



Fire Fighter Suffers Sudden Cardiac Death While Exercising During His Shift - California

SUMMARY

On February 5, 2001, a 33-year-old male Fire Fighter began his shift at 0800 hours. At approximately 0900 hours, he began his routine fitness program that consisted of aerobic and strength conditioning. Around 1000 hours, he had an unwitnessed collapse. He was unconscious for up to 5 minutes before his crew member, a paramedic, found him unresponsive and pulseless. A cardiac monitor showed ventricular fibrillation which was unresponsive to several defibrillation attempts. Subsequently cardiopulmonary resuscitation (CPR) and advanced life support (ALS) were administered at the fire station for approximately 15 minutes by his crew, a responding engine company, and a private ambulance service. Despite this and continued CPR and ALS administered by the hospital emergency room for another 30 minutes, the victim died. The death certificate and the autopsy completed by the County Coroner's Office listed cardiac dysrhythmia associated with exertion due to dilated cardiomyopathy as the cause of death.

Other agencies have proposed a three-pronged strategy for reducing the risk of cardiac arrest and sudden cardiac death among fire fighters. While some of these strategies could be utilized at this Fire Department, it is unlikely any of these measures could have prevented this victim's untimely death. 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. Issues relevant to this fire department include

- *The content of Candidate Fire Fighter's preplacement medical evaluations should*

be consistent with the National Fire Protection Association (NFPA) Standard 1582 (Medical Requirements for Fire Fighters and Information for Fire Department Physicians).

- *Incumbent Fire Fighters should have mandatory regular medical evaluations and periodic physical examinations to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.*
- *Incumbent Fire Fighters should have mandatory regular medical evaluations and periodic physical examinations to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.*

INTRODUCTION AND METHODS

On February 5, 2001, a 33-year-old male Fire Fighter lost consciousness while he was exercising at his assigned fire station. Despite CPR and ALS

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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administered by his engine crew (a paramedic and an emergency medical technician [EMT]), a paramedic and an EMT from another engine crew (E-10), ambulance paramedics, and emergency department personnel, the victim died. The National Institute for Occupational Safety and Health (NIOSH) was notified of this fatality on February 10, 2001, by the United States Fire Administration. On February 11, 2001, NIOSH contacted the affected Fire Department (FD) to initiate the investigation. On July 16, 2001, an Occupational Medicine Physician from the NIOSH Fire Fighter Fatality Investigation Team traveled to California to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met with the

- Fire Chief
- Battalion Chief on duty the day of the incident
- Local President of the International Association of Fire Fighters (IAFF)
- Crew members involved in this incident
- Victim's wife
- Pathologist who conducted the autopsy

During the site visit NIOSH personnel also reviewed the

- Existing FD investigative records, including the incident report, the Engine's run report, and dispatch records
- Ambulance run report
- Death certificate
- Autopsy report from the County Coroner's Office
- Pathology report from a local academic medical center
- Victim's preplacement medical evaluation conducted by the FD
- FD annual report for 1999

INVESTIGATIVE RESULTS

Incident Response. On February 5, 2001, at 0800 hours, the victim reported for duty at his fire station. After doing a routine check of equipment and gear, the victim and the two other crew members of Engine 12 (E-12) began their morning exercise program. This consisted of stretching exercises for about a half-hour followed by a warm-up walk on the treadmill and some weight lifting. The victim was doing shoulder muscle resistance exercises when the crew's Captain stepped away to the office, and then the other crew member, a paramedic, stepped away to the kitchen. After about 5 minutes, when the paramedic returned to the exercise equipment, he found the victim lying on his side in the fetal position. The paramedic noted the victim's ashen skin color but no obvious trauma or bleeding. He ascertained the victim was unresponsive and pulseless, called for E-12's Captain to call an ambulance, and rolled the victim onto his back.

At 1003 hours Dispatch notified Engine 10, the on-duty Battalion Chief, and a private ambulance company for a fire fighter down at Station 12. At approximately 1004 hours, E-12's paramedic retrieved his ALS equipment from the rig located only 10 feet from where the victim collapsed. The cardiac monitor revealed ventricular fibrillation (a heart rhythm not able to sustain life) and a shock of 200 joules was delivered. The victim's heart rhythm remained in ventricular fibrillation (V.Fib.), and the paramedic quickly shaved the victim's chest for a better electrical contact. Another shock of 300 joules was delivered and his heart rhythm remained in V. Fib. A third shock of 300 joules was delivered without successful cardioversion, and then CPR was initiated by E-12's Captain as the paramedic prepared for intubation.

E-10's crew arrived at 1006 hours and assisted with the intubation, started an intravenous (IV) line, and assisted with the chest compressions. The Battalion

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Chief and the private ambulance service arrived on the scene at 1008 hours and assisted with the ongoing CPR and ALS measures. After IV medications were administered consistent with ALS protocols, another series of shocks at 360 joules were delivered for the refractory V. Fib. One of these shocks briefly converted the victim's heart rhythm to ventricular tachycardia (another type of lethal heart rhythm), but this quickly reverted into V. Fib. The victim was placed onto a backboard and carried into the ambulance, and at 1016 hours the ambulance transported the victim to the nearest hospital. A total of 11 shocks were given by paramedics during the 16-minute resuscitation effort in the field.

The ambulance arrived at the hospital's emergency department at 1020 hours. Resuscitation efforts continued for another 30 minutes. At 1050 hours, hospital personnel pronounced the victim dead.

Medical Findings. After an autopsy, the Chief Deputy Coroner listed the cause of death as cardiac dysrhythmia associated with exertion due to dilated cardiomyopathy. The autopsy was performed by the County Coroner's office with a more detailed autopsy of the heart conducted by a local academic medical center. Pertinent findings are listed below:

A. HEART

1. The heart had a rounded "globoid" configuration rather than the normal pyramidal shape.
2. The heart was enlarged (weighing 480 grams versus 400 grams, the upper limit of normal).
3. All four chambers of the heart were moderately dilated (enlarged).
4. Both heart ventricles were hypertrophied (thick).
5. No evidence indicated old or recent myocardial infarctions (heart attacks).

6. No atherosclerotic changes were evident in the coronary arteries (no blockage in the coronary arteries).

7. A focal fenestration of one cusp of the pulmonary artery was thought to be a congenital abnormality of no clinical significance.

8. Microscopic examination of the left ventricle, the right ventricle, and the interventricular tissue showed myocyte hypertrophy (muscle cell thickening) characterized by enlarged "box car" nuclei and some patchy interstitial fibrosis (scar tissue between some of the muscle cells).

9. There was no evidence of vasculitis, myocarditis, sarcoidosis, Fabry's disease, amyloidosis, or hemochromatosis.

Other findings of no clinical significance follow:

1. Focal submucosal hemorrhage in the laryngeal pharynx (abrasion in the back of the throat) consistent with the intubation procedure
2. Diffuse lung hypoaeration (lungs not fully expanded) due the resuscitation efforts.
3. Mild enlargement of the liver and spleen (probably consistent with the body size and passive congestion).
4. Multiple gastric muscosal (stomach lining) erosions (possibly consistent with gastritis).

His spouse and coworkers reported he maintained a significant amount of on- and off-the-job aerobic activity without chest pain, shortness of breath, or ankle swelling. He did report some upper abdominal pains for 1 to 2 months prior to this episode. Other than some dietary supplements that he was taking intermittently (creatine, whey protein, metabolo, and melatonin), he was taking no medications. His wife and coworkers denied his using any illicit drugs.

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On February 7, 2001, a blood drug screen was conducted by a toxicology laboratory at the request of the coroner. Three types of medications administered during the resuscitation effort were detected (lidocaine, atropine, amiodarone), but no illicit drugs, alcohol, or steroids were found. At the request of the spouse, the coroner sent a blood and urine sample for heavy metals testing. The blood lead level, the urine arsenic level, and the urine mercury level were below the laboratory's level of detection (<3 micrograms (mcg) per deciliter, <15 mcg per liter (mcg/l), <5 mcg/l, respectively). The urine lead level was elevated at 76 mcg/l and when corrected for urine creatinine was 165 mcg per gram creatinine (reference range <50). However, the laboratory noted the dilute nature of the urine [creatinine of 0.46 grams per liter (g/l)] and commented that "the excretory mechanism on analytes can be altered when the urine specimen is very dilute (creatinine <5.0 g/l) or very concentrated (creatinine >3.0 g/l). In either case, measurements in urine samples are not reliable and should be repeated on a specimen collected on some other occasion."

Past Fire Department medical records indicated that the victim's last medical evaluation was his preplacement medical evaluation in 1996. At that time a resting electrocardiogram (ECG) showed an incomplete right bundle branch block. An exercise stress test was performed under the Bruce protocol for 10 minutes when he achieved 95% of his predicted heart rate and 12.9 METS. He complained of leg fatigue but no chest pain. He had a normal blood pressure response and his ECG revealed no ischemic changes.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the FD was comprised of 72 personnel serving a population of

80,000 residents in a geographic area of 27.5 square miles. There are 5 fire stations where fire fighters work 24-hour shifts every other day for 4 days followed by 4 days off. Then fire fighters work 24-hour shifts every other day for 4 days followed by 6 days off. Each shift of an engine company is staffed with an officer and two fire fighters, while the ladder company is staffed with an officer and three fire fighters. All members of the FD are certified emergency medical technicians, and each station has at least one fire fighter certified as a paramedic working at all times. In 1999, the department responded to 6,764 calls: 75% medical calls, 16% fires; and 9% false alarms. All FD apparatus are equipped with cardiac monitor and defibrillators. The day of the incident the victim and his crew were working the fourth day of the tour cycle. That morning he did not report or show any signs of discomfort to his spouse or his coworkers.

Training. The FD provides all newly hired fire fighters with the basic 12-week recruit training conducted at the county's Fire Academy to become certified to the National Fire Protection Association (NFPA) Fire Fighter I level and as a Driver-Operator. In addition, all fire fighters are State-certified EMTs certified in CPR. The victim had 5 years of fire fighting experience and was an NFPA-certified Fire Fighter I and a Driver-Operator.

Preemployment/Preplacement Evaluations. The department requires a preemployment/preplacement medical evaluation for all new hires, regardless of age. Components of this evaluation for all applicants include

- A complete medical history
- Height, weight, and vital signs
- Physical examination
- Vision test
- Hearing test
- Complete blood count (CBC)

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- Blood lipid profile (total cholesterol, HDL cholesterol, triglycerides)
- Blood chemistries (chem 30)
- Urinalysis
- Urine drug test (amphetamines, benzodiazepines, cocaine metabolites, methadone, opiate metabolites, pencyclidine (PCP), propoxyphene, marijuana metabolites)
- Chest X-ray
- Spirometry
- Exercise stress test (ECG treadmill test based on the Bruce protocol)
- Lumbar spine X-rays (two views - flexion and extension)
- Range of motion back exam

These evaluations are performed by a contract physician hired by the City, with results given to the City's human resources department. Once this evaluation is complete, a decision regarding medical clearance for fire fighting duties is made by the contractor. Prior to the medical examination, new hires are also required to complete a physical capabilities test. This is a timed performance evaluation of typical fire fighting duties. Finally, medical clearance for SCBA use is determined as part of the physical examination.

Periodic Evaluations. Periodic medical evaluations for fire fighters are not offered by this department. However, prior to fire fighter promotions, a urine drug test is administered.

Subsequent medical clearance for SCBA use is determined by the self-administered OSHA respiratory questionnaire. The completed questionnaire is reviewed by the FD personnel during annual respirator training and fit testing.

If a fire fighter misses work for more than three shifts, the FD may require a physician's note for the fire fighter to be cleared for "return to work." If the fire

fighter misses work for more than 4 months, the FD may require another physical ability (agility) test.

All stations have exercise equipment, but few aerobic machines are available, and most of the equipment is dated. The FD encourages fire fighters to exercise during work hours, but participation is voluntary. The FD does not offer other wellness programs such as smoking cessation, and control programs for weight, blood pressure, cholesterol, and diabetes.

DISCUSSION

Cardiomyopathy is a disease of the heart muscle not resulting from ischemia (reduced blood supply to the heart muscle), hypertension (high blood pressure), heart valve problems, or congenital abnormalities.¹ Dilated cardiomyopathy is characterized by dilatation of the heart chambers and impaired ventricular contraction (pumping). Microscopic findings are non-specific, typically being myocyte hypertrophy (best appreciated as nuclear hypertrophy [e.g., "box-car nuclei"]) with varying degrees of interstitial fibrosis.^{2,3} Although most cases of dilated cardiomyopathy are of unknown etiology (idiopathic), a variety of acquired or hereditary disorders can cause the disorder. These secondary and potentially reversible forms are listed in Table 1.³

Idiopathic cardiomyopathy (IDC), diagnosed in this fire fighter from the autopsy, is not rare. Its age-adjusted prevalence in the United States averages 36 cases per 100,000 population,⁴ and it accounts for 10,000 deaths each year.⁵ Most patients are first seen between the ages of 20 and 50 years presenting with symptoms of moderate heart failure (shortness of breath on exertion, palpitations [fast heart beats], diminished exercise capacity) and advanced heart failure (shortness of breath upon lying down and swelling of the ankles).³ This fire fighter had sudden death as the initial presentation of IDC. Although sudden death is rarely the initial

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presentation,^{6,7} it is a common cause of death among IDC patients, accounting for 28 percent of all IDC deaths.³

The prognosis for IDC is poor. Early studies reported 1- and 5-year death rates of approximately 25 and 50% respectively,^{8,9} but recent studies report an average 5-year death rate of 20%.^{6,7,10,11} This improved survival probably reflects the earlier detection of disease, a shift to population-based studies, and better treatment.^{7,12} Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden death or in need of antiarrhythmic therapy cannot yet be prospectively identified.³ Given the inability to identify patients at high risk for sudden death, the low degree of efficacy of antiarrhythmic agents for IDC, the numerous side effects of these antiarrhythmic agents, and the lack of symptoms in this fire fighter, it is unclear if an earlier diagnosis could have prevented his sudden death.

Investigations into the pathogenesis of IDC have focused on four basic mechanisms: (1) inherited factors, (2) viral myocarditis and other cytotoxic insults, (3) immune abnormalities, and (4) metabolic, energetic, and contractile abnormalities. These mechanisms are not mutually exclusive, and several may combine to produce clinical disease in susceptible patients. The inherited factors account for approximately one third of all IDC cases,¹³⁻¹⁵ and 20% of patients with IDC have at least one first-degree relative with a decreased ejection fraction and cardiomegaly.¹³ Although IDC can be transmitted as a recessive or X-linked trait, autosomal dominant inheritance occurs most frequently and exhibits both clinical variability and genetic heterogeneity.¹⁶ It is unclear if this victim's IDC was due to inherited factors or due to post-viral myocarditis. In either case, first-degree relatives of this fire fighter should consult with their physicians regarding when, or if, an echocardiogram is warranted to screen for IDC.

IDC is often accompanied by conduction system disease, and genetic studies have identified individual loci on chromosome responsible for these cases.¹⁶ The reported conduction systems diseases associated with IDC are sinus bradycardia, atrioventricular conduction block (first-, second-, and third-degree), and atrial arrhythmias.¹⁶ Right bundle branch block rarely occurs,³ and incomplete RBBB, as seen in this fire fighter, has not been previously reported in the literature. Except for family history, no clinical or histopathological characteristics can distinguish familial from nonfamilial disease.³ Future molecular genetic studies may lead to the identification and treatment of asymptomatic carriers who are at risk for symptomatic dilated cardiomyopathy.¹⁶

There was some confusion regarding the significance of the victim's elevated urine lead level, particularly in light of his low (normal) blood lead level. In general, blood lead measures the concentration of lead in soft tissues and is a good measurement of recent exposure. Urine lead levels also reflect recent exposure, but the levels can fluctuate with time and their correlation with blood levels are variable. Because of this, most researchers consider blood lead levels to be the best indicator of recent lead exposure and do not recommend measuring lead in urine for the routine assessment of lead exposure.¹⁷ This information, together with the laboratory's concern for the reliability of tests conducted in dilute urine, argue against the victim having elevated levels of lead in his body.

