2007
05

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

September 5, 2007

Volunteer Fire Fighter/Emergency Medical Technician Suffers Sudden Death 2 Hours After Completing Vehicle Extrication Training—New York

SUMMARY

On September 21, 2006, a 38-year-old volunteer fire fighter/emergency medical technician (EMT) arrived for training at his fire station at 1945 hours. The training scenario involved vehicle extrication with hydraulic rescue tools. After training for 2 hours, he left the fire station at about 2145 hours complaining of fatigue, which fellow crew members attributed to his 12-hour EMT shift immediately before the training. He returned home and showered. Just before going to bed, he told his roommate that he was experiencing an "aura." Shortly thereafter, he began exhibiting seizure activity. The emergency medical system was called and an ambulance arrived at 0016 hours. He was unresponsive with no pulse or respiration. He died even though he had received cardiopulmonary resuscitation (CPR) at home and advanced cardiac life support in the ambulance, the emergency department, and the intensive care unit of the hospital. The death certificate and autopsy, completed by the chief medical examiner, listed the immediate cause of death as "intramural coronary artery disease with severe fibromuscular dysplasia of the artery to the AV node of the heart following a volunteer fire training session." Other significant conditions contributing to death but not related to the given cause was "seizure disorder." The NIOSH investigator concurs with this conclusion.

NIOSH investigators offer these recommendations to reduce the risk of on-duty sudden cardiac arrest among fire fighters.

- ***Consider modifying the current medical evaluation program to be consistent with NFPA 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments.**
- ***Following an injury/illness, the final determination of a fire fighter's return-to-work status should be made by the fire department physician who is - knowledgeable about the physical demands of fire fighting, the medical requirements of fire fighters, and the various components of NFPA 1582.***

Although unrelated to this fatality, the fire department should consider these additional recommendations:

- ***Phase in a wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***

- ***Perform an annual physical performance (physical ability) evaluation for ALL fire fighters to ensure they are physically capable of performing the essential job tasks of structural fire fighting.***

INTRODUCTION AND METHODS

On September 21, 2006, a 38-year-old fire fighter/EMT suffered sudden death at his home following strenuous fire fighter training. On September 27, NIOSH was notified of the fatality and subsequently contacted the fire department. On February 13, 2007, an occupational health nurse practitioner from the NIOSH Fire Fighter Fatality Investigation and Prevention Team traveled to New York to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel met with or interviewed the following people:

- Fire chief
- Assistant fire chiefs
- The fire fighter/EMT's roommate
- The fire fighter/EMT's primary care physician
- The fire fighter/EMT's family
- The fire fighter/EMT's employer

During the site visit, NIOSH personnel reviewed the following documents related to this incident:

- Crew members statements
- Dispatch records
- Ambulance response reports
- Emergency department record of the resuscitation effort
- Death certificate
- Autopsy report
- The fire fighter/EMT's medical records
- The fire fighter/EMT's training records at the fire department

RESULTS OF INVESTIGATION

On September 21, 2006, the volunteer fire fighter/EMT arrived for training at his fire station at 1945 hours. The evening training was "vehicle extrication," which involved the use of hydraulic rescue tools to rescue a trapped driver from a motor vehicle accident. Wearing their bunker gear, members used Amkus® tools (spreader and cutter) to gain access to the interior of the vehicle. Once inside the vehicle, members removed the driver's seat to simulate the rescue of a trapped driver. The training scenario was considered physically strenuous by participating members. After training, the fire fighter/EMT helped clean the tools and place them back in their carrying cases. He left the station at about 2145 hours complaining of fatigue, which fellow crewmembers attributed to his 12-hour EMT shift before the training session.

The fire fighter/EMT returned home and showered. Just before going to bed, he told his roommate he was experiencing an "aura," an unusual sensation that typically precedes seizures (2330 hours). The fire fighter/EMT had epilepsy, the history of which is described in more detail later in this report. At around 2335 hours, the fire fighter/EMT closed his eyes and began moaning. Within seconds he had a witnessed generalized tonic-clonic seizure activity for about 12 minutes. According to the roommate, she had been instructed by the fire fighter/EMT to delay activating the emergency medical system for 10

minutes if he ever lost consciousness. When the seizure activity ceased and he did not regain consciousness, the roommate called 911 (about 2357 hours).

