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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation July 7, 2003

Fire Fighter Dies of Complications of Heart Failure Suffered at Fire Scene - Wisconsin

SUMMARY

On February 12, 2001, a 60-year-old male volunteer fire fighter responded to a structural fire in a rural area. At about 2116 hours, about two minutes after arriving at the scene, he developed difficulty breathing after helping pull fire hose off the engine and straightening it on the ground. A crew member and the Chief advised him to sit down and await the ambulance that was also responding to the fire. The ambulance arrived about a minute later, the ill fire fighter walked to it, and the ambulance departed at 2128 for the nearest hospital, arriving at 2147 hours. En route, the fire fighter was treated with oxygen, aspirin, and nitroglycerin. He remained conscious, though in increasing respiratory distress, until he lost his pulse as the ambulance was approaching the hospital. Cardiopulmonary resuscitation (CPR) was begun in the ambulance, and after about six minutes of advanced life support (ALS) in the hospital emergency department, his heartbeat was restored. He was stabilized, and at 2300 hours he was evacuated by helicopter to a tertiary care hospital. He never regained consciousness, and neurological assessment indicated irreversible brain damage. On February 19, at the family's request, ventilatory support was discontinued, and the fire fighter died.

Although a myocardial infarction (heart attack) was initially suspected, this was not supported by subsequent electrocardiographic findings or elevated blood levels of cardiac enzymes. The autopsy found arteriosclerosis of some of the arteries to the brain, and atherosclerotic coronary artery disease, but no coronary artery thrombosis or other signs of myocardial infarction. Autopsy findings indicated acute brain and spinal cord damage due to hypoxia/ischemia (lack of oxygen), apparently a result of the cardiac arrest. The autopsy documented congestive heart failure, and based on the clinical history and autopsy results, concluded that this, complicated by an arrhythmia (abnormality of heart rhythm), was the most likely cause of the acute illness at the fire scene. The death certificate, completed by the coroner of the deceased fire fighter's county, listed "Hypoxia / Ischemia, Acute [of the brain and spinal cord]" as the immediate cause of death, various autopsy findings as intermediate causes, and "Overexertion from responding to a fire call with Fire Dept" as the underlying cause.

The following recommendations address some general health and safety issues identified during this investigation. 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. These selected recommendations have not been evaluated by NIOSH, but represent published research, consensus votes of technical committees of the National Fire Protection Association (NFPA), or fire service labor/management groups.

- ***Institute pre–placement and periodic medical evaluations. These should incorporate exercise stress testing (EST), depending on the fire fighter's age and coronary artery disease (CAD) risk factors.***

- ***Fire fighters should be cleared for duty and for respirator use by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians.***

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

INTRODUCTION & METHODS

On February 19, 2001, a 60-year-old volunteer fire fighter died seven days after he became ill shortly after arriving at the scene of a structural fire. On February 22, the United States Fire Administration notified NIOSH of the death. On September 18, NIOSH contacted the affected Fire Department to initiate the investigation. On October 8, a NIOSH contract physician traveled to Wisconsin to conduct an on-site investigation of the incident.

People interviewed included:
- The Fire Chief;
- An Assistant Chief;
- Crew members on duty with the deceased fire fighter;
- The deceased fire fighter's spouse and son (who was one of the crew members);
- A law enforcement officer at the scene;
- The deceased fire fighter's physician.

Documents reviewed included:
- Fire Department policies and operating guidelines;
- The deceased fire fighter's training records;
- Fire Department annual report for 2000;
- The deceased fire fighter's medical records maintained by his private physician;
- Ambulance response report;
- Community hospital emergency department records;
- Referral hospital transport and inpatient records;
- Fire Department incident report;
- Death certificate;
- Autopsy report.

