F2000 24
NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *December 11, 2000*

Fire Fighter Dies During Search-and-Rescue Training - Ohio

SUMMARY

On April 11, 2000, a 46-year-old male "paid-call" Fire Fighter was performing search-and-rescue training in the basement of a three-story office building. Five minutes after completing a rigorous 20-minute training exercise in full bunker gear and self-contained breathing apparatus (SCBA), the victim had a witnessed collapse. Despite cardiopulmonary resuscitation (CPR) and advanced cardiac life support (ACLS) administered on the scene and at the hospital, the victim died. The autopsy showed a large heart (cardiomegaly) and only moderate coronary artery disease (CAD). The death certificate listed "Cardiomegaly - Acute Cardiac Arrhythmia" as the immediate cause of death.

The following recommendations address some general health and safety issues. 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 or consensus votes of technical committees of the National Fire Protection Association (NFPA) or labor/management groups within the fire service.

- ***Fire fighters should have mandatory 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.***
- ***Exercise stress tests should be incorporated into the Fire Department's medical evaluation program.***
- ***Provide fire fighters with medical evaluations and clearance to wear self-contained breathing apparatus (SCBA).***
- ***Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***The ambulance service, which is separate from the Fire Department, should provide defibrillator unit refresher training to its personnel.***
- ***Provide adequate fire-fighter staffing to ensure safe operating conditions.***

INTRODUCTION AND METHODS

On April 11, 2000, a 46-year-old male Fire Fighter lost consciousness after completing a rigorous training exercise and ascending one set of steps. Despite CPR and ACLS administered by crew members,

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:

http://www.cdc.gov/niosh/firehome.html

or call toll free **1-800-35-NIOSH**

the ambulance crew, and in the emergency department, the victim died. NIOSH was notified of this fatality on April 20, 2000, by the United States Fire Administration. On May 25, 2000, NIOSH contacted the affected Fire Department to initiate the investigation. On June 19, 2000, a Safety and Occupational Health Specialist and an Epidemiologist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Ohio to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel interviewed the following:

- Fire Chief
- Prevention Chief
- Crew members on duty with the victim
- Responding ambulance service personnel
- Food and Drug Administration (FDA), Defibrillator Certification Branch
- Manufacturer of the defibrillator unit
- Coworker from the victim's regular job
- Victim's wife

During the site visit NIOSH personnel reviewed the following:

- Fire Department policies and operating guidelines
- Fire Department training records
- Fire Department annual report for 1999
- Emergency medical service (ambulance) report
- Fire Department physical examination protocols
- Death certificate
- Autopsy record
- Past medical records of the deceased

INVESTIGATIVE RESULTS

Incident. On April 11, 2000, at 1900 hours, the involved Fire Department was conducting search-and-rescue training in the basement of a three-story office building. One pumper and 20 fire fighters were on the scene as training began. Crew members performed a walk-through of the structure while training objectives were discussed. Two teams, each consisting of two fire fighters, would conduct a search-and-rescue training exercise in a simulated smoky basement. A Safety Officer would oversee the exercise within the basement area. A smoke machine filled the basement with non-toxic smoke while the two search teams, including the victim, wearing full bunker gear and breathing air from SCBAs, began the training exercise. Each team searched a separate area of the basement, crawling in a left-hand sweep pattern. The evolution took approximately 20 minutes. The first team to finish, including the victim, entered the hallway and waited for the second team to finish. The victim sat down in a chair and removed his SCBA facepiece. Both the victim and his crew member were sweating and breathing heavily from the training exercise. The victim rose from the chair and began to ascend the stairs. The Safety Officer told the victim to wait on the other group and that all four personnel would exit the structure together. The second group arrived about 5 minutes later and all four fire fighters began to ascend the stairs. The victim reached the first landing, took two steps up the next set of stairs, and then collapsed. A crew member found the victim unresponsive, pulseless, and gasping for air. The Safety Officer was called to bring the medical bag and oxygen was administered via non-rebreather mask. Shortly thereafter, the victim stopped breathing and CPR (chest compressions and bag-valve mask ventilations) was begun. An ambulance was requested at 2025 hours for a man down.

