F2000 14
NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *October 19, 2000*

Fire Fighter Dies at a Single-Family Dwelling Fire - Iowa

SUMMARY

On February 6, 2000, a 42-year-old male Fire Fighter responded to a fire in a single-family dwelling. After ascending a 14-foot roof ladder, removing a 2-foot square section of wooden tongue-and-groove siding, further ascending up the same ladder to the roof in anticipation of performing roof ventilation, then descending to the ground, the victim had a witnessed collapse. Despite cardiopulmonary resuscitation (CPR) and advanced cardiac life support (ACES) administered on the scene and at the hospital, the victim died. The death certificate, completed by the County Coroner, listed "occlusive coronary artery disease" as the immediate cause of death due to "atherosclerotic vascular disease." Pertinent autopsy results included severe coronary artery disease, acute agonal pulmonary congestion, and pulmonary anthracosis without emphysema.

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

- ***Fire Fighters should have annual medical evaluations to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.***
- ***Exercise stress tests should be incorporated into the Fire Department's medical evaluation program.***
- ***Reduce risk factors for cardiovascular disease and improve cardiovascular capacity by offering a wellness/fitness program for fire fighters. Phase in a mandatory wellness/ fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***Self-contained breathing apparatus (SCBAs) should be upgraded with regard to the weight of the SCBAs and air cylinder.***
- ***As contained in the OSHA Revised Respiratory Protection Standard, provide fire fighters with medical evaluations to determine fitness to wear a self-contained breathing apparatus (SCBAs).***

INTRODUCTION AND METHODS

On February 6, 2000, a 42-year-old male Fire Fighter lost consciousness after descending from the roof of a single-family dwelling. Despite CPR and

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**

ACES administered by the ambulance crew and in the emergency department, the victim died. NOSH was notified of this fatality on February 8, 2000, by the United States Fire Administration. On February 17, 2000, NOSH contacted the affected Fire Department to initiate the investigation. On March 21, 2000, a Safety and Occupational Health Specialist and an Epidemiologist from the NOSH Fire Fighter Fatality Investigation Team traveled to Iowa to conduct an on-site investigation of the incident.

During the investigation NOSH personnel interviewed

- The Fire Chief
- Crew members on duty with the victim
- Responding ambulance service personnel
- The victim's wife

During the site visit NOSH personnel reviewed the

- Fire Department incident report
- Fire Department policies and operating guidelines
- Fire Department training records
- The Fire Department annual report for 1999
- Emergency medical service (ambulance) report
- Hospital's records of the resuscitation effort
- Death certificate
- Autopsy results
- Past medical records of the deceased

INVESTIGATIVE RESULTS

Incident. On February 6, 2000, at 1902 hours, the involved volunteer Fire Department was dispatched to a fire in a single-family dwelling. The dwelling was a two-story structure with a one-story addition. Attack Truck 613 (Chief and one Fire Fighter), Engine 313 (victim and two Fire Fighters), and Equipment Bus 913 (18 crew members, including the Assistant Chief and the Safety Officer) responded and arrived on the scene at 1905 hours. Engine 313 was connected to a hydrant while an entry team of three fire fighters prepared to enter the structure. After entering the structure, the entry team, utilizing a 1½-inch HOSELINES, began to extinguish the fire which was burning inside the wall beside the chimney. A light smoke was emitting from the eaves. Three additional fire fighters formed a backup team and stood by.

Meanwhile, the victim and other nearby fire fighters removed a 14-foot roof ladder from Engine 313 and placed it against the north side of the dwelling, beside the chimney. The victim requested another fire fighter get a Halligan tool for him. The victim, wearing full turnout gear and breathing air from an SCBAs, ascended the ladder to ascertain the siding materials that would be removed to determine fire spread. The fire fighter handed the Halligan tool (weighing approximately 10 pounds) to the victim.

Ambulance 726 (two Emergency Medical Technician-Paramedics [EMT-Ps] and one EMT-Basic) was dispatched at 1910 hours and arrived at 1914 hours. It is standard practice for the ambulance to be dispatched on all structure fires. Additionally, an EMT-P/FF (also a volunteer member of the involved Fire Department) responded in his privately-owned vehicle. Upon arrival, the ambulance notified the Assistant Chief and was positioned approximately one-half block away.

The victim removed a 2-foot square section of the wooden tongue-and-groove siding utilizing the Halligan tool. After removing the siding, the victim and another fire fighter ascended the ladder to the roof in anticipation of performing ventilation. Due to the clear conditions on the roof, the victim was not utilizing SCBAs air while on the roof.