INVESTIGATIVE RESULTS

Incident. At 2058 hours, on February 12, 2001, the now-deceased fire fighter received a page indicating a fire call. He went to the fire station, where Engine 110, staffed by him and four other fire fighters, departed for the scene of a structural fire, arriving at about 2116 hours. The engine parked about 100 feet upwind of the fire; there was no smoke exposure in this area. The only other fire fighter at the scene at the time was the Chief, who had arrived about eight minutes earlier, assessed the scene, and established command. The Engine 110 crew began unloading hoses; the now-deceased fire fighter, wearing turnout gear, went around the truck shutting drains, helped pull fire hose off the truck, and then started straightened (still uncharged) the hose while a member of the attack team pulled it. (No respiratory protection was needed for these tasks there was no smoke exposure.) Snow piled on the sides of the driveway where the engine was parked made straightening the hose more difficult than usual. After about two minutes at the scene the now-deceased fire fighter said to a crew member that he was having trouble breathing; the crew member told him to sit down and notified the Chief. The ill fire fighter told the Chief that he was sweating, had head and chest

pain, and felt dizzy. He was gasping for air but was able to talk. The Chief told the fire fighter to sit on the side of the engine and asked a law enforcement officer, who had responded to the fire call, to watch him until the ambulance, which was also responding to the call, arrived.

The ambulance, staffed by three intermediate-level emergency medical technicians (EMT-I), arrived within a minute, and the ill fire fighter walked the short distance to it. The ambulance crew put him on the cot and noted that he was sweating and bringing up pink phlegm. He was unable to talk, but in response to questions, nodded to indicate that he had chest pain. His pulse was 78 and his systolic blood pressure was 191 millimeters of mercury (mm Hg).. The ambulance crew administered aspirin, nitroglycerin, and oxygen. A 12-lead electrocardiogram (ECG) showed a left bundle branch block (LBBB, a heart rhythm abnormality) and Q-wave and ST-T changes that would indicate ischemia (lack of oxygen to the heart) in the absence of LBBB, but not necessarily in its presence. [The fire fighter's LBBB had been previously diagnosed (see below), but the ambulance crew and emergency medical personnel at the hospital would not have known this.] An intravenous fluid line and a nasal airway were inserted. The ambulance departed for the nearest hospital at about 2128 hours. En route, the fire fighter's respiratory distress increased despite airway suctioning, and his pulse decreased. Two attempts to place an endotracheal tube were unsuccessful. As the ambulance approached the hospital, the fire fighter had a cardiac arrest (loss of heartbeat), and the ambulance crew began CPR.

Upon his arrival in the emergency department at 2145 hours, the fire fighter had no heartbeat (asystole), but resuscitation efforts resulted in its restoration six minutes later. A chest x-ray showed signs of congestive heart failure. Based on the reported symptoms and initial ECG findings (also present in the emergency department after resuscitation), the fire fighter was treated with a thrombolytic drug for a suspect myocardial infarction (MI). Although the LBBB persisted, the other ECG findings returned to normal, and cardiac enzymes [CK-MB: 24 nanograms per milliliter (ng/mL), troponin: 0.0 ng/mL) were not elevated. His pulse and blood pressure were stabilized, his pulmonary edema was treated, and at 2300 hours he was transferred by helicopter to a tertiary care hospital. His heart continued to function, and there was no further electrocardiographic or cardiac enzyme evidence of an MI. He never regained consciousness after the cardiac arrest, and various neurologic examinations and tests at the referral hospital indicated anoxic (lack of oxygen) brain damage, with an increasingly remote likelihood of meaningful recovery as time went on. On February 19, at the family's request, ventilatory support was discontinued, and the fire fighter died six hours later.

Medical Findings. Pertinent findings from the autopsy report, prepared by staff of the referral hospital, include:

1. Congestive heart failure.
   Cardiomegaly with left and right ventricular hypertrophy
   Myocyte hypertrophy, heart.
   Pulmonary edema, congestion, and hemosiderin-laden macrophages, lungs.
   Chronic passive congestion, mild to moderate, liver
2. Arteriosclerotic coronary artery disease with luminal occlusion of over 95% in the proximal circumflex which arises aberrantly from the right sinus of Valsalva [and] up to 50% occlusion in anterior interventricular artery, distal circumflex, and posterior intraventricular artery, heart.
3. Anomalous coronary artery distribution.
   Two right coronary ostia and a single left coronary ostium at base of aorta.

Circumflex arises from the same sinus of Valsalva as the right coronary artery and transverse to the left posterior of the aorta.
Left dominant coronary artery distribution, heart.

4. Bronchopneumonia, focal, mild, acute, lungs.
5. Hypoxia/ischemia, acute, varying severity, semi-global, (cerebral, cerebellar, and spinal cord).
Infarct, acute/recent, middle and inferior temporal gyrus and occipital lobes, bilateral).
Atherosclerosis, moderate to severe, right vertebral artery, basilar artery, temporal branch of right middle cerebral artery.
Status post cardiac arrest (pulseless time 6-8 minutes).