Squad 1 (one Paramedic and three emergency medical technicians [EMTs]) responded immediately and arrived on the scene at 2028 hours. The victim remained unresponsive, pulseless, and not breathing. Crew members carried the victim up the remaining steps to the first floor. A cardiac monitor was applied to the victim and showed ventricular fibrillation (V. Fib.). Two attempts to defibrillate the victim were unsuccessful because the defibrillation unit would not

charge. CPR continued as the victim was intubated and loaded into the ambulance. The ambulance departed the scene at 2038 hours. No intravenous access was obtained because the victim was wearing bunker gear and the trip to the hospital was short. The ambulance arrived at the emergency department (ED) at 2040 hours. ACLS protocols were continued in the ED for 30 minutes until the victim was pronounced dead at 2110 hours.

The day after the incident, the ambulance service had the defibrillator unit analyzed by its manufacturer. The manufacturer reported that the energy selector was found to be in the "0," or storage, position. In this position, the unit will analyze the patient's heart rhythm but will not charge for defibrillation. Subsequent testings by the manufacturer showed that, with the energy selector out of the storage position, the defibrillator charged and discharged properly. The manufacturer concluded that the failure of the defibrillator unit to charge was due to operator error.

Medical Findings. An addendum to the death certificate completed by the County Coroner after the autopsy was performed listed "cardiomegaly - acute cardiac arrhythmia" as the immediate cause of death. Since the Fire Fighter was not engaged in fire-suppression activities, his blood was not tested for carbon monoxide poisoning (carboxyhemoglobin level). Pertinent findings from the autopsy, performed by his personal physician (who was also the Deputy County coroner), and a forensic pathologist, on April 12, 2000, included

- Cardiomegaly (enlarged heart)
  A weight of 690 grams
- Moderate coronary atherosclerosis
- 50-60% blockage of the midpoint of his left anterior descending coronary artery
- Chronic and acute lung congestion

The Fire Fighter had the following risk factors for coronary artery disease (CAD): hypertension (approximately 162/102), advancing age (greater than 45 years old), smoking, and male gender. The victim was prescribed two anti-hypertensive medications but did not take the medications regularly. During the victim's preemployment physical examination in November 1998, an electrocardiogram (EKG) was completed. This test revealed left atrial enlargement and left ventricular hypertrophy. This abnormality was attributed to his hypertension without subsequent medical testing, such as an echocardiogram.

According to his spouse, 4 months before his death, the victim attempted to stop smoking. The day of the incident, the victim worked 8 hours at his regular job and did not report any symptoms consistent with angina or heart failure to his spouse, coworkers, or crew members.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the combination Fire Department consisted of 39 uniformed personnel (14 career and 25 paid-call volunteers) and served a population of 18,000 residents in a geographic area of 40 square miles. There are two fire stations. The emergency medical service is not part of the Fire Department.

In 1999, the Department responded to 767 calls: 71 structure fires, 48 wildland fires, 41 vehicle fires, 24 refuse fires, 15 other fires, 1 steam rupture, 17 rescue calls, 16 ambulance-assist calls, 10 emergency medical calls, 7 extrication calls, 305 hazardous-condition calls, 40 service calls, 83 good-intent calls, 76 false alarms, and 13 other calls. The day of the incident, the victim worked at his regular job of Facilities Maintenance for the County.

Training. The Fire Department requires all new fire-fighter applicants to pass an agility test and an interview before being recommended to the City Manager for becoming a member. Newly hired fire fighters must complete the Fire Fighter 1A course before performing activities at an emergency scene. The training is provided in-house and at other local fire departments. The State minimum requirement for fire-fighter certification is the 36-hour Fire Fighter 1A course. Subsequent training is provided monthly. The State has no minimum requirement for recertification; however, the Fire Department requires completion of 36 hours of training annually. The victim was certified as a Fire Fighter, and he had 1 year of fire-fighting experience.

