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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 *February 22, 2000*

Fire Fighter Suffers a Fatal Heart Attack 15 Minutes After Returning from a Fire Scene—Ohio

SUMMARY

On October 25, 1997, a 47-year-old female fire fighter from a volunteer Fire Department assisted a neighboring Fire Department fight a tire fire which generated a large amount of smoke. The victim's primary responsibilities during the incident consisted of spraying water on the burning tires. She was wearing full turnout gear including her self-contained breathing apparatus (SCBA), but had complained to her partner that an unusual hissing sound was coming from the SCBA. The victim used a single tank of air over approximately 25 minutes of fire suppression activities. At the fire ground's rehabilitation unit she did not complain of any chest pain, and her pulse and blood pressure were within acceptable limits. Total time "in service," which includes the time traveling to the fire scene, at the fire scene, and returning from the fire scene, was 3 hours and 10 minutes.

A few minutes after returning to the fire station the victim complained of not feeling well, and while coworkers were evaluating her, she collapsed. CPR was immediately initiated by emergency medical technicians (EMTs) at the fire station, followed by advanced life support (ALS) administered by paramedics from the responding ambulance service. Despite ALS measures administered for a total of 21 minutes en route to the hospital, and for more than 2½ hours in the hospital's emergency department, the victim died. An autopsy report listed "coronary atherosclerosis, moderate, with hemorrhage into a plaque" as the final diagnosis. Subsequent testing of the SCBA revealed no malfunctions, and ante-mortem and post-mortem carboxyhemoglobin levels were not detected, indicating that the victim was not exposed to excessive concentrations of carbon monoxide prior to her death. A blood alcohol and drug screen were negative.

The following recommendations address preventive measures that have been recommended by other agencies to reduce, among other things, the risk of on-duty heart attacks and cardiac arrests among fire fighters. It cannot be determined, however, whether these recommendations could have prevented the sudden cardiac arrest and subsequent death of this Fire Fighter. These recommendations have not been evaluated by NIOSH but represent research presented in the medical literature or of consensus votes of Technical Committees of the National Fire Protection Association (NFPA) or labor/management groups within the fire service. This strategy consists of (1) medical screening to identify and subsequently rehabilitate individuals at higher risk, and (2) encouraging increased individual physical capacity. Steps that could be taken to accomplish these ends include

- ***Fire Fighters should have annual medical evaluations to determine their medical***

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:

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ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

- ***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 (SCBA).***

- ***Reduce risk factors for cardiovascular disease and improve cardiovascular capacity by offering a wellness/fitness program for fire fighters.***

INTRODUCTION

On October 25, 1997, a 47-year-old female fire fighter collapsed at the fire station approximately 15 minutes after returning from a fire scene. Despite CPR and ALS administered by the Fire Fighters, EMTs, paramedics, and hospital emergency department personnel, the victim died on October 26, 1997. NIOSH was notified of this fatality on October 28, 1997, by the United States Fire Administration. In December 1997, NIOSH telephoned the affected Fire Department to initiate the investigation. On January 13-14, 1998, and on December 8-9, 1999, a Senior Medical Officer 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 met with and interviewed the

- Fire Chief
- Fire Department personnel involved in this incident
- Emergency medical technicians providing treatment
- The neighboring town's Fire Department chief
- The neighboring town's police chief (the cause of the fire is suspected arson)

During the site visit NIOSH personnel also reviewed the

- Fire Department incident report
- Neighboring Fire Department's incident report
- Neighboring Police Department's incident report
- Emergency Medical Service's incident report
- Personal statements from the Fire Department staff
- Rehabilitation unit's report sheets
- Photographs of the fire scene
- Autopsy report
- Personal medical records
- Emergency department and hospital medical records

Telephone interviews were conducted with the

- Victim's personal physician
- Physician performing the autopsy
- Local hospital attempting the resuscitation

Finally, the fire scene was surveyed and a tour of the grounds was given by an employee of the affected business.

INVESTIGATION

On October 25, 1997, at 1800 hours, a fire was reported in the jurisdiction of the neighboring volunteer Fire Department. As part of a county dual-response/mutual-aid policy, an engine with five members of the victim's volunteer Fire Department was dispatched to the fire scene at 1805 hours and arrived at 1835 hours. A stack of used tires, approximately 20 feet in diameter and 10 feet high, was burning, and large amounts of smoke were billowing from the stack. The neighboring Fire Department Chief was Incident Commander and

requested that the victim's company secure a water supply from the nearby hydrant. Once the water source was established, SCBA was donned, and a 2.5-inch handline was laid to the fire with Fire Fighter (FF) #1 on the nozzle, and FF #2 (victim) as backup. The victim notified FF #1 that a hissing sound was coming from her SCBA. FF #1 checked the mask seal and tightened some of the tank's straps. While FF #1 could not find an explanation for the hissing sound, the victim stated that it was "fixed." FF #1 and FF #2 fought the fire for approximately 20-25 minutes and returned to their Department's engine for a second tank of air. At the engine they were advised to take a 15-minute break. At this time the victim mentioned to FF #1 that she was still having problems with her SCBA. Both inspected the SCBA, but neither could find any problems.

As FF #1 and the victim prepared to reengage the fire, the Incident Commander ordered their Department to move into a "stand-by" mode. The victim removed her SCBA and assisted others from the Department loading the hoses onto the engine. During this time the wind direction changed and engulfed their engine in thick smoke. The crew temporarily suspended loading operations until the smoke cleared. Once in the stand-by mode, the crew checked into the rehabilitation unit. In rehabilitation the victim did not complain of any symptoms, showed no signs of discomfort, and her vital signs were unremarkable (pulse 93, blood pressure 140/90). At 2030 hours, the victim's Fire Department was released from the fire scene. En route to their station the victim, again, did not complain of any symptoms and showed no signs of discomfort.

The engine returned to the fire station at 2115 hours. Then, for the first time, the victim complained of not feeling well and wanted to lie down and rest. While coworkers went to get a blood pressure cuff, an oxygen saturation monitor, and a heart monitor, she complained of difficulty breathing. Oxygen saturation was checked (100%), and the heart monitor showed, by report, S-T segment elevation (a finding suggestive of a heart attack). A few seconds later the victim's heart rhythm degenerated, by report, into ventricular fibrillation (V. Fib), and at 2127 hours the victim collapsed. Oxygen saturation immediately dropped to 68%, blood pressure was nondetectable, and no pulse could be felt. CPR was initiated by the Department's EMTs while the victim was transferred into the an ambulance, which departed for the hospital at 2130 hours. En route to the hospital the victim was shocked (electrical cardioversion) four times for V.Fib. In addition, she had a breathing (endotracheal) tube inserted into her trachea and had a peripheral intra-venous line placed, through which medications were given consistent with advanced life support (ALS) protocols. CPR and ALS measures were continued for the 30-minute ride to the hospital.

Upon arrival at the hospital at 2200 hours, the victim's cardiac rhythm was as asystole (no heart beat). ALS measures continued in the hospital's emergency department (ER) including (1) the use of external, followed by an internal, pacemaker to stabilize the victim's heart rhythm, and (2) the administration of a cyanide toxicity antidote because of the victim's history of potential smoke inhalation. A 12-lead electrocardiogram (EKG) showed a "wide complex tachycardia" suggesting either ventricular tachycardia or an intra-ventricular conduction delay. Blood tests taken in the ER showed elevated levels of cardiac iso-enzymes consistent with an acute heart attack. After 2 hours, the victim's heart stopped responding to the pacemaker and CPR was reinitiated. Despite the extensive and appropriate ALS and CPR for over 2 hours, 38 minutes in the hospital, the victim never regained consciousness and was pronounced dead at 0038 hours on October 26, 1997.

Medical Findings. An autopsy was completed by two physicians: the county coroner and a forensic

pathologist. Pertinent findings include moderate atherosclerosis on sectioning of the coronary arteries. Microscopic (histologic) examination of a section of a coronary artery revealed concentric atherosclerosis with 85% narrowing after hemorrhage into an atherosclerotic plaque. A blood clot (thrombosis) in the lumen of the coronary artery was also noted. Multiple blood tests in the ER and at autopsy revealed low levels of carboxyhemoglobin, indicating that the victim was not exposed to excessive concentrations of carbon monoxide prior to her death. A blood alcohol and drug screen were negative.

Medical records indicated that the victim had several risk factors for coronary artery disease (CAD). They included (1) family history, (2) high blood pressure diagnosed in 1995, which was well controlled on anti-hypertensive medications, and (3) high blood cholesterol. Her last EKG, prior to her cardiac arrest, was conducted in 1993 for evaluation of an episode of chest pain. That EKG was interpreted as having nonspecific changes, and the ER physician diagnosed her chest pain as "probably chest wall in nature," and thus not due to ischemic heart disease. She did not have an EKG or an exercise stress test prior to becoming a volunteer of this department.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the Fire Department was comprised of 35 volunteers (27 men and 8 women). In 1997 the Department responded to 260 calls: 90% medical first response, 8% fire, 2% hazardous materials (Hazmat).

Training. The Fire Department provides all new fire fighters with the basic 36-hour recruit training required by the State of Ohio. In the early 1980s the victim was certified as an EMT. In 1990 she volunteered in this Department as an EMT. In 1994 she volunteered as a fire fighter after passing the Basic Fire Fighter IA class. In 1997, she made 73 squad runs until her untimely death in October.

Preemployment/Preplacement Evaluations. The Department requires a preemployment/preplacement medical evaluation for all volunteer applicants, regardless of age. Components of this evaluation for all applicants include the following:

- A complete health history
- Vision test
- Qualitative and quantitative hearing test
- Physical examination
- Complete blood count (CBC)
- Blood lipid profile (total cholesterol, HDL cholesterol, triglycerides)
- Urinalysis
- Radiography (e.g,. Chest X-ray) as needed
- EKG as needed

These evaluations are performed by the Department's Medical Director, who then makes a decision regarding medical clearance for fire fighting duties. The Fire Department does not require a physical ability test for applicants or for current members of the Department.

Periodic Evaluations. The Department does not require periodic medical evaluations; however, if an employee is injured while responding to an incident, or has a non-fire-fighting-related injury resulting in lost work day(s), the fire fighter must be cleared for "return to work" by his or her personal physician or the Department's Medical Director. Hazmat responders, however, are required by State Law to have an annual medical evaluation and obtain medical clearance. This testing is paid for by the State.

DISCUSSION

At the time of the victim's collapse, the heart monitor revealed V.Fib. V.Fib is the most common type of

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arrhythmia associated with cardiac arrest, occurring in 65-80% of all cardiac arrests.[1] In the United States, atherosclerotic coronary artery disease (CAD) 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 CAD, smoking, high blood pressure, high blood cholesterol, obesity, physical inactivity, and diabetes.[2] The victim had several of these risk factors and had moderate atherosclerotic lesions documented at autopsy.

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. The victim had one of these blood clots present in the lumen of one of her coronary arteries and, in addition to the blood tests finding elevated markers of heart damage (troponin I and CK-MB index), confirms the diagnosis of a heart attack (myocardial infarction).

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.[4] Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased HR, increased catecholamines, and shear forces, which occur during heavy exercise.[6,7] Epidemiologic studies have found that heavy physical exertion sometimes immediately proceeds and triggers the onset of acute heart attacks.[8-11]

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 persist through the course of fire suppression activities.[12-14] The mental and physical stress of responding to the fire department alarm and conducting fire suppression activities, along with her underlying atherosclerotic CAD, all contributed to this fire fighter's heart attack, subsequent cardiac arrest, and death.

When the victim presented to the hospital's emergency department, one of the initial diagnoses under consideration was respiratory arrest due to smoke inhalation. We consider this to be unlikely for several reasons.