The entry team knocked the fire down and began to perform overhaul. As their SCBAs low-air alarms began to sound, the Safety Officer advised the entry

team to exit the dwelling. After the entry team exited the dwelling, the backup team entered to continue overhaul. The entry team stood by at the side of the dwelling. At 1935 hours, the victim descended the ladder from the roof and walked to the south side of the dwelling in anticipation of assisting the backup team. As the victim neared the entry team, he grabbed a fire fighter's shoulder and collapsed. Initially, the fire fighter thought the victim had tripped and he knelt down to assist the victim, but after assessing the victim and finding him unresponsive, the fire fighter called for EMTs' assistance. The EMT-P/FF found the victim unresponsive, and observing cervical spine precautions, performed a modified jaw thrust to open the victim's airway. The victim gasped a few times, then stopped breathing. The ambulance crew brought equipment to the victim's location, an oral airway was inserted and assisted ventilation was performed via a demand-valve mask and oxygen. To check the victim's pulse, the victim's turnout coat, SCBAs strap, and clothing (two sweat shirts) had to be cut and the gear removed. Inside the ambulance, assisted ventilating with demand-valve mask and oxygen continued. A heart monitor was attached to the victim at 1939 hours which revealed ventricular fibrillation (V. Fib.). The victim was checked for a pulse, found to be pulse less, and one shock (cardioversion) was delivered. The ambulance departed the scene at 1940 hours. En route to the hospital, two more shocks were delivered. The monitor again revealed V. Fib. and CPR (chest compressions and bag-valve mask ventilating) was begun. En route to the hospital, two attempts at incubation were unsuccessful due to the victim vomiting and assisted ventilating were continued via bag-valve-mask and 100% oxygen. Intravenous access was obtained and ACES protocols were followed. At 1944 hours, the heart monitor revealed systole and CPR continued. The ambulance arrived at the hospital at 1957 hours. ACES protocols were continued in the emergency department for 8 minutes until the victim was pronounced dead at 2005 hours.

Medical Findings. The death certificate, completed by the County Coroner, listed "occlusive coronary artery disease" as the immediate cause of death. The death certificate also listed "atherosclerotic vascular disease" as other significant conditions. His blood carbon monoxide level was 4%, within the normal range for a smoker.

Medical records indicated that the victim had three coronary artery disease (CAD) risk factors: male gender, smoking, and family history. In November 1999, the victim's private physician ordered an exercise stress test (EST) for recurrent chest pain occurring after exercise or labor intensive work. He exercised for 12 ½ minutes and achieved Stage 4 of the Bruce Protocol (4.2 mph, 16% grade). He stopped due to fatigue and knee pain. No chest pain, no abnormal ST segment changes, no arrhythmias, or abnormal blood pressure response was reported.

Pertinent findings from the autopsy, performed by the hospital pathologist on February 7, 2000, are listed below:

- Atherosclerotic vascular disease
  - Severe coronary artery disease
  - Right coronary artery, 75% stenotic
  - Left circumflex artery, 80% stenotic
  - Left anterior descending artery unavailable due to organ harvesting for donation
- Focal contraction band necrosis in the right ventricle
- Acute pulmonary congestion, agonal
- Pulmonary anthracosis without emphysema
- Carbon monoxide level of 4%

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NOSH investigation, the volunteer Fire Department consisted of 23 uniformed personnel and served a population of 5,000 residents in a

geographic area of 110 square miles. There is one fire station. The emergency medical service is a separate function of the city.

In 1999, the Department responded to 61 calls: 10 extrication calls, 5 structure fires, 7 grass fires, 3 vehicle fires, 2 hazardous-materials calls, 16 false alarms, 13 good-intent calls, and 5 other calls. The day of the incident, the victim had previously responded to one hazardous-condition standby call.

Training. The Fire Department requires all new fire fighters to attend in-house training during the first 6 months of membership before performing interior fire suppression while wearing an SCBAs and before driving fire apparatus. Subsequent training is provided monthly. The Department also recommends completion of State Fire Academy courses. There is no minimum state requirement for new fire fighters to become certified. The victim was certified as a Fire Fighter 1 and Hazardous Materials Technician, and he had approximately 6 years of fire fighting experience.

Medical Clearance and Physical Fitness. The Fire Department has no requirement for physical examinations, and thus, provides none. The Department also does not require a medical clearance evaluation to wear a respirator. No specific Department programs were in place to enhance the cardiovascular/respiratory fitness of the fire fighters.