Preemployment/Preplacement Evaluations. The Department requires a preemployment/preplacement medical evaluation for all new hires (career and paid-call), regardless of age. Components of this evaluation include the following:

- A complete medical history
- Height, weight, and vital signs
- Physical examination
- Blood tests: Complete blood count with differential (CBC), comprehensive metabolic panel, eight-panel non-Department of Transportation (DOT) drug screen
- 12-lead resting EKG
- Exercise stress test (EST) (performed only on career fire fighters)
- Pulmonary function test (PFT)
- Audiogram

These evaluations are performed by a contract physician hired by the City. Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire-fighting duties and forwards this decision to the City's personnel director.

Periodic Evaluations. Voluntary periodic medical evaluations and examinations are offered by this Department to all career fire fighters; however, the evaluations and examinations are mandatory for HAZMAT technicians. Paid/Call volunteer fire fighters are not given the option to participate in the Fire Department physical evaluations or examinations. The content of this evaluation for career fire fighters includes the following:

- A complete medical history
- Height, weight, and vital signs
- Physical examination
- Blood tests: Complete blood count with differential (CBC), comprehensive metabolic panel, eight-panel non-DOT drug screen
- 12-lead resting EKG
- EST (performed only on career fire fighters)
- PFT
- Audiogram

The victim's last Fire Department medical evaluation was in 1998. Hypertension was noted, and he was cleared for fire-fighting duties. If an employee is injured at work or ill, the employee is evaluated and must be cleared for "return to work" by the fire fighter's private physician, and the clearance is then reviewed by the Fire Chief. No exercise (strength and aerobic) equipment or fitness/ wellness programs are in place for the Department.

DISCUSSION

Both the death certificate and autopsy attribute the victim's death to a heart arrhythmia due to his cardiomegaly (enlarged heart). The most common cause for an enlarged heart is ischemic or hypertensive (chronic high blood pressure) heart disease.[1] The lack of significant atherosclerosis in his coronary arteries, the lack of any fibrosis or scarring of his heart on direct visualization (gross anatomy), and the lack of any fibrosis on microscopic examination (histopathology), rule out ischemia

(remote or recent heart attacks) as the cause of his cardiomegaly.[2] Another less common cause of cardiomegaly is hypertrophic cardiomyopathy.[1] Given the localized nature of the victim's cardiomegaly (primarily the left ventricle), the unremarkable histologic pattern on histopathology (hypertrophic cardiomyopathy has a characteristic disarray of the heart muscle fibers), and no family history of this disorder (it is a autosomal dominant), hypertrophic cardiomyopathy can be ruled out as a cause of his cardiomegaly.[3] This leaves hypertensive disease as the most likely cause. The victim had a history of hypertension treated with two prescription medications.

To reduce the risk of heart attacks and sudden cardiac arrest among fire fighters, NFPA has developed a non-regulatory standard entitled "Medical Requirements for Fire Fighters and Information for Fire Department Physicians," otherwise known as NFPA 1582.[4] NFPA 1582 recommends a preemployment medical evaluation which includes a baseline EKG. In 1998, the victim had an EKG as part of the Fire Department's preemployment medical evaluation which showed left ventricular hypertrophy (increased wall thickness). NFPA 1582 classifies hypertrophy of the heart as a "category B" condition, a condition that, depending on severity, could preclude a fire fighter from performing his duties. While this finding alone should not have precluded the victim from fire-fighting duties, further evaluation using another component of the medical examination recommended by NFPA 1582, the exercise stress test, might have uncovered his risk for heart arrhythmias.

The inclusion of EST as part of NFPA 1582 is controversial due to problems with false negatives (inadequate sensitivity) and false positives (inadequate specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of angina).[5,6] This has led other expert groups to **not** recommend EST for asymptomatic individuals without risk factors for CAD.[7,8]

When these asymptomatic individuals **have** risk factors for CAD; however, recommendations vary by organization. The American College of Cardiology/American Heart Association (ACC/AHA) identifies two groups for EST: (1) men over the age of 40 with a history of cardiac disease (as a screening test prior to beginning a strenuous exercise program), and (2) men over age 40 with one or more risk factors.[7] They define five risk factors for CAD: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic greater than 140 mm Hg or diastolic greater than 90 mm Hg), smoking, diabetes, and family history of premature CAD (cardiac event in first-degree relative less than 60 years old).[7] The U.S. Preventive Services Task Force (USPSTF) does not recommend EST for asymptomatic individuals, even those with risk factors for CAD; rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes).[8]

These recommendations change for individuals who might endanger public safety if an acute episode were experienced or those who require high cardiovascular performance such as police and fire fighters. The National Fire Protection Association (NFPA) recommends EST for fire fighters without CAD risk factors at age 40 and for those with one or more risk factors at age 35.[2] NFPA considers risk factors to be family history of premature (less than age 55) cardiac event, hypertension, diabetes mellitus, cigarette smoking, and hypercholesterolemia (total cholesterol greater than 240 or HDL cholesterol less than 35).[4] The EST should then be performed on a periodic basis, at least once every 2 years.[4] The ACC/AHA indicates that data are insufficient to justify periodic exercise testing in people involved in public safety; however, as mentioned previously, they recommend that men over age 40 with a history of

cardiac disease be screened before beginning a strenuous exercise program.[7] Fire-suppression activities involve strenuous physical activity; therefore, the ACC/AHA seem to be making a distinction between those already engaged in strenuous physical activity (conditioning), and those **beginning** a strenuous exercise program. The USPSTF indicates that evidence is insufficient to recommend screening middle-age and older men or women in the general population; however, "screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety."[8]

In either case, given that the victim had two risk factors for CAD (hypertension and smoking) and an abnormal EKG (left ventricular hypertrophy), an EST would have been reasonable to perform. An EST might have identified his predisposition to ventricular arrhythmias, thereby leading to further evaluation and treatment and possibly the prevention of this sudden cardiac death.

During the resuscitation effort, a problem with charging the defibrillator occurred. After the unit mode selector was placed in the "analyze" position and the patient was determined to be in V.Fib., the selector on the paddles should have been turned from "0" to a certain joule rating (200, 300, 360). If a joule rating had been selected, the paddles would have charged. Unfortunately, the paddle energy setting was not changed, and the paddles did not charge. This resulted in an approximately 10-minute delay of defibrillation until the victim reached the hospital's ED. This delay reduced an already low chance of immediate survival.[9]

RECOMMENDATIONS AND DISCUSSION

The following recommendations address health and safety generally. It is unclear if any of these recommendations could have prevented the sudden cardiac arrest and subsequent death of this Fire Fighter. 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 recommendations have not been evaluated by NIOSH but represent published research or consensus votes of Technical Committees of the NFPA or labor/management groups within the fire service.

Recommendation #1: Fire Fighters should have <u>mandatory</u> 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 evaluations for fire fighters can be found in NFPA 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians,[4] and in the report of the International Association of Fire Fighters/ International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative.[10]

Recommendation #2: Exercise stress tests should be incorporated into the Fire Department's medical evaluation program.

NFPA 1582 and the IAFF/IAFC wellness/fitness initiative both recommend at least biannual EST for fire fighters.[4, 10] They recommend that these tests begin at age 35 for those with CAD risk factors and at age 40 for those without CAD risk factors. The EST could be conducted by the fire fighter's personal physician or the Department's contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the City contract physician, who should be responsible for decisions regarding medical clearance for fire-fighting duties.

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.[11] In 1997, the International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) published a comprehensive Fire Service Joint Labor Management Wellness/Fitness Initiative to improve 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.[10] The Fire Department and the Union should review these materials to identify applicable elements for their department. Other large-city negotiated programs can also be reviewed as potential models.

Recommendation #4: Provide fire fighters with medical evaluations and clearance to wear self-contained breathing apparatus (SCBA).

OSHA's Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection.[12] These clearance evaluations are required for private-industry employees and public employees in States operating OSHA-approved State plans. Ohio is not a State-plan State; therefore, public-sector employers are not required to comply with OSHA standards. However, we recommend following this standard, and a copy of the OSHA medical checklist has been provided to the Fire Department. Compliance with the standard should not involve a financial burden to the Fire Department beyond that required for the fitness-for-duty medical evaluation.

Recommendation #5: The ambulance service, which is separate from the Fire Department, should provide defibrillator unit refresher training to its personnel.