The autopsy report concluded that congestive heart failure, complicated by an arrhythmia (abnormality of heart beat), was the most likely cause of the acute illness at the fire scene, and that before heart function was restored following the cardiac arrest, irreversible brain damage had occurred. The report notes that anomalous coronary arteries have been associated with sudden death in young athletes but that their contribution in this case is unknown.

The death certificate was signed on February 21, 2001, by the coroner of the deceased fire fighter's county of residence; it recorded the manner of death recorded as "pending." On July 6, approximately three months after the autopsy report was completed, the coroner revised the death certificate to record the manner of death as "accident" (the other choices being "natural," "suicide," "homicide," and "undetermined"). The immediate cause of death was recorded as "Hypoxia / Ischemia, Acute, Varying Severity [affecting various areas of the brain and spinal cord]." A number of findings listed in the autopsy report, including "Pulmonary Edema," were listed as intermediate causes. The underlying cause was recorded as "Overexertion from responding to a fire call with Fire Dept."

The deceased fire fighter, a former plumber, managed a plumbing company. He smoked in the past, but not in the last 30 years. He had no family history of heart disease. He played golf regularly, walking the course where permitted. He also bowled, walked, cut his lawn with a push mower, and exercised regularly at home, including fast walking on a treadmill for 30 minutes three times a week. He never mentioned symptoms of coronary artery disease (CAD) or congestive heart failure (CHF) to his family or crew members. He had no fire calls in the 24 hours preceding the one at which he became ill. On the day before this incident, he worked for five hours on an addition to his son's house. On the day of his death, he came home from work and had dinner. He reported nothing unusual prior to the fire call and did not seem ill. On the way to the fire, he rode in the right front seat of the engine, talking and not showing any sign of illness.

The deceased fire fighter took oral medications for diabetes (diagnosed in 1999) and hypertension (diagnosed in 1990). He also took a platelet aggregation inhibitor as prophylaxis against heart attack and stroke. In 1999, a carotid ultrasound showed minimal plaque and no high-grade stenosis. In 2000, neurologic evaluation for visual disturbances (episodes of double vision and blurred vision) revealed substantial stenosis (narrowing) of both vertebral arteries (which supply the brain) and less severe atherosclerosis of other arteries to the brain. This evaluation resulted in a diagnosis of transient ischemic attacks. In January 2000, an exercise stress test (EST) was cancelled because the initial ECG showed LBBB. (Evaluation of the exercise ECG for ischemic changes can be problematic in the presence of LBBB.[1]) Instead, a myocardial perfusion study with vasodilator stress was done; no coronary artery disease was found.

The deceased fire fighter's last medical check-up was in January 2001. His blood glucose was 197

(high, though lower than the 227 in June 2000), and his hemoglobin A1c (an indicator of blood sugar over the preceding several weeks, and therefore a better indicator of diabetes control than a single blood glucose) was 6.5% (upper limit of normal). His blood pressure was 170/90 (with a "recent" blood pressure of 146/74 noted). His medication dosages were not changed. His weight was 199.5 pounds, unchanged over the preceding year. He was 71 inches tall and thus had a body mass index (BMI) of 28 kg/m^2. (A BMI above 25 kg/m^2 indicates overweight, and a BMI above 30 kg/m^2 indicates obesity.[2] At neither this visit nor past visits did the medical record indicate any symptoms or signs of CHF.

DESCRIPTION OF THE FIRE DEPARTMENT

The Fire Department, which operates out of one fire station, has up to 35 (currently 29) paid-call volunteer fire fighters. It serves a population of 5,200 residents in a geographic area of 160 square miles. In 2000, the Department responded to 172 calls: 65 rescues, 35 hazardous conditions, 29 structural fires, 26 wildland fires, 9 emergency medical assists, and 8 vehicle incidents. (Medical assistance calls are handled by a county-wide volunteer emergency medical service, but the fire department provides rescue assistance if needed.)

Training. To qualify as a fire fighter, an applicant must pass a physical agility test. Successful applicants are assigned probationary status, during which they must demonstrate various proficiencies and complete the Wisconsin Fire fighter 1 training course. The deceased fire fighter had been with the department continuously since 1963, prior to current formal training requirements. Thus, he had experience as a driver/operator and fire inspector without certification. He did, however, have formal Fire Fighter 1 training . During his more than 37 years of service for the Fire Department, he held various positions in the department, including training officer, captain, and assistant chief.

Medical Evaluations. The Department's volunteer fire fighter application asks a limited number of health questions (tobacco use, contact lenses, allergies, medications, physical limitations), but the Department otherwise requires no pre-placement medical evaluation. Nor are any periodic medical evaluations required or offered. A volunteer who is injured or has a work-related illness must be cleared to return to work as a fire fighter by a personal physician. Medical clearance for respirator use is not required. The fire station does not have exercise equipment, and the Department does not have exercise/fitness or health promotion programs.

DISCUSSION

In the United States, coronary artery disease (CAD, atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[3] Risk factors for its development include increasing age, male gender, heredity, tobacco smoke, high blood cholesterol, high blood pressure, physical inactivity, obesity and overweight, and diabetes.[4] Left bundle branch block is an abnormal heart rhythm that can be an indicator of ischemic heart disease, hypertension, aortic valve disease, or cardiomyopathy (disease of the heart muscle).[5] The deceased fire fighter had hypertension, and although the autopsy documented CAD, he had no medical history of ischemic heart disease prior to the fatal incident. The autopsy revealed no evidence of aortic valve disease or cardiomyopathy.

Congestive heart failure[6,7] is the inability of the heart to pump blood normally at a sufficient rate to meet the body's needs. CHF can result from a number of underlying conditions, including cardiomyopathies, CAD, heart valve abnormalities, and hypertension. Shortness of breath is the most common initial

presentation of CHF. Since there are multiple mechanisms by which the body can adapt, or compensate, for impaired cardiac function, CHF can be present without any symptoms or interference with ordinary activity. Conditions that can precipitate overt CHF include infection (in the lung or elsewhere), anemia, thyrotoxicosis, pregnancy, cardiac arrhythmias, myocarditis (inflammation or infection of the heart muscle), infective endocarditis (infection of a heart valve), hypertension (with rapid elevation of blood pressure), heat stress, physical overexertion, discontinuation of heart failure medication, blood transfusion, increased sodium intake, emotional crisis, myocardial infarction, and pulmonary embolus. The deceased fire fighter had hypertension and an arrhythmia, and at the onset of his acute heart failure he was engaged in relatively heavy, though not unaccustomed, physical exertion. [Straightening uncharged fire hose in piled snow while wearing turnout gear would be considered relatively heavy work, requiring 6-7 metabolic equivalents (MET); fast walking requires about 6 MET.[8-11]] The autopsy found no evidence of myocarditis, endocarditis, myocardial infarction, or pulmonary embolus. Mild pneumonia was present, but this could have occurred after his acute heart failure and cardiac arrest. There was no indication in his medical record of anemia or thyroid disease. Therefore, the most likely etiology of the deceased fire fighter's CHF was CAD and/or chronic hypertension, with the acute onset possibly triggered by physical exertion at the fire.

NFPA 1582, *Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians*,[12] recommends a brief medical evaluation annually and a more extensive evaluation periodically according to the age of the fire fighter (less than 30: every 3 years; 30-39: every 2 years; over 40 years: every year). NFPA 1582 recommends EST for fire fighters over the age of 35 with risk factors for CAD and for all fire fighters over age 40.

The deceased fire fighter was overweight for his height but not obese. His hypertension and diabetes were under treatment, and he was physically active, engaging in aerobic exercise regularly. Although the autopsy revealed longstanding CHF, this condition was apparently physiologically compensated (see above) prior to the fatal incident. A cardiac stress test 12 months before his heart attack did not detect CAD.

NFPA 1582 considers hypertension and LBBB Category B conditions, that is, "a medical condition that, based on its severity or degree, could preclude a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the member or others."[12] The deceased fire fighter's blood pressure readings at his physician's office were within the range considered acceptable by NFPA 1582 (less than 180 mm Hg systolic, less than 100 mm Hg diastolic). If diabetes is under treatment with insulin or an oral hypoglycemic agent and there is a history of incapacitating hypoglycemia (low blood sugar), then NFPA considers it a Category A condition, that is, "a medical condition that would preclude a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the member or others." Otherwise, it is a Category B condition. There is no record of the deceased fire fighter having had a hypoglycemic episode. NFPA 1582 provides no specific criteria for determining whether Category B diabetes is of a "severity or degree" that would preclude medical clearance. NFPA 1582 considers "cerebral arteriosclerosis as evidenced by documented episodes of neurological impairment" a Category A condition, Whether the deceased fire fighter's transient visual disturbances would constitute "episodes of neurologic impairment," and whether a fitness-for-duty medical evaluation within the year preceding the fatal incident would have resulted in medical clearance, with or without restrictions/ accommodations, are open questions.

RECOMMENDATIONS

The following recommendations address health and safety issues identified during this investigation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of on-the-job cardiac arrest among fire fighters. These selected recommendations have not been evaluated by NIOSH, but represent published research or consensus votes of Technical Committees of the National Fire Protection Association, or fire service labor/management groups.

Recommendation #1: Institute pre–placement and periodic medical evaluations. These should incorporate exercise stress testing (EST), depending on the fire fighter's age and coronary artery disease (CAD) risk factors.

The purpose of pre-placement and periodic medical evaluations is to ensure that fire fighters have the ability to perform duties without presenting a significant risk to the safety and health of themselves or others. Guidance regarding the content of the evaluations and scheduling of periodic medical examinations for fire fighters can be found in NFPA 1582, *Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians*.[12] In addition to providing guidance on the frequency and content of the medical evaluations, NFPA 1582 provides guidance on medical requirements for persons performing fire fighting tasks. NFPA 1582 recommends pre-placement and periodic EST beginning at age 35 for those with CAD risk factors and at age 40 for those without CAD risk factors.

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.[13] 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. Unfortunately, the second and third requirements may not be workable in a volunteer department and could thus impair both acceptance by fire fighters and the Fire Department's ability to retain fire fighters.

Applying this recommendation involves economic repercussions and may be particularly difficult for small, rural, volunteer Fire Departments to implement. To overcome the financial obstacle, the Fire Department could urge current members to get annual medical clearances from their private physicians (but see Recommendation #2). Another option is having the brief annual medical evaluations recommended by NFPA 1582 completed by the volunteer fire fighters themselves (medical and occupational history) and by EMTs from the county's EMS (vital signs, height, weight, and visual acuity). This information could then be provided to a community physician, perhaps volunteering his or her time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive periodic medical examinations could be performed by a private physician at the fire fighter's expense, provided by a physician volunteer, or paid for by the Fire Department. Sharing the financial responsibility for these evaluations between volunteers, the Fire Department, and willing physician volunteers should reduce the negative financial impact on recruiting and retaining needed volunteers.

Recommendation #2: Fire fighters should be cleared for duty and for respirator use by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

The decision regarding medical clearance for fire fighters requires knowledge not only of the fire fighter's medical condition, but also of the fire fighter's job duties. Likewise, the decision regarding medical clearance for respirator use requires knowledge of the respiratory protection devices used by fire fighters and the conditions under which they are used. Since the medical clearances for fire fighting duty and respirator use require much the same health information, it makes sense to coordinate scheduling to obtain both of these clearance decisions from the same medical evaluation.

The Occupational Safety and Health administration (OSHA) respiratory protection standard[14] requires employers whose employees are required to use respirators to have a formal respiratory protection program, including periodic medical evaluations. Since Wisconsin does not have an OSHA-approved State plan, public employers, including volunteer fire departments, are not legally subject to OSHA standards.[15] Nevertheless, we recommend that the Fire Department voluntarily adhere to the health and safety-related provisions of the OSHA standard, including periodic medical evaluations.

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

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[13] The International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) joined in a comprehensive Fire Service Joint Labor Management Wellness/Fitness Initiative to improve fire fighter quality of life and maintain physical and mental capabilities of fire fighters. 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.[16] The Wellness/Fitness Initiative provides guidance regarding wellness program content, to include physical examination and evaluation, fitness, and behavioral health. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[17, 18] An unpublished analysis by the Phoenix, Arizona, city auditor found a reduction in disability pension costs following a 12-year commitment to the wellness program at the Fire Department.

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INVESTIGATOR INFORMATION

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