DISCUSSION

In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[1] Risk factors for its development include increasing age, male gender, family history of coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes.[2] The victim had several of these risk factors (male gender, smoking, and family history).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[3] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[4] Heart attacks typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply.[5] This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. Less than 50% of heart attack victims have a thrombosis at autopsy. The victim did not have a thrombosis noted at autopsy.

Blood clots, or thrombus formation, in coronary arteries are initiated by disruption of atherosclerotic plaques. Certain characteristics of the plaques (size, composition of the cap and core, presence of a local inflammatory process) predispose the plaque to disruption.[5] Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased heart rate, increased catecholamines, and shear forces, which occur during heavy exercise.[6, 7]

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[8] Fire fighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and to persist through the course of fire suppression activities.[9-11] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[12-15] The victim was performing ventilation activities while wearing full turnout gear with SCBAs (weighing approximately 50-60 pounds total) , breathing air from the SCBAs,

standing on a ladder, and working overhead with the Halligan tool (weighing approximately 10 pounds). He was undergoing a moderate-heavy level of physical exertion during this phase. Additionally, he had been actively participating in physical training at home (riding a stationary exercise bike and walking at least three times per week). At his regular job, he was very active.

To reduce the risk of heart attacks and sudden cardiac arrest among fire fighters, the National Fire Protection Association (NFPA) has developed guidelines entitled "Medical Requirements for Fire Fighters," otherwise known as NFPA 1582.[16] They recommend, in addition to screening for risk factors for CAD, an exercise stress electrocardiogram (EKG), otherwise known as an exercise stress test (EST). The EST is used to screen individuals for CAD. Unfortunately, it has problems with both false negatives (inadequate sensitivity) and false positives (inadequate specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of angina).[17,18] This has led other expert groups to **not** recommend EST for asymptomatic individuals without risk factors for CAD.[19,20]

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.[19] They define five risk factors for CAD: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic greater than140 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).[19] 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).[20]

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.[16] 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).[16] The EST should then be performed on a periodic basis, at least once every two years.[16] The ACC/AHA indicates that there is insufficient data 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.[19] 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."[20]

Thus, disagreement remains regarding whether asymptomatic fire fighters should have ESTs.

RECOMMENDATIONS AND DISCUSSION

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. These recommendations have not been evaluated by NOSH, but represent research presented in the literature or of consensus votes of Technical Committees of the National Fire Protection Association or labor/management groups within the fire service. In addition, they are presented in a logical programmatic order and are not listed in a priority manner.

Recommendation #1: Fire fighters should have annual medical evaluations to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

Guidance regarding the content and frequency of periodic medical evaluations for fire fighters can be found in NFPA 1582, Medical Requirements for Fire Fighters and Information for Fire Department Physicians,[10] and in the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFF) wellness/fitness initiative.[21]

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

NAPA 1582, Standard on Medical Requirements for Fire Fighters, and the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFF) wellness/fitness initiative both recommend at least biannual EST for fire fighters.[10,21] 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. These EST will undoubtably increase the costs associated with the medical evaluations. To some extent these costs could be offset by reducing the frequency of other tests included in the current annual examination. The EST could be conducted by the fire fighter's personal physician or the City'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 fighter duties.

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

NAPA 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.[22] In 1997, the International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFF) joined in a comprehensive Fire Service Joint Labor Management Welles/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.[21] The Fire Department should review these materials to identify applicable elements. Other large-city negotiated programs can also be reviewed as potential models.

Recommendation #4: Self-contained breathing apparatus (SCBAs) should be upgraded with regard to weight of the SCBAs and air cylinder.

Although protective gear is designed to protect fire fighters, it can also work against them at the same time.[21] Selection of an SCBAs is an important function, particularly when resources are limited and SCBAs have to be used for different applications and with different equipment. Weight and stress reduction should be an objective in the acquisition of new SCBAs and when upgrading SCBAs currently in use. Weight and other stress factors can reduce work performance and are major contributions to fire fighter fatigue and injury, and SCBAs should be chosen accordingly.[22-24] The difference between the weight of ordinary street clothes and fire fighting gear (turnout gear, boots, helmet, hood, and gloves) can be an extra 25 pounds. The breathing unit alone can weigh from 25 to 35 pounds, depending on size and type.[23] SCBAs cylinders are made from steel (the heaviest), aluminum, hoop-wrapped fiberglass, fully wrapped fiberglass, and fully wrapped carbon (lightest). Currently, SCBAs is available that weighs as little as 18 pounds, depending on size and type.