For safety reasons, the defibrillator should be stored with the paddle energy selector set at "0." The unit will still analyze a patient's heart rhythm but will not charge unless the energy selector on the paddles is changed to a specific joule rating. The mode selector on the unit must be set on "Analyze" to analyze the patient and then moved to "Battery 1" or "Battery 2" for the charging process to begin. However, the selector on the paddles must be changed to a specific joule rating above "0" (200, 300, 360) for the unit to charge to that energy level. The emergency medical service should review resuscitation techniques and practice those techniques periodically to ensure all steps necessary for a resuscitation attempt are accomplished.

Recommendation #6: Provide adequate fire-fighter staffing to ensure safe operating conditions.

The Fire Department maintains 14 career personnel. Typically an Engine and the Ladder are each staffed with four personnel. However, due to sick leave and vacations, apparatus staffing often falls to three personnel. NFPA 1500 recommends a minimum of four fire fighters be present where only one team (company) is operating in the hazardous area at a working structural fire; two individuals working as a team in the hazard area and two individuals present outside this hazard area for assistance or rescue.[11] This staffing recommendation could be accomplished by any of the following: (1) increasing the number of fire fighters assigned to a company, (2) hiring fire

fighters to act as "floaters" to fill in positions vacated by employees who are sick or who are on vacation, (3) staggering vacation days in conjunction with hiring "floating" fire fighters. The staffing issue is not related in any way to the death of this fire fighter. Rather, it addresses a safety issue raised during the fatality investigation.

REFERENCES

1. Wynne J, Braunwald E [1998]. The cardiomyopathies and myocarditides. In: Fauci AS, Braunwald E, Isselbacher KJ, et al., eds. Harrison's principles of internal medicine. 14th ed. New York: McGraw-Hill, p. 1328-1332.

2. Vermani R [1997]. Cardiomyopathy, ischemic. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology. Philadelphia: Lippencott - Raven, p. 28-29.

3. Siegel RJ [1997]. Cardiomyopathy, hypertrophic. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology. Philadelphia: Lippencott - Raven, p. 24-25.

4. National Fire Protection Association [2000]. NFPA 1582, standard on medical requirements for fire fighters and information for fire department physicians. Quincy, MA: National Fire Protection Association.

5. Michaelides AP, Psomadaki ZD, Dilaveris PE, et al [1997]. Improved detection of coronary artery disease by exercise electrocardiography with the use of right precordial leads. New Eng J Med *340*:340-345.

6. Darrow MD [1999]. Ordering and understanding the exercise stress test. American Family Physician, January 15, 1999.

7. Gibbons RJ, Balady GJ, Beasley JW, Bricker JT, Duvernoy WFC, Froelicher VF, Mark DB, Marwick TH, McCallister BD, Thompson PD, Winters WL Jr, Yanowitz FG [1997]. ACC/AHA guidelines for exercise testing: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). J Am Coll Cardiol *30*:260-315.

8. U.S. Preventive Services Task Force [1996]. Guide to clinical prevention services. 2nd ed. Baltimore: Williams & Wilkins, p. 3-15.

9. Myerburg RJ, Castellanos A [1998]. Cardiovascular collapse, cardiac arrest, and sudden cardiac death. In: Fauci AS, Braunwald E, Isselbacher KJ, et al., eds. Harrison's principles of internal medicine. 14th ed. New York: McGraw-Hill, p. 1328-1332.

10. International Association of Fire Fighters, International Association of Fire Chiefs [2000]. The fire service joint labor management wellness/fitness initiative. Washington, D.C.: International Association of Fire Fighters, International Association of Fire Chiefs.

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

12. 29 CFR 1910.134. Code of Federal Regulations. Occupational Safety and Health Administration: Respiratory Protection. Washington, D.C.: National Archives and Records Administration, Office of the Federal Register.

INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by Kristen Sexson, MPH, Epidemiologist, and Tommy N. Baldwin, MS, Safety and Occupational Health Specialist. Ms. Sexson and Mr. Baldwin are with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component, located in Cincinnati, Ohio.