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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 *November 8, 2000*

Fire Fighter Dies as a Result of a Cardiac Arrest at the Scene of a Commercial Structure Fire - Pennsylvania

SUMMARY

On October 11, 1998, a 51-year-old male volunteer Fire Fighter responded to a commercial