



Fire Captain Dies as a Result of a Cardiac Arrest While Fighting a Wildland/Urban Interface Fire - California

SUMMARY

On October 5, 1998, a 44-year-old male career Fire Captain collapsed after active involvement in forcible entry activities at a residential structure fire. This fire began as a wildland fire that covered a geographic area of 27,000 acres and burned residences in the wildland/urban interface area. The Captain had been committed to the fire fighting effort for approximately 10 hours and was involved in fire suppression activities at a residential structure fire when he collapsed. Just prior to his collapse, the Captain had trouble catching his breath and began using a resuscitator oxygen tank and mask from one of the fire trucks. The Captain collapsed while resting in a neighboring yard. Medics in the area immediately initiated cardiopulmonary resuscitation and advanced life support (ALS) protocols that were continued at the fire site, in the ambulance during transport, and in the hospital emergency department. He was pronounced dead approximately 37 minutes after he collapsed. The death certificate listed acute myocardial infarction due to thrombosed coronary artery and atherosclerotic cardiovascular disease as the cause of death based upon autopsy results. Autopsy carboxyhemoglobin results of 1% did not indicate smoke inhalation as contributory to his death.

Other agencies have proposed a three-pronged strategy for reducing the risk of heart attacks among fire fighters. This strategy consists of (1) minimizing physical stress on fire fighters; (2) screening to identify and subsequently rehabilitate high-risk individuals; and (3) encouraging increased individual physical capacity. The following issues are relevant to this fire department:

- *Fire fighters should have annual medical evaluations to determine their medical*

ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

- *As a minimum, municipal fire fighters in California must be provided with medical evaluations to determine their fitness to wear self-contained breathing apparatus (SCBA).*
- *The Department should reinforce the requirement that personnel shall wear only the protective clothing issued by, or approved by, the employing fire department.*
- *The Department should review standard operating procedures (and related training) regarding self-treatment of chest pain or shortness of breath.*

INTRODUCTION

NIOSH was notified of this fatality on October 11, 1998. NIOSH telephoned the fire department on October 12, 1998, to initiate the investigation. The investigation was carried out by an industrial hygienist

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. 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:

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and a medical officer who traveled to the employing fire department on December 1, 1998, to conduct an investigation of the incident.

NIOSH personnel began the investigation by meeting with and interviewing the following:

- Fire department officers
- Fire department personnel involved in this incident
- The local vice-president of the International Association of Fire Fighters (IAFF)
- The risk management analyst for the employing fire department
- The spouse of the fallen fire fighter

NIOSH also reviewed

- Fire department investigative records including incident reports, photographs and videotapes of the fire, coworker statements, dispatch records
- Ambulance records
- Emergency department records of the resuscitation effort
- Related medical records
- Autopsy results and the death certificate of the deceased
- Fire department policies and operating procedures
- Fire department annual report for 1997
- Fire department "Request for Proposals" for employee health services to begin January 1999

INVESTIGATION

Fire Scene Response

On October 5, 1998, a 44-year-old male career Fire Captain with 21 years of service with the employing fire department collapsed after conducting wildland and structural fire fighting activities for approximately 9 hours. This wildland fire ultimately covered an area of 27,000 acres and spread to a number of wildland/urban interface areas. At the time of peak fire suppression activity, 2,462 people

and 137 pieces of equipment (94 fire engines, 22 bulldozers, and 21 water tenders) had been involved in the fire fighting activities.

The Captain was working his first day on duty after a 24-hour off-duty period. He began his shift at 0800 hours that morning, at which time he conducted physical training activities (riding the exercycle at the fire station). At 1021 hours, he was committed to the fire incident that began at approximately 0630 hours in a State wildland area in a neighboring county. The Captain was designated as the assistant team leader of a 5-engine, 16-person strike team that was to assist in fighting this large wildland fire. His strike team assembled at an area outside of town and proceeded to the fire site. At this time the Captain did not speak of symptoms or exhibit any signs of illness.

The strike team arrived at the fire scene at 1122 hours and conducted structure protection activities (assisting hand crews in a firing operation). From that assignment, the strike team went to a staging area (a designated location for distribution of equipment and personnel) where team members drank liquids and ate lunches provided by staging area personnel. The Captain ate and drank an unknown amount. He was alert and appeared in good spirits and health while conversing with coworkers in the staging area.

After this rest break, the strike team proceeded to a residential area where the fire, driven by wind, was threatening residential structures. Strike team units were placed along the streets to protect residential structures. Two units from the strike team (including the Captain's unit) were joined by single unit resources from other agencies and proceeded further up the street where they became heavily involved in fire suppression and structure protection.

When this task was completed, the Captain's unit joined others further down the street to suppress

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another residential fire. The Captain was assigned the position of fire attack (operations) for the involved structure. Two other units were assigned to interior attack on this fire, and their crews donned self-contained breathing apparatus (SCBA) and structural fire fighting gear. (Witness statements are unclear as to the type of protective gear the Captain was wearing. Some state that he was wearing wildland gear, some that he was wearing structural gear.) At various times during these activities, the Captain was observed wearing a “Hot Shield” face mask, which is a non-approved respirator consisting of a fabric filter housed in fire-resistant material. The Captain was observed outside the residence, running back and forth, directing activities of the other fire fighters, while a number of other fire fighters conducted activities such as interior attack and fire suppression on the roof. The strike team leader communicated with the Captain at this point, and the Captain did not express any symptoms.

The Captain began using an axe to gain forcible entry to the garage of the dwelling. At this point, without entering the building, he began to experience shortness of breath or fatigue, and began using a resuscitator (oxygen tank and mask) from one of the fire engines. He returned to fire fighting activities and shortly thereafter complained of shortness of breath again. He returned to the fire engine for the resuscitator which he took to the yard of a neighboring residence. At this time, the Captain was wearing a tee shirt and his fire fighting pants and boots. His fire fighting jacket was lying off to the side. The Captain was observed sitting on the ground trying to “hook up” his own oxygen. A coworker asked the Captain if he was okay, and the Captain answered yes.

The occupant of the residence where the Captain was sitting observed him alternately sitting and lying in the yard, trying to catch his breath. He appeared to be trying to find a comfortable position and to be tired, with difficulty breathing. The Captain was self-

administering oxygen from the resuscitator, alternately using the mask and then putting it down. The resident spoke with the Captain for about 5 minutes, during which he continued to have difficulty breathing and continued to deny needing assistance. He was leaning against a pillow and a rolled-up jacket during this time. The Captain suddenly sat upright and then fell over backwards. His collapse occurred at approximately 1838 hours. Nearby fire fighters immediately began assisting the fallen Captain.

Medical Emergency Response

Fire fighters noted in their description of the incident that the Captain was “seizing” when he collapsed. They called for fire fighter medics already in the area for the fire, who responded carrying a drug box and defibrillator. Advanced life support (ALS) activities were begun immediately. Vital signs were checked, and paramedics recognized that the Captain was in cardiac arrest. They ordered an ambulance. Cardiac monitoring revealed that the Captain’s heart was in ventricular fibrillation. Medics also noted that the Captain was hypoxic. They intubated the Captain, administered advanced cardiac life support (ACLS) drugs and procedures, including cardiopulmonary resuscitation (CPR) and defibrillation. Defibrillation was administered five times prior to the arrival of the ambulance at 1852 hours (14 minutes after the Captain’s collapse). Compressions and ventilations were continued while the Captain was transported to the hospital, and defibrillation was attempted once more in the ambulance. The ambulance arrived at the hospital at 1904 hours. Upon arrival at the emergency department, the Captain had no blood pressure, pulse rate, heart rate, or spontaneous movement. ACLS drugs were again administered at the emergency department, with no response. The Captain was pronounced dead at 1915 hours.

Medical Findings

The cause of death, determined by autopsy, was acute myocardial infarction due to thrombosed

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coronary artery and atherosclerotic cardiovascular disease. Blood tests for carbon monoxide exposure were negative (carboxyhemoglobin was 1%), indicating that the deceased was not exposed to excessive concentrations of carbon monoxide prior to his death.

Medical records indicated that the Captain had the following risk factors for coronary artery disease: a family history of coronary artery disease and mild/borderline hypercholesterolemia (total cholesterol of 208, HDL 40). He was involved in a regular program involving aerobic exercise and was not overweight (200 pounds; 6 feet, 3 inches tall). His most recent resting electrocardiogram (EKG) (March 1998), and stress EKGs done annually from 1990 to 1994 were all normal.

His most recent hazardous materials medical evaluation was in 1994, at which point he was approved for the job requirements without restrictions. He had had no Department-sponsored/required medical evaluations since 1994.

Pertinent findings from the autopsy, performed on October 7, 1998, are listed below:

- Complete occlusion of the proximal left anterior descending coronary artery with fresh thrombus
- 75% occlusion of the left anterior descending coronary artery
- 50% occlusion of the circumflex coronary artery
- 50% occlusion of the right coronary artery
- Mildly enlarged heart (cardiomegaly) with left ventricular hypertrophy
- Congestive hepatomegaly and splenomegaly

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this combination career/volunteer, wildland/urban fire department was comprised of 721 career fire fighters

and 631 paid call fire fighters. The department also employs 37 fire management personnel (chief officers) and 234 non-safety personnel. The 62-station fire department serves a resident population of 1.1 million people, 200,000 acres of county wildlands, 19 incorporated cities, and an airport. The distance between the furthest Department stations is 55 miles; the geographic area covered by the department is over 500 square miles. The Department also assists in wildland fire fighting efforts in locations distant from their municipality.

DESCRIPTION OF MEDICAL/PHYSICAL TRAINING/SUPPORT SERVICES PROVIDED FOR FIREFIGHTERS

At the time of the NIOSH investigation, the Department provided preemployment medical evaluations for fire fighters. Medical evaluations for respirator usage were included in the preemployment physical exam. The Department required return-to-work medical evaluations after injury or a 2-week absence for medical reasons. Annual medical evaluations were required only for fire fighters who were assigned to hazardous material (HazMat) teams.

The Department provided physical conditioning programs; fire fighter participation in the programs is voluntary. An estimated 80% of the fire fighters participate.

DISCUSSION

Very shortly after the Captain's collapse, medics found him in ventricular fibrillation (V. Fib). V.Fib is the most common type of arrhythmia associated with cardiac arrest, occurring in 65-80% of all cardiac arrests.¹ In the United States, atherosclerotic coronary artery disease (CAD) is the most common risk factor for cardiac arrest and sudden cardiac death.² Data collected by the National Fire Protection Association (NFPA) indicate that 49%

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of on-duty fire fighter deaths occurring nationally in 1996 resulted from heart attacks.³ NFPA data also indicate that heart attacks have always been the most common cause of on-duty fire fighter deaths since the agency began collecting data in 1978. An analysis of National Wildfire Coordinating Group (NWCG) data indicated that 21% of on-duty wildland fire fighter deaths occurring from 1990 to 1998 resulted from heart attacks, which represented the second leading cause of fatality in this group.⁴ Risk factors for the development of CAD include increasing age, male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity, physical inactivity, and diabetes.⁵

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.

Blood clots, or thrombus formation, in coronary arteries is initiated by disruption of atherosclerotic plaques. Certain characteristics of the plaques (size, composition of the cap and core, presence of a local inflammatory process) predispose the plaque to disruption.⁷ Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased heart rate, increased catecholamines, and shear forces, which occur during heavy exercise.^{9,10} Epidemiologic studies have found that heavy physical exertion sometimes immediately proceeds and triggers the onset of acute heart attacks.¹¹⁻¹⁴

Firefighting activities are strenuous and often require fire fighters 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.¹⁵⁻¹⁷ Exposure to the heat of the fire, the stress of carrying out fire fighting activities, and chronic exposure to the many components of smoke all present an intense burden and corresponding high oxygen demand on the body and heart of a fire fighter. The physical stress of conducting fire fighting activities for 10 hours and underlying atherosclerotic CAD probably contributed to this fire fighter's heart attack, subsequent cardiac arrest, and sudden death.

The duration of the Captain's fire fighting activities, and his shortness of breath, led to questions about his extent of exposure to smoke and the contribution of this exposure to his death. The measured carboxyhemoglobin concentration at the time of autopsy was low (1%). This measurement may have been impacted by the fact that the Captain self-administered oxygen for an estimated period of 20 to 40 minutes. The half-life of carbon monoxide in the blood when oxygen is administered under atmospheric pressure is between 45 and 80 minutes.¹⁸ Thus, his carboxyhemoglobin level when he began administering oxygen would have been 2% or lower, which is just above the range of background levels of 0.5 to 1.5% for the general population,¹⁹ but well below the 9% or below carboxyhemoglobin level of a typical cigarette smoker.²⁰ A carboxyhemoglobin concentration 2% or lower is insufficient to cause an acute myocardial infarction (heart attack), but could theoretically impact the size of the infarct.

There were differences in the frequency and content of the Department's medical evaluation and those recommended by the NFPA.²¹ For example, the Department conducted extensive preemployment/preplacement medical examinations for all career firefighters, and annual medical examinations (including treadmill stress tests) for HazMat team members. NFPA recommends annual medical evaluations for all fire fighters, which include annual

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medical examinations for all fire fighters 40 years of age and older, biannual examinations for those 30 to 39 years of age, and examinations every 3 years for those less than 30. NFPA also recommends periodic treadmill tests (also known as exercise EKG tests, or stress tests) for fire fighters beginning at age 40. If the fire fighter has one or more risk factors for CAD, the NFPA recommends beginning periodic exercise EKG testing at age 35. The Captain had not had a treadmill test in 4 years. A more current treadmill test may have identified the underlying CAD so that he could have been directed toward further evaluation and treatment.^{22, 23}

Prior to this investigation, this employing Fire Department contacted NIOSH to request assistance in determining the appropriate disposition for autopsy specimens. The Department had requested that the coroner follow the autopsy protocol developed by the United States Fire Administration (USFA) in conjunction with the International Association of Fire Fighters.²⁴ The USFA autopsy protocol was designed to uncover pertinent forensic information consistent with the distinct occupational aspects of fire fighting and was primarily intended to be applicable to line-of-duty deaths. The protocol contains directions for the internal examination that includes collection of 19 tissue/fluid samples for toxicologic analysis. Unfortunately, the protocol does not specify the type of analyses nor the intent for many of these tissue samples. In addition, there are no provisions for archiving specimens for later use. The USFA should clarify these issues.

RECOMMENDATIONS AND DISCUSSION

The following recommendations address health and safety generally. This list includes preventive measures that have been recommended by other agencies to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. These recommendations have not been evaluated by

NIOSH but represent research presented in the literature or consensus votes of Technical Committees of the National Fire Protection Association or labor/management groups within the fire service. In addition, they are presented in a logical programmatic order and are not necessarily listed in order of priority.

Recommendation #1: Fire Fighters should have annual medical evaluations 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 periodic medical evaluation for fire fighters can be found in *NFPA Standard 1582: Medical Requirements for Fire Fighters*,²¹ and in the report of the International Association of Fire Fighters/International Association of Fire Chiefs wellness/fitness initiative.²⁵ Although the Department is not legally required to follow these standards, we recommend that the county and the Union negotiate the content and frequency of medical evaluations and examinations to be consistent with the above organizations. It is assumed that if an exercise stress test was performed on this fire fighter more currently than 4 years ago, his underlying CAD may have been identified and he would have been directed toward further evaluation and treatment. This standard (NFPA 1582) should be shared with physicians responsible for clearing individuals for fire fighting duties.

Recommendations #2: As a minimum, municipal fire fighters in California must be provided with medical evaluations to determine their fitness to wear self-contained breathing apparatus (SCBA).

In 1997, the Federal Occupational Safety and Health Administration (OSHA) published a revised

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respiratory protection standard.²⁶ This standard requires, among other things, that an annual medical evaluation of fire fighters wearing SCBA be performed by a physician or other licensed health care professional. The medical evaluation must use a medical questionnaire or an initial medical examination that obtains the same information as the medical questionnaire. If an employee gives a positive response to any questions among questions 1-8 in Section 2, Part A, then a follow-up medical examination must be provided. The content of that medical examination is to be determined by the physician or other licensed health care professional.

Because California has an Occupational Safety and Health Administration (OSHA)-approved state plan, requirements equivalent to or in excess of the Federal OSHA Standards are applicable to this municipal fire department. CalOSHA's equivalent respiratory protection standard (Title 8, Section 5144) took effect on November 23, 1998, with compliance required by May 22, 1999.

Recommendation 3: The Department should reinforce the requirement that personnel shall wear only the protective clothing issued by, or approved by, the employing fire department.

This fire fighter was using a respirator that was not approved by either the employer or any recognized approving organization for respirators. His use of the "Hot Shield" respirator was in violation of both the employing department's written standard operating procedures, as well as the California OSHA requirement that NIOSH-approved respirators be used. The purpose of these requirements is to ensure that the respirator itself does not become a hazard to the health of the employee, as well as to ensure that the respirator provides adequate protection from a hazardous environment.

Recommendation 4: The Department should review standard operating procedures (and related training) regarding self-treatment of chest pain or shortness of breath.

In this incident, the Captain was symptomatic for 20 to 40 minutes prior to his collapse. During this period, he treated himself for shortness of breath by administering oxygen. Although the Captain was certified as a first responder and all first responders receive training in the signs and symptoms of heart attacks, recognizing these symptoms in yourself is difficult for a variety of reasons. This difficulty is aggravated when the symptoms resemble common conditions such as heartburn, exertion-related shortness of breath, or exertion-related perspiration. However, in this incident, the Captain's severe shortness of breath was not proportional to his physical exertion, and other fire fighters had witnessed his difficulty without intervening. Had the victim sought medical assistance, or other fire fighters evaluated his condition, resulting transport to a hospital emergency department prior to his collapse may have prevented his death at this time. Therefore, the Department should revise current procedures to discourage any self-treatment of severe symptoms, clarifying when fire fighters should report these symptoms to appropriate medical personnel, and establishing guidelines requiring that other fire fighters refer an incapacitated fire fighter for medical evaluation and treatment.

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INVESTIGATOR INFORMATION

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