While the gear worn by the victim did not malfunction in any way to contribute to his death, the extra weight of the gear (50 pounds) certainly added to the physical stress involved in his fire fighting activities.

Recommendation #5: As contained in the OSHA Revised Respiratory Protection Standard, provide fire fighters with medical evaluations to determine fitness to wear a self-contained breathing apparatus (SCBAs).

OSHA's Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection.[25] These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. Since Iowa is a State-plan State, public sector employers are required to comply with OSHA standards. A copy of the OSHA medical checklist has been provided to the Fire Department and should not involve a financial burden to the Fire Department beyond that required for the fitness-for-duty medical evaluation.

REFERENCES

1. Fauci AS, Braunwald E, Isselbacher KJ, et al. [1998]. Harrison's principles of internal medicine. 14th ed. New York: McGraw-Hill, pp. 222-225.

2. American Heart Association [1998]. AHA scientific position, risk factors for coronary artery disease, Dallas, TX.

3. Fauci AS, Braunwald E, Isselbacher KJ, et al. [1998]. Harrison's principles of internal medicine, 14th ed. New York: McGraw-Hill, p. 1348.

4. Shah PK [1997]. Plaque disruption and coronary thrombosis: new insight into pathogenesis and prevention. Clin Cardiol *20*(11)(Suppl2):II-38-44.

5. Fuster V, Badimon JJ, Badimon JH [1992]. The pathogenesis of coronary artery disease and the acute coronary syndromes. N Eng J Med *326*:242-250.

6. Kondo NI, Muller JE [1995]. Triggering of acute myocardial infarction. J Cardiovasc Risk *2*(6):499-504.

7. Opie LH [1995]. New concepts regarding events that lead to myocardial infarction. Cardiovasc Drug Ther *9*(Suppl3):479-487.

8. Gledhill N, Jamnik VK [1992]. Characterization of the physical demands of firefighting. Can J Spt Sci *17*(3):207-213.

9. Barnard RJ, Duncan HW [1975]. Heart rate and ECG responses of fire fighters. J Occup Med *17*:247-250.

10. Manning JE, Griggs TR [1983]. Heart rate in fire fighters using light and heavy breathing equipment: simulated near maximal exertion in response to multiple work load conditions. J Occup Med *25*:215-218.

11. Lemon PW, Hermiston RT [1977]. The human energy cost of fire fighting. J Occup Med *19*:558-562.

12. Willich SN, Lewis M, Lowel H, et al. [1993]. Physical exertion as a trigger of acute myocardial infarction. N Eng J Med *329*:1684-1690.

13. Mittleman MA, Maclure M, Tofler GH, et al. [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Eng J Med *329*:1677-1683.

14. Siscovick DS, Weiss NS, Fletcher RH, Lasky T [1984]. The incidence of primary cardiac arrest during vigorous exercise. N Eng J Med *311*:874-877.

15. Tofler GH, Muller JE, Stone PH, et al. [1992]. Modifiers of timing and possible triggers of acute myocardial infarction in the Thrombolysis in Myocardial Infarction Phase II (TIMI II) Study Group. J Am Coll Cardiol *20*:1049-1055.

16. National Fire Protection Association [2000]. NAPA 1582, standard on medical requirements for fire fighters. Quincy, MA: National Fire Protection Association.

17. Michaelides AP, Psomadaki ZD, Dilaveris PE, et al. [1999]. Improved detection of coronary artery disease by exercise electrocardiography with the use of right precordial leads. New Eng J Med *340*:340-345.

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

19. 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.

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

21. International Association of Fire Fighters [1997]. The fire service joint labor management wellness/fitness initiative. Washington, D.C.: International Association of Fire Fighters, Department of Occupational Health and Safety.

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

23. International Fire Service Training Association [1999]. Essentials of fire fighting. Still water, OK: International Fire Service Training Association.

24. National Fire Protection Association [1996]. NAPA 1404, standard for a fire department self-contained breathing apparatus program. Quincy, MA: National Fire Protection Association.

25. 29 CAR 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 Kirsten Sexson, MPH, Epidemiologist; and Tommy N. Baldwin, MS, Safety and Occupational Health Specialist. Ms. Sexson and Mr. Baldwin are with the NOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component, located in Cincinnati, Ohio.