A member of the fire fighter/EMT's volunteer fire department responded to the 911 call at 0005 hours. He arrived at the residence about 5 minutes later and found the fire fighter/EMT face down on his bed. He was unresponsive with no pulse, and CPR was initiated. The ambulance arrived at 0016 hours and a manual defibrillator showed asystole (no heart beat), and no shock was administered. The fire fighter/EMT was placed onto a stretcher and loaded into the ambulance as CPR continued. The fire fighter/EMT remained in asystole as the ambulance departed for the emergency department at 0022 hours. En route to the hospital, an intravenous line was inserted, and advanced cardiac life support medications were administered with no change in his heart rhythm. An attempt to intubate the fire fighter/EMT (placing a breathing tube into the airway) was unsuccessful, and oxygen was administered via a bag-valve-mask.

The ambulance arrived at the emergency at 0032 hours, approximately 60 minutes after his seizure, and after at least 22 minutes with no pulse. Once in the emergency department, the fire fighter/EMT was intubated and the emergency department physician noted that the rhythm was either fine ventricular fibrillation (a heart rhythm incompatible with life) or asystole. After additional intravenous medications, he regained a normal heart rhythm but remained unconscious. Lab values were consistent with heart damage (troponin-I=10.79 ng/ml, normal is <0.6 ng/ml). He was admitted to the hospital's intensive care unit, started on Dilantin® to prevent further seizures, and transferred to another hospital on September 22 around 0900 hours for further evaluation. At that hospital, the neurosurgical consult felt the fire fighter/EMT suffered severe ischemic brain damage due to his prolonged cardiac arrest, and described his prospects for recovery as grim. Based on this assessment, medical support was withdrawn. He died at 1135 hours on September 22.

Medical Findings. The death certificate and autopsy, completed by the chief medical examiner, listed the immediate cause of death as "intramural coronary artery disease with severe fibromuscular dysplasia of the artery to the AV node of the heart following a volunteer fire training session." A history of seizure disorder was listed as contributing to the death.

Significant findings from the autopsy included the following:

Heart

1. Cardiomegaly, 565 grams (The medical examiner predicted heart weight would be 395 grams, based on the height and weight of the fire fighter/EMT.)
2. Concentric left and right ventricular hypertrophy of the heart
   - — Left ventricular free wall, 1.7 centimeters (cm) (normal thickness is 0.6–1.1 cm) [Armstrong and Feigenbaum 2001].
   - — Intraventricular septum, 1.6 cm (normal is 0.6–1.1 cm)

— Right ventricle, 0.6 cm (normal is 0.3–0.5 cm).

3. Severe intramural fibromuscular dysplasia of the coronary artery to the AV node of the heart
4. All major coronary arteries free of significant atherosclerosis
5. No thrombi found in any coronary artery
6. Minimally enlarged mitral and aortic valves
   — The mitral valve measured 10.8 cm (expected 8.0–10.5 cm)
   — The aortic valve 8.1 cm (expected 6.0–7.5 cm) [Moore 1999].

Brain

1. Anoxic changes
2. No evidence of an intra-cranial hemorrhage (stroke)

Lungs

1. No evidence of a pulmonary embolus (blood clot in the lung arteries)

Blood

1. Negative blood drug test for illegal drugs
2. Negative for alcohol in the blood stream
3. Dilantin in postmortem blood = 6.4 micrograms per milliliter (µg/mL) (therapeutic range 10–20 μg/mL).

As a child, the fire fighter/EMT had a heart murmur. Since this murmur may have represented a congenital heart abnormality, he had a cardiac catheterization at age 11. According to the fire fighter/EMT's parents, the catheterization was normal except for mitral valve prolapse. Since he was asymptomatic, no further treatment was advised.

In June 2002, one month after he joined the fire department, the fire fighter/EMT supplied the fire department with a medical release completed by his primary care physician stating he was physically capable of performing fire fighter duties. In December 2003, he had another fire department medical evaluation conducted as part of the department's periodic medical monitoring program. Pertinent findings included high blood cholesterol of 260 milligram per deciliters mg/dL (normal is < 200 mg/dL), high low-density lipoprotein (LDL) cholesterol of 177 mg/dL (normal is < 130 mg/dL), and high blood triglycerides of 188 mg/dL (normal is 20–160 mg/dL). He also had non-diagnostic electrocardiogram (EKG) changes (left ventricular hypertrophy by voltage criterion, non-specific ST wave changes, and Q waves in the inferior leads). An echocardiogram was performed, which found mitral valve prolapse but without mitral insufficiency or leaflet thickening. Therefore no treatment was prescribed. The left ventricular internal dimensions and wall thickness were normal, and only the right ventricular size was at the upper limits of normal (although no values were given). The fire fighter EMT's physician and the fire department's contract physician used this information to clear him to perform the job tasks of an interior/structural fire fighter.

In April 2005, the fire fighter/EMT underwent his second routine fire department medical evaluation. This evaluation did not include any laboratory tests or an EKG, and he was cleared for interior fire attack duties. In May 2006, the fire fighter/EMT had his third routine yearly fire department medical evaluation. No blood work was performed, but an EKG showed the same abnormalities noted in the December 2003 tracing and was interpreted as "no acute

problems." Again, he was cleared to work as an interior/structural fire fighter.

Since December 2003, the fire fighter/EMT was employed as an EMT/driver for a local ambulance company. The ambulance company required medical evaluations, however, results of these evaluations were not available to the NIOSH investigator at the time of this report. It appears that the fire fighter/EMT was cleared to work as an EMT/driver. In April 2006, he had a witnessed seizure at work. He was re-assigned to dispatch and was told not to return to ambulance duty until he was seizure free for 6 months.

The fire fighter/EMT had a long history of a seizure disorder (epilepsy) attributed to head trauma from a bike accident in 1978. He was followed by both his physician and a neurologist for this seizure disorder. After having four seizures from 1986 to 1989, he was placed on Dilantin 300 mg per day. He had varying control of his seizure disorder with multiple seizures in 1994, 1998, 2000, and 2003. During each episode of seizures, he exhibited low Dilantin blood levels. The fire fighter/EMT was placed on 500 mg per day, and had been seizure-free for more than 3 years until 2006, when an attempt was made to wean off Dilantin (described below).

Approximately 15 months before his death, the fire fighter/EMT had a minor vehicle incident. It was unclear whether the incident was due to falling asleep at the wheel or to a seizure. After receiving a letter asking for clarification from the NY Department of Motor Vehicles, he went to a neurologist who determined that the incident had been caused by fatigue. In February 2006, this neurologist suggested the fire fighter/EMT try to wean off Dilantin or switch to another anti-seizure medication. Even though the fire fighter/EMT was not complaining of any side effects, the neurologist was concerned about the length of time the fire fighter/EMT had been taking the Dilantin (almost 20 years). An electroencephalogram (a test for brain wave seizure-like activity) was performed which was essentially normal, and weaning began.

About 2 months after lowering his dose, the fire fighter/EMT had a seizure at work and was taken to the emergency department. His Dilantin level was 3.1 μg/mL (reference range 10.0–20.0 μg/mL). Upon discharge, he was told to continue his original dose of Dilantin and see his neurologist. Three days later, he saw his neurologist who recommended the FF/EMT start a newer anti-epileptic drug, Lamictal®. To reach a therapeutic level of this new medication without having another seizure, he was instructed to start the Lamictal while continuing with his full dose of Dilantin (500 mg).

However, concerned about his employment status if another seizure occurred, the fire fighter/EMT never started the Lamictal and just continued taking his Dilantin. This was communicated to his neurologist in June 2006. In September 2006 (13 days before his death), the neurologist again suggested he change medications but left that decision to the fire fighter/EMT. He was given a medical release to return to driving and riding in the ambulance (6 months since his last seizure). Because of this seizure activity, the fire department where he worked as a volunteer changed his duty status

from interior/structural fire fighter to exterior fire fighter, until his next scheduled fire department medical evaluation in May 2007.

DESCRIPTION OF THE FIRE - DEPARTMENT

At the time of the NIOSH investigation, the fire department consisted of 52 volunteer fire fighters. One fire station served a population of 5,000 in a geographic area of 48 square miles.

Training. The fire department requires all new volunteer fire fighter applicants to complete an application and to interview with the fire chief. Accepted applicants are then given an arson background check and sent for a physical evaluation that determines the fire fighter duties they can perform (described below). They must attend a fire school within 2 years of joining the department. Training at the local fire school is 78 hours long with classes one night per week and Saturday morning. Graduates from this school are certified at the equivalent level of National Fire Protection Association (NFPA) Fire Fighter I. The fire fighter was trained in apparatus operation, driver/operator, EMT, and Fire Fighter I. He had more than 4 years of volunteer fire fighting experience.

The pre-placement medical evaluation is conducted by a physician under contract to the fire department. Components of this medical evaluation include the following:

- Complete medical and occupational history
- Height, weight, and vital signs
- Physical examination
- EKG (if indicated by age)
  - Age 29 and under: at least every 3 years
  - Age 30–39: at least every 2 years
  - Age 40 and older: every year
- Blood tests: complete blood count with differential, chemistry panel (SMA 18), and lipid panel
- Chest X-ray
- Urine tests: urinalysis
- Spirometry
- Vision test: Snellen vision screen and color vision
- Audiometry
- Mantoux test (skin test for tuberculosis)

Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the fire chief. The categories of duty are interior/structural fire fighter, exterior fire fighter, support personnel, fire police, logistics, or driver.

The fire department also has an annual medical evaluation conducted by the same physician group doing the pre-placement medical evaluations. The content of this medical evaluation is the same as the pre-placement except the CXR and urine test is not repeated, and the physical examination and laboratory panel are age dependent:

- Age 29 and under: at least every 3 years
- Age 30–39: at least every 2 years
- Age 40 and older: every year

Fire fighters injured while performing fire department duties must be evaluated and

cleared for return to duty by their physician. The fire department conducts annual respirator fit tests, but does not conduct physical ability/agility tests or offer a fitness/wellness program. There is no exercise equipment (strength or aerobic) in the fire stations.

DISCUSSION

Any of the following three conditions could have been responsible for the fire fighter/EMT's death:

- Intramural coronary artery disease with severe fibromuscular dysplasia of the artery to the AV node of the heart (as described by the medical examiner)
- Concentric left and right ventricular hypertrophy leading to an arrhythmia and sudden cardiac death
- Sudden unexpected death in epilepsy (SUDEP).

Fibromuscular Dysplasia. Autopsy by the chief medical examiner found severe fibromuscular dysplasia of the artery to the AV node. Fibromuscular dysplasia is a noninflammatory vascular disease that is manifested as a nonatherosclerotic stenosis or aneurysm [Slovut and Olin 2004]. It most commonly affects the renal and cerebrovascular circulation, but can be found in coronary arteries. The diagnosis is made with either imaging studies (with the gold standard being angiography) or at post mortem evaluation (as in this case) [Huizar et al. 2006]. When detected before death, treatment options include angioplasty or in extreme cases, surgical revascularization. As described by the chief medical examiner, this probably led to ischemia to the fire fighter/EMT's AV node (part of the heart's conduction system), which caused an arrhythmia and ultimately his sudden death.

Left Ventricular Hypertrophy. The autopsy showed an enlarged heart and left ventricular and right ventricular hypertrophy. Left ventricular hypertrophy is a relatively common finding among persons with chronic cardiac ischemia (reduced blood supply to the heart muscle), a heart valve problem, or hypertension. Since the autopsy showed no definitive signs of ischemia and he had no medical history of hypertension and only slightly enlarged heart valves, it is possible he had an underlying cardiomyopathy. LVH, by itself, increases the risk for a cardiac arrhythmia and sudden cardiac death [Siegel 1997].

Unexplained (idiopathic) cardiac hypertrophy is one form of hypertrophic cardiomyopathy. Idiopathic hypertrophic cardiomyopathy (IHC) is a relatively rare heart condition, affecting approximately 0.2% of the population [Spirito et al. 1997]. Most patients are asymptomatic, and sudden cardiac death is often its first clinical manifestation [Synne and Braunwald 2001]. Risk factors for sudden death among IHC patients include young age (<30 years old) at diagnosis, a family history of IHC with sudden death, an abnormal blood pressure response to exercise, severe symptoms, non-sustained ventricular tachycardia, marked hypertrophy, marked left atrial dilatation, and genetic abnormalities associated with increased prevalence of sudden death [Spirito et al. 1997; Synne and Braunwald 2001; Olivotto et al. 1999].

Epilepsy. Epilepsy is defined as a condition characterized by two or more unprovoked seizures. Epileptics can be categorized by the following medical characteristics:

- Frequency of seizures (in-remission versus active, which is defined as more than one seizure during the past 5 years)
- Etiology (cause): idiopathic (unknown), remote symptomatic (central nervous system lesion with or without neurodeficits) [Commission on Epidemiology and Prognosis 1993]
- Seizure type: generalized tonic-clonic, partial, other

The fire fighter/EMT had active epilepsy of the generalized tonic-clonic type, although he had been in remission up until the weaning of his anti-seizure medication, Dilantin.

The overall death rate of epileptics is significantly increased relative to the general population: epileptics have up to a three-fold higher rate [Forsgren et al. 2005]. The following risk factors have been consistently associated with an increased death rate among epileptics: etiology (remote symptomatic > idiopathic), seizures type (GTC > partial or other), and duration (short and long > intermediate) [Cockerell et al. 1994; Olafsson et al. 1998; Loiseau et al. 1999; Lindsten et al. 2000; Nilsson et al. 1997]. The death of patients with epilepsy is primarily due to the underlying cause of epilepsy, but can also be related to seizures, or unrelated to the epilepsy all together [Cockerell et al. 1994]. The following discussion explores the possibility of death due to seizures in more detail.

SUDEP is defined as "sudden, unexpected, witnessed or unwitnessed, nontraumatic and nondrowning deaths in patients with epilepsy, with or without evidence of a seizure and excluding documented status epilepticus, in which post-mortem examination does not reveal a toxicologic or anatomic cause of death" [Nashef 1997]. The mechanism is unclear, but it may involve autonomic or cardiorespiratory disturbances [Schraeder and Lathers 1989; Nashef et al. 1996]. Rates of SUDEP range from 0.3 to 1.0 per 1,000 person-years in unselected populations [Leestma et al. 1997; Annegers et al. 1984; Tomson and Kenneback 1997; Hou et al. 1998], to 10 per 1,000 person-years in high risk persons (e.g., surgical candidates for refractory seizures) [Racoosin et al. 2001; Annegers et al. 1998]. In one study, the rate of SUDEP among 20–40 year olds was 24 times the rate of sudden death among 20–40 year olds in the general population. When witnessed, only GTC seizures have been reported with SUDEP [Leestma et al. 1997]. In addition to GTC seizures, risk factors for SUDEP include seizure frequency (>1 seizure during the year of observation), seizure onset at an early age, and long duration of the seizure disorder [Tomson et al. 2005]. The fire fighter/EMT had all of these risk factors.

Although the fire fighter/EMT had several risk factors for SUDEP, it is unclear whether this was responsible for his death. The fire fighter described an "aura" just before his seizure, suggesting SUDEP. On the other hand, he had four risk factors for sudden cardiac death: arrhythmias associated with (1) severe fibromuscular dysplasia of the artery to the AV node, (2) left ventricular hypertrophy, (3) cardiomegaly, and (4) possible hypertrophic cardiomyopathy. Any or all of these conditions could have contributed to this fire fighter's untimely death. The extent to which the heavy physical exertion of the vehicle extraction training triggered his sudden death is unclear.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to prevent similar incidents.

Recommendation 1. **Consider modifying the current medical evaluation program to be consistent with NFPA 1582, Standard on comprehensive occupational medical program for fire departments [NFPA 2007].**

Although this department is to be commended for having a medical evaluation program, it should consider modifying it to more closely align with the NFPA 1582. The frequency of some of the components differs from the recommendations of NFPA 1582. The department may want to review guidance regarding the content and frequency of pre-placement and periodic medical evaluations and examinations for fire fighters found in NFPA 1582 and in the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative [IAFF/IAFC 2000]. However, the fire department is not legally required to follow any of these standards.

Recommendation 2. **Following an injury/illness, the final determination of a fire fighter's return-to-work status should be made by the fire department physician who is knowledgeable about the physical demands of fire fighting, the medical requirements of fire fighters, and the various components of NFPA 1582.**

Physicians who provide input regarding medical clearance for fire fighting duties should be knowledgeable about the physical demands of fire fighting and understand that fire fighters frequently respond to incidents in immediately dangerous to life and health (IDLH) environments. They should also be familiar with a fire fighter's personal protective equipment and the consensus guidelines published by NFPA 1582. Many primary care physicians or specialists are not familiar with a fire fighter's job duties or with guidance documents such as NFPA 1582. To ensure physicians are aware of these guidelines, we recommend that the fire department make contracted physicians, primary care physicians, and specialists aware of NFPA 1582.

In addition, we recommend the fire department carefully evaluate the opinion of the primary care physician and specialists regarding return to work. We recommend that all return-to-work clearances be carefully reviewed by a fire department-contracted physician.

Although unrelated to this fatality, the fire department should consider these additional recommendations based on safety and health considerations:

Recommendation 3. **Phase in a wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.**

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Physical inactivity, or lack of exercise, is associated with other CAD risk factors: obesity and diabetes [Plowman and Smith 1997]. NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being [NFPA 1997]. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days [Maniscalco et al. 1999; Stein et al. 2000; Aldana 2001]. 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 [City Auditor 1997]. Guidance for how to implement and components of a wellness and fitness program include the following:

- NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters* [NFPA 2000]
- International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC), *Fire Service Joint Labor Management Wellness/Fitness Initiative* [IAFF, IAFC 2000].
- National Volunteer Fire Council (NVFC)/United State Fire Administration (USFA) *Health and Wellness Guide for the Volunteer Fire Service* [NVFC, USFA 2004].

NIOSH has supplied the fire department with these documents.

Recommendation 4. **Perform an annual physical performance (physical ability) evaluation for ALL fire fighters to ensure they 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 evaluated and certified annually by the fire department as meeting the physical performance requirements identified in paragraph 8–2.1 of the Standard [NFPA 1997].

REFERENCES

Aldana SG [2001]. Financial impact of health promotion programs: a comprehensive review of the literature. Am J Health Promot *15*:296–320.

Annegers IF, Coan SP, Hauser WA, Leestma J, Duffell W, Tarver B [1998]. Epilepsy, vagal nerve stimulation by the NCP system, mortality and sudden, unexpected, unexplained death. Epilepsia *39*:206–212.

Annegers IF, Hauser WA, Shirts SB [1984]. Heart disease mortality and morbidity in patients with epilepsy. Epilepsia *25*:699–704.

Armstrong WF, Feigenbaum H [2001]. Echocardiography. In: Braunwald E, Zipes DP, Libby P, eds. Heart disease: a text of cardiovascular medicine. 6th ed. Vol. 1. Philadelphia, PA: W.B. Saunders Company, p. 167.

City Auditor, City of Phoenix, AZ [1997]. Disability retirement program evaluation. January 28, 1997.

Cockerell OC, Johnson AL, Sander JW, Hart YM, Goodridge DM, Shorvon SD [1994]. Mortality from epilepsy: results from a prospective population based study. Lancet *344*:918–921.

Commission on Epidemiology and Prognosis [1993]. International league against epilepsy. Guidelines for epidemiologic studies on epilepsy. Epilepsia *34*:592–596.

Forsgren L, Hauser A, Olafsson E, Sander JW, Sillanpaa M, Tomson T [2005]. Mortality of epilepsy in developed countries: a review. Epilepsia *46*(Suppl 11):18–27.

Hou M, Huang M, Huang M, Huang M, Chan M, Wang M, Liu M, Wu M, Tomson T, Ericson M, Ihrman C [1998]. Heart rate variability in patients with epilepsy. Epilepsy Res *30*:77–83.

Huizar JF, Awasthi A, Kozman H [2006]. Case report and brief review: Fibromuscular dysplasia and acute myocardial infarction: evidence for a unique clinical and angiographic pattern. J Invasive Cardiol *18*:2:E99–E101.

IAFF, IAFC [2000]. The fire service joint labor management wellness/fitness initiative. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Leestma JE, Annegers IF, Brodie ME, Brown S, Schraeder P, Siscovick D, Wannamaker BB, Tennis PS, Cierpial MA, Earl NL [1997]. Sudden unexplained death in epilepsy: observation from a large clinical development program. Epilepsia *38*:47–55.

Lindsten H, Nystrom L, Forsgren L [2000]. Mortality in an adult cohort with newly diagnosed unprovoked epileptic seizure. A population-based study. Epilepsia *41*:1469–1473.

Loiseau J, Picot M-C, Loiseau P [1999]. Short-term mortality after a first epileptic seizure: a population-based survey. Epilepsia *40*:1388–1393.

Maniscalco P, Lane R, Welke M, Mitchell J, Husting L [1999]. Decreased rate of back injuries through a wellness program for offshore petroleum employees. J Occup Environ Med *41*:813–820.

Moore GW [1999]. Anatomic pathology procedure manual. Available at: www.medparse.com/axsop/axsop146.htm.

Nashef L [1997]. Sudden unexpected death in epilepsy: terminology and definitions. Epilepsia *38*(Suppl 11):6–8.

Nashef L, Walker F, Allen P, Sander JW, Sorvon SV, Fish DR [1996]. Apnoea and bradycardia during epileptic seizures: relation to sudden death in epilepsy. J Neurol Neurosurg Psychiatry *60*:297–300.

NFPA [1997]. NFPA 1500: Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association.

NFPA [2000]. NFPA 1583. Standard on health-related fitness programs for fire fighters. Quincy, MA: National Fire Protection Association.

NFPA [2007]. NFPA 1582: Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association.

NVFC, USFA [2004]. Health and wellness guide for the volunteer fire service, Emmitsburg, MD: Federal Emergency Management Agency; USFA, Publication No. FA–267/January 2004. National Volunteer Fire Council and United States Fire Administration.

Nilsson L, Tomson T, Farahmand B, Diwan V, Persson PG [1997]. Cause-specific mortality in epilepsy: a cohort study of more than 9000 patients once hospitalized for epilepsy. Epilepsia *38*:1062–1068.

Olafsson E, Hauser WA, Gunmundsson G [1998]. Long-term survival of people with unprovoked seizures: a population-based study. Epilepsia *39*:89–92.

Olivotto I, Maron BJ, Montereggi A, Mazzuoli F, Dolara A, Cecchi F [1999]. Prognostic value of systemic blood pressure response during exercise in a community-based patient population with hypertrophic cardiomyopathy. J Am Coll Cardiol *22*:805.

Plowman SA and Smith DL [1997]. Exercise physiology: for health, fitness and performance. Boston, MA: Allyn and Bacon.

Racoosin JA, Feeney J, Burkhart G, Boehm G [2001]. Mortality in anti-epileptic drug development programs. Neurology *56*:514–519.

Schraeder PL, Lathers CM [1989]. Paroxysmal autonomic dysfunction, epileptogenic activity and sudden death. Epilepsy Res *3*:55–62.

Siegel RJ [1997]. Myocardial hypertrophy. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology acquired diseases. Philadelphia, PA: Lippencott-Raven, pp. 55–57.

Slovut DP, Olin JW [2004]. Fibromuscular dysplasia. N Engl J Med *350*:1862–1871.

Spirito P, Seidman CE, McKenna WJ, Maron BM [1997]. The management of hypertrophic cardiomyopathy. N Engl J Med *336*:775.

Stein AD, Shakour SK, Zuidema RA [2000]. Financial incentives, participation in employer sponsored health promotion, and changes in employee health and productivity: HealthPlus health quotient program. J Occup Environ Med *42*:1148–1155.

Synne J, Braunwald E [2001]. The cardiomyopathies and myocarditides. In: Braunwald E, Zipes DP, Libby P, eds. Heart disease: a text of cardiovascular medicine. 6th ed. Vol. 2. Philadelphia, PA: W.B. Saunders Company, pp. 1760–1774.

Tomson T, Kenneback G [1997]. Arrhythmia, heart rate variability, and antiepileptic drugs. Epilepsia *38*(Suppl 11):48–51.

Tomson T, Walczak T, Sillanpaa, Sander JWAS [2005]. Sudden unexpected death in epilepsy: a review of incidence and risk factors. Epilepsia *46*(Suppl 11):54–61.

INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by

J. Scott Jackson, RN, MSN
Occupational Nurse Practitioner

Mr. Jackson is with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio.