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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 *January 7, 2004*

Fire Fighter Suffers a Heart Attack and Dies While Exercising In Firehouse - New York

SUMMARY

On January 4, 2001, a 39-year-old male Fire Fighter collapsed while exercising in the fitness room of his firehouse. He was found approximately five to ten minutes later by a fellow crew member. The crew member noted the fire fighters cyanotic appearance, checked his vital signs, and found no pulse. He notified Emergency Medical Services (EMS) of a "down" firefighter, and initiated cardiopulmonary resuscitation (CPR), including the use of an automated external defibrillator (AED). Despite CPR and advanced life support (ALS) administered on scene, en-route, and at the hospital, the victim died. The death certificate, completed by the Medical Examiner's Office listed "atherosclerotic cardiovascular disease" as the immediate cause of death. Pertinent autopsy results included: 1) marked atherosclerotic coronary artery disease (CAD), 2) focal fibrotic changes of the heart adjacent to its conduction fibers consistent with a remote (at least three months prior) heart attack (myocardial infarction), 3) myxoid changes of the mitral valve, and 4) no evidence of blood clots in the lung arteries (pulmonary emboli).

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 National Institute for Occupational Safety and Health (NIOSH), but they represent published research or consensus votes of technical committees of the National Fire Protection Association (NFPA) or fire service labor/management groups. However, it is unknown if any of these recommendations could have prevented the unfortunate death of this fire fighter.

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

Although unrelated to this fatality, the Fire Department should consider this additional recommendation based on safety considerations:

- ***Use a secondary (technological) test to confirm appropriate placement of the endotracheal (ET) tube during emergency intubations.***

INTRODUCTION & METHODS

On January 4, 2001, a 39-year-old male Fire Fighter collapsed while exercising in the fitness area of the fire station. Despite CPR by on-scene fire fighters (trained and certified as first responders) and ALS by ambulance paramedics and the hospital emergency department, the victim died. NIOSH was notified of this fatality on January 5, 2001, by the United States Fire Administration. On September

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6, 2001, NIOSH contacted the affected Fire Department (FD) to initiate the investigation. On December 2, 2002, an occupational nurse practitioner, occupational physician and a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to New York to conduct an onsite investigation of the incident.

During the investigation NIOSH personnel met and/or interviewed the following:

- FD Executive Officer, Safety Command
- FD Deputy Chief Medical Officer
- Director, Occupational Safety and Health
- EMS personnel
- Local Union Safety Representative
- Crew members on-duty with the victim
- Victim's wife.

During the site-visit NIOSH personnel reviewed:

- FD investigative report of the fatality
- FD policies and operating guidelines
- FD training records of the victim
- FD medical records of the victim
- FD annual report for 2000
- Hospital records
- Emergency medical service (ambulance) report
- Death certificate
- Autopsy report.

INVESTIGATIVE RESULTS

Incident. On January 4, 2001, at approximately 0915 hours (at the conclusion of his shift), the deceased firefighter was last seen heading to the fitness area of the fire station. Approximately five to ten minutes later, a fellow firefighter observed the victim lying on the treadmill. He thought the victim was stretching, but as he approached, he noted the victim had a cyanotic appearance. He quickly checked his vital signs and found no pulse and no respirations. The crew member ran back upstairs to activate the EMS system and retrieve the AED.

EMS was notified at 0936 hours as multiple crew members from the station returned to the victim to begin CPR and use the AED. AED pads were placed on the victim's chest while an oral-pharyngeal airway was inserted. The victim began to receive oxygen at 15 liters per minute via bag-valve-mask. The AED recorded no heart beats (asystole), therefore no shocks (defibrillations) were indicated or delivered. Chest compressions were begun and continued by various firefighters. The resuscitation effort was complicated by two to three episodes of regurgitation, each handled by suction.

EMS-Paramedics arrived at 0940 hours and they conducted ALS treatment including intubation (a breathing tube placed into the victim's windpipe and correct placement confirmed using bilateral breath sounds) and placing an intra-venous (IV) line. The unit departed for the hospital at 0956 hours. Further attempts at resuscitation, conducted en-route, included the administration of ALS medications until they arrived at the hospital Emergency Department (ED) at 1007 hours.

Inside the hospital ED, the cardiac monitor continued to reveal asystole. Despite this heart rhythm, three shocks were delivered without success. Another round of ALS IV medications were administered, proper intubation was confirmed by bilateral breath sounds, but the firefighters's heart rhythm never returned. CPR and ALS measures continued until 1040 hours, at which time he was pronounced dead and resuscitation efforts were discontinued.

Medical Findings. The death certificate, completed by the Medical Examiner, listed "atherosclerotic cardiovascular disease " as the immediate cause of death. Pertinent findings from the autopsy, performed by the Medical Examiner's Office on January 4, 2001, are listed below:

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1. Atherosclerotic Cardiovascular Disease:
   - Coronary artery with marked atherosclerotic stenosis (80%) of the proximal left anterior descending artery;
   - Myocardial infarct, remote (at least three months old), septum (microscopic), focal fibrosis of septum adjacent to conduction fibers
2. Myxoid Mitral Valve
3. No evidence of a blood clot (embolus).

Prior to his fatal heart attack, the victim did not complain of pain suggestive of angina (heart pain due to reduced blood supply). The fire fighter had increased his physical activity over the previous seven months to include aerobic activity five times a week. Prior to the incident (approximately 0800 hours), he was seen shoveling snow around the fire house. During the previous 12 hour period the firefighter had been on one medical call in which he performed CPR for approximately 30 minutes.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the Fire Fighter's death, the FD consisted of approximately 11,495 Uniformed Fire Fighters and Fire Officers, 2,677 EMT (Emergency Medical Technicians) and Paramedics, 222 Fire Marshals, 195 Fire Inspectors, and 1,741 administrative support personnel serving a population of eight million residents, in a geographic area of 322 square miles. There are over 300 fire stations and buildings. The emergency medical services have operated as a function of the FD since 1996. Fire fighters work the following shifts: Day 1 & 2: 9am to 6pm; Day 3: off; Day 4&5: 6pm to 9am; Day 6-8: off.

In 2000, the FD made 933,295 fire apparatus responses to 449,296 fires, non-fire emergencies, and medical calls to include: 29,281 structural fires, 31,058 non-structural fires, 174,620 non-fire emergencies, 155,531 medical emergencies, and 58,806 malicious false alarms. Included in the responses were 3,289 serious incidents: 2,970 all hands, 249 second alarm, 49 third alarm, 16 fourth alarm, and 5 fifth alarm or greater incidents. The EMS units of the FD made 1,262,599 runs to 1,064,591 incidents. The number of runs exceeds the number of incidents because more than one unit can be dispatched to a single incident. Typical engine company staffing is four fire fighters plus one officer (some engine companies have five fire fighters plus one officer); typical ladder company staffing is five fire fighters plus one officer. (This staffing level meets NFPA 1710). AEDs are carried on all engines.

Training. The FD requires all fire fighter candidates to complete an application, background checks, and pass a candidate physical ability test prior to being offered conditional employment. Candidates must then pass a pre-placement medical examination prior to being fully hired. The newly hired fire fighters then attend a 12-week training program at the Division of Training, after which they are certified fire fighters. This training includes certification as a first responder, which includes CPR and AED. Chauffeurs (Driver/Operators) are required to undergo an additional two-week training course. The state requires 100 hours training for annual recertification. The victim was a certified as a Fire Fighter, Hazardous Materials Operations level, and First Responder, and had 14 years of fire fighting experience.

Pre-placement Evaluations. The FD requires a pre-placement medical evaluation for all fire fighter candidates. Components of the pre-placement evaluation include:

- A complete medical history and questionnaire
- Height, weight, and vital signs
- Physical examination
- Vision test
- Hearing test

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- Blood tests: Complete blood count (CBC), chemistry panel (SMA 20) which includes a cholesterol and triglyceride measurement
- Urinalysis
- Urine drug test
- Spirometry (lung function tests)
- Resting electrocardiogram
- Chest X-ray
- Skin test for tuberculosis (PPD)
- Immunizations administered if proof of vaccination cannot be provided (hepatitis B, measles, mumps, & rubella [MMR], tetanus if a booster had not been given within the past ten years)
- Fire fighters assigned to waterways also are offered a hepatitis A vaccine.

These evaluations are performed by the FD Medical staff, who make a decision regarding medical clearance for fire fighting duties. As part of this medical clearance, new hires are also required to complete an aerobic test by the Fire Department health services unit at the time of the medical evaluation. The aerobic test involves three minutes on a Stairmaster at 60 steps per minute with a sixty-pound pack. An electrocardiogram (EKG) is not taken, but the heart rate is recorded and must be less than 90% of maximum (220 minus age). Opportunities for retesting are provided.

Periodic Evaluations.

Since 1998, periodic medical evaluations have been required by this Department for **all** fire fighters. The goal has been to conduct these on an annual basis, but logistical problems have resulted in their being conducted approximately every 15 months. Components of this evaluation are identical to the pre-placement evaluation with three exceptions: the chest X-ray is required only every three years, 2) the drug screen is not required, 3) and modification of the aerobic fitness test. The modification includes no requirement to wear a 60-pound pack and a new target heart rate of no more than 85% of the fire fighter's maximum. The victim's last periodic medical evaluation was conducted by the FD in 2000. The examination was remarkable for a Body Mass Index of 31.3 which is considered "Obese (Class 1)" by the National Heart, Lung, and Blood Institute of the National Institute of Health[20], and an aerobic fitness test (submaximal step test) score that was 163 beats per minute which was above the 85% goal. Accordingly, the examining physician checked the "unfit for full duty" box on the health unit evaluation form, however, the victim continued in his position at full duty.

Wellness/Fitness.

A fire fighter who is injured at work must be evaluated and cleared for "return to work" by a physician in the FD's medical clinic. A fire fighter who misses work for one or more days because of an illness (work-related or not), must also be evaluated and cleared for "return to work" by the FD Medical staff.

All fire houses have exercise (strength and aerobic) equipment, typically purchased by the fire fighters themselves. There are voluntary smoking cessation and weight control programs, and a voluntary wellness/fitness program consistent with the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative.[1]

DISCUSSION

In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death.[2] Risk factors for its development include increasing age (> 45 years old), male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes.[3] The victim had two of these risk factors (male gender and obesity).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[5] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[6] 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.[7] This sudden blockage is primarily due to blood clots (thrombus) forming on the top of atherosclerotic plaques.

Blood clots, or thrombus formation, in coronary arteries is 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.[6] 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.[26,27] Less than 50% of heart attack victims have a thrombus at autopsy. The victim did not have a thrombus noted at autopsy, but did have marked atherosclerotic stenosis of the left anterior descending artery, which was probably responsible for his probable heart attack and sudden cardiac death.

Firefighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[4] Firefighting 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 persist through the course of fire suppression activities.[8-10] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[11-14] Shoveling snow would have been a stressful activity. In addition, exercising on the treadmill could have been heavy physical exertion. It appeared that the safety shut-off device on the treadmill was utilized so no decision could be reached regarding the victim's exertion status. The physical stress of these activities probably increased his heart rate and blood pressure thereby increasing his cardiac oxygen demand. This, along with his underlying CAD, was responsible for this fire fighter's probable heart attack, subsequent cardiac arrest, and sudden death. The term "probable" is used because an acute (recent) heart attack can only be confirmed by one of the following:
1. Blood test finding elevated cardiac iso-enzymes;
2. On autopsy, thrombus (blood clot) formation in one of the coronary arteries;
3. If there is a heart beat, characteristic findings on the EKG.

Unfortunately, the victim did not have blood taken in the emergency room for cardiac iso-enzymes, did not have a thrombus formation on autopsy, and he had no heart beat to show the characteristic findings of a heart attack on his EKG. Both his autopsy findings of marked atherosclerotic disease in the left anterior descending coronary artery and his clinical course were consistent with an acute heart attack leading to his sudden cardiac death.

The victim did have evidence of fibrosis consistent with an old (at least three months prior) heart attack on autopsy. Unfortunately, in 20 to 25% of cases, the first clinical manifestation of CAD is sudden cardiac death.[25]

To reduce the risk of heart attacks and sudden cardiac arrest among fire fighters, the NFPA has developed guidelines entitled "Comprehensive Occupational Medicine Programs for Fire Departments," otherwise known as NFPA 1582.[15] They recommend an exercise stress EKG, otherwise known as an exercise stress test (EST), for individuals with two or more CAD risk factors. 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).[15] The NFPA acknowledges that their recommendations are based on "no firm guidelines", but rely on a "reasonable approach" using expert consensus. Unfortunately, the EST has problems with both false negatives (inadequate sensitivity) and false positives (inadequate specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of angina).[16,17] This has led expert groups to **not** recommend EST for asymptomatic individuals without risk factors for CAD.[18,19]

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 three groups of asymptomatic individuals with known CAD who they recognize may need an EST. For the first two groups, the usefulness of an EST is less well-established. They are: 1) men over the age of 45 and women over the age of 55 with a history of cardiac disease (as a screening test prior to beginning a strenuous exercise program), 2) men over age 40 with multiple risk factors.[18] The last group, the ACC/AHA guideline states that the weight of evidence/opinion is in favor of the usefulness of performing an EST. This group includes asymptomatic persons with diabetes mellitus who plan to start a vigorous exercise. They further define five risk factors for CAD: hypercholesterolemia (total cholesterol > 240 mg/dL), hypertension (systolic >140 mm Hg or diastolic > 90 mm Hg), smoking, diabetes, and family history of premature CAD (cardiac event in 1st degree relative < 60 years old.[18] 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).[19]

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 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 45 or women over the age of 55 with a history of cardiac disease be screened before beginning a strenuous exercise program.[18] 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 there is insufficient evidence 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."[19] The USPSTF did not specifically address whether asymptomatic fire fighters with CAD risk factors should undergo EST.

Since the victim had only one risk factor for CAD, an EST would not have been recommended by NFPA 1582. However, the AHA and the USPSTF are less clear about whether an EST should have been performed on this individual. It is possible an EST may have identified if the victim had CAD and possibly led to medical treatment that would have prevented his sudden cardiac death.

As mentioned in the periodic evaluation section of this report, in 2000 the deceased fire fighter did not meet the heart rate criteria during his aerobic fitness test. Accordingly, the examining physician checked the "unfit for full duty" box on the health unit evaluation form. From the personnel records available to NIOSH, the fire fighter was never assigned any

restricted duty. It is unclear what, if any, effect this decision had on his subsequent death. To investigate this discrepancy, the Deputy Chief Medical Officer of the FD reviewed the deceased fire fighter's entire medical record. He concluded that the "unfit for full duty" box was checked in error.

On autopsy, the deceased fire fighter was found to have a myxoid valve. In the absence of any heart murmur, it is unlikely the screening examination, recommended by NFPA 1582, would have discovered this condition. Even if this abnormality was identified, it probably played no role in his probable heart attack or his sudden cardiac death. The autopsy also identified some focal fibrosis of the septum occurring adjacent to the conduction fibers. This probably resulted from a "silent" heart attack several months or years ago. This lesion may have contributed to a heart arrhythmia and/or contributed to the failure to resuscitate. This condition might have been identified with a comprehensive EST.

RECOMMENDATIONS AND DISCUSSION

Other agencies have proposed a three-pronged strategy for reducing the risk of on-duty heart attacks and cardiac arrests among fire fighters. These recommendations have not been evaluated by NIOSH, but represent research presented in the literature or of consensus votes of Technical Committees of the NFPA or labor/management groups within the fire service. This strategy consists of: 1) minimizing physical stress on fire fighters; 2) screening to identify and subsequently rehabilitate high risk individuals; and 3) encouraging increased individual physical capacity. Issues relevant to this Fire Department include:

Recommendation #1: 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, and NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, require a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[23,24] In 1997, the IAFF and the 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.[1] They produced a manual and a video detailing elements of such a program. The Fire Department should review these materials to identify applicable elements. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[21, 22]

Although unrelated to this fatality, the Fire Department should consider this additional recommendation based on safety considerations:

Recommendation #2: Use a secondary (technological) test to confirm appropriate placement of the ET tube during emergency intubations.

This finding did not contribute to this fatality, but was identified during the NIOSH investigation. To reduce the risk of improper intubation, the American Heart Association along with the International Liaison Committee on Resuscitation published recommendations in the Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care.[28] These guidelines recommend cricoid pressure by a second rescuer followed by the actual intubation. Placement is confirmed by primary and secondary methods. Primary confirmation is the 5-point auscultation: left and right

anterior chest, left and right midaxillary, and over the stomach. Secondary confirmation requires a technology test, either an end-tidal CO_2 detector or an esophageal detector device. After both primary and secondary confirmations have been performed, cricoid pressure can then be released. In this incident, the fire fighter had bi-lateral breath sounds confirmed by auscultation, however secondary confirmation was not performed.

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INVESTIGATOR INFORMATION

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