- It would be unusual for primary respiratory failure to act in such a sudden manner, particularly without the victim showing signs of respiratory distress prior to her collapse.
- The victim had repeated blood samples taken for carboxyhemoglobin; none were elevated suggesting the victim was not exposed to excessive concentrations of carbon monoxide—a major constituent of fire smoke.
- The chest X-ray taken during her hospitalization showed no signs of toxic lung damage (pneumonitis).
- The blood tests showed the victim's lungs were able to adequately oxygenate her blood.
- The autopsy did not reveal any soot in her lungs (tracheobronchial tree), suggesting insignificant or no smoke inhalation.

It is unlikely that the victim succumbed to toxic chemicals from the tire smoke due to (1) the lack of elevated carboxyhemoglobin levels, (2) the emergency department's administration of the antidote for hydrogen cyanide poisoning, and (3) few cardiotoxic chemicals known to be present in tire smoke.[15]

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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 Requirement for Fire Fighters*, otherwise known as Standard 1582.[16] They recommend, in addition to screening for risk factors for CAD, an exercise stress 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 (sensitivity) and false positives (specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of angina).[17-18] This has led most organizations 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 before 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 as 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 first-degree relative < 60 years old).[19] The U.S. Preventative Services Task Force (USPSTF) does not recommend EST for asymptomatic individuals 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 who require high cardiovascular performance such as police and fire fighters. The National Firefighter 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 premature family history (less than age 55), 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 2 years.[16] The ACC/AHA indicates that there is insufficient data to justify periodic exercise testing in this group; 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 there is insufficient evidence to recommend screening men and/or women of middle and advancing age 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. Had an EST been performed in this fire fighter, her underlying CAD **may** have been identified, and she could have been directed toward further evaluation and treatment.

RECOMMENDATIONS AND DISCUSSION

The following recommendations address some general health and safety issues. It cannot be determined, however, whether these recommendations could have prevented the heart attack 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 the result of research presented in the medical literature or of consensus votes of Technical Committees of the National Fire Protection Association or labor/management groups within the fire service. This strategy consists of (1) medical screening to identify and subsequently rehabilitate individuals at higher risk, and (2) encouraging increased individual physical capacity. Steps that could be taken to accomplish these ends include the following:

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 scheduling of periodic medical examinations for fire fighters can be found in *NFPA 1582, Standard on Medical Requirements for Fire Fighters*.[16] In addition to providing guidance on the frequency and content of the medical evaluation, NFPA 1582 provides guidance on medical requirements for persons performing fire fighting tasks. Applying this recommendation involves economic repercussions and may be particularly difficult for small, rural volunteer Fire Departments, such as the one involved in this incident, to implement.

To overcome the financial obstacle, this Fire Department could urge current members to get annual medical clearances from their private physicians. The recommended content of these evaluations is contained in NFPA 1582. Another option includes having the brief annual medical evaluations recommended by NFPA completed by the volunteer fire fighter (medical and occupational history) and by EMT/paramedics already on staff (vital signs, height, weight, and visual acuity), and this information could be shared with a Fire Department Medical Director, perhaps volunteering his or her time, to review this 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 among volunteers, the Fire Department, the Department's Medical Director, and willing physician volunteers should reduce the negative financial impact on recruiting and retaining needed volunteers.

Recommendation #2: 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 (SCBA).

OSHA's revised respiratory protection standard requires employers to provide medical evaluations and clearance for employees using respiratory protection.[21] These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. Since Ohio is not a State-plan State, public sector employers are **NOT** required to comply with OSHA standards. Nonetheless, we recommend voluntary compliance with this aspect of the respiratory protection standard to help ensure that fire fighters can safely wear SCBA (and safely do fire fighting work, with or without an SCBA). 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.

Recommendation #3: Reduce risk factors for cardiovascular disease and improve cardiovascular capacity by implementing a wellness/fitness program for fire fighters.

NFPA 1500 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 and the International Association of Fire Chiefs 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 with a video detailing elements of such a program.[23] Fire Departments should review these materials to identify applicable elements for their department.

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INVESTIGATOR INFORMATION

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