follow these consensus standards, the FD is not legally required to follow these standards.

Recommendation #2: Ensure that FFs are cleared for duty by a physician knowledgeable about the physical demands of fire fighting and the various components of NFPA 1582 and that the results of the examination are discussed with the FF.

Many private physicians are not familiar with a FF's job duties or with guidance documents such as NFPA 1582. To ensure physicians are aware of these guidelines, we recommend that the FD provide the contract and private physicians copies of NFPA 1582. In addition, we recommend the FD carefully evaluate the opinion of the private physician regarding return to work. Thus, we recommend that all return-to-work clearances be reviewed by a FD-contracted physician. Thereby, the final decision regarding medical clearance for return to work lies with the FD physician with input from many sources including the FF's private physicians.

Recommendation #3: Consider conducting exercise stress tests for male FFs above 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 FFs with two or more CAD risk factors.^{20,23} The AHA states EST may be indicated for men with two or more risk factors for CAD who are over 45 years of age.²¹ The EST could be conducted by the FF's personal physician or the City/County contract physician. If the FF's personal physician conducts the test, the results, not just the clearance letter, must be communicated to the Fire Department physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

Recommendation #4: Phase in a mandatory wellness/fitness program for FFs to reduce risk factors for cardiovascular disease and improve cardiovascular conditioning.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Additionally, physical inactivity is associated with other risk factors: obesity and diabetes.²⁴



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NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters*, require a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.^{25,26}

In 1997, the International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) published a comprehensive Fire Service Joint Labor Management Wellness/Fitness Initiative to improve FF quality of life and maintain physical and mental capabilities of FFs. Ten fire departments across the United States joined this effort to pool information about their physical fitness programs and to create a practical fire service program. They produced a manual and a video detailing elements of such a program.²³ The Fire Department should review these materials to identify applicable elements. Other large-city negotiated programs can also be reviewed as potential models. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.²⁷⁻²⁹ A similar cost savings has been reported by the wellness program at the Phoenix Fire Department, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.³⁰

In January 2004, the National Volunteer Fire Council and US Fire Administration published a comprehensive *Health and Wellness Guide for the Volunteer Fire Service*.³¹ The guide provides suggestions for program initiation and features. This guide is useful for not only volunteer fire departments, but also small combination fire departments that could benefit from some type of fitness and wellness program.

Recommendation #5: Perform an annual physical performance (physical ability) evaluation to ensure FFs are physically capable of performing the essential job tasks of structural fire fighting.

NFPA 1500 requires fire department members who engage in emergency operations to be annually evaluated and certified by the fire department as meeting the physical performance requirements identified in paragraph 8-2.1.²⁵

Recommendation #6: 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*.³² 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 confirmed by auscultation, however secondary confirmation was not performed.

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