RECOMMENDATIONS

The following recommendations address health and safety generally. This list includes some 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. While some of these strategies could be utilized at this Fire Department, it is unlikely any of these



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measures could have prevented this victim's untimely death. These recommendations have not been evaluated by NIOSH, but represent research presented in the literature or of consensus votes of Technical Committees of the NFPA or labor/management groups within the fire service. 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. Issues relevant to this fire department include

Recommendation #1: The content of Candidate Fire Fighter's preplacement medical evaluations should be consistent with NFPA Standard 1582 (Medical Requirements for Fire Fighters and Information for Fire Department Physicians).

The FD currently performs preemployment physical evaluations, which include routine lumbar spine X-rays. While these X-rays may be useful in the evaluation of individuals with existing problems, the American College of Radiology, American College of Occupational and Environmental Medicine, and NIOSH all have concluded that lumbar spine X-rays have no value as a routine screening measure to determine those at risk for back injuries.^{18,19} This procedure involves both an unnecessary radiation exposure for the applicant and an unnecessary expense for the Department. Guidance regarding the content of preemployment medical evaluations for fire fighters can be found in NFPA 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians,²⁰ and in the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative.²¹ NIOSH has supplied both these documents to the FD.

Recommendation #2: Incumbent Fire Fighters should have regular medical evaluations and periodic physical examinations to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

As mentioned previously, guidance regarding the content and scheduling of periodic medical examinations for fire fighters can be found in NFPA 1582, and in the report of the International Association of Fire Fighters/International Association of Fire Chiefs wellness/fitness initiative.^{20,21} The FD is not legally required to follow these standards, but we recommend the City and Union follow these guidelines.

Applying NFPA 1582 involves legal and economic issues, so it should be carried out in a **confidential, nondiscriminatory** manner. Appendix D of NFPA 1582 provides guidance for Fire Department administrators regarding legal considerations in applying the standard. The 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, addresses these issues in Chapter 8-7.1 and 8-7.2.²² The success of medical programs hinges on protecting the affected fire fighter. The department must (1) keep the medical records confidential, (2) provide alternate duty positions for fire fighters in rehabilitation programs, and (3) if the fire fighter is not medically qualified to return to active fire fighting duties, provide permanent alternate duty positions or other supportive and/or compensated alternatives.

3. Reduce risk factors for cardiovascular disease and improve cardiovascular capacity by phasing in a mandatory wellness/fitness program.

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The fitness/wellness initiative developed by the International Association of Fire Fighters/International Association of Fire Chiefs provides health promotion activities for preventing health problems and enhancing overall well-being.^{21,23} Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.^{24,25} 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.²⁶

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INVESTIGATOR INFORMATION

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Table 1. Known Causes of Dilated Cardiomyopathy³

Toxins

Ethanol
Chemotherapeutic agents (doxorubicin, bleomycin)
Cobalt
Anti-retroviral agents (zidovudine, didanosine, zalcitabine)
Phenothiazines
Carbon monoxide
Lead
Cocaine
Mercury

Metabolic Abnormalities

Nutritional deficiencies (thiamine, selenium, carnitine)
Endocrinologic disorders (hypothyroidism, acromegaly, thyrotoxicosis,
Cushing's Disease, pheochromocytoma, diabetes mellitus)
Electrolyte disturbances (hypocalcemia, hypophosphatemia)

Infectious

Viral (coxsackie virus, cytomegalovirus, human immunodeficiency virus)
Rickettsial
Bacterial (diphtheria)
Mycobacterial
Fungal
Parasitic (toxoplasmosis, trichinosis, Chagas' disease)

Noninfectious

Collagen vascular disorders (scleroderma, lupus erythematosus , dermatomyositis)
Hypersensitivity myocarditis
Sarcoidosis
Peripartum dysfunction

Neuromuscular Causes

Duchenne's muscular dystrophy
Facioscapulohumeral muscular dystrophy
Erb's limb-girdle dystrophy
Myotonic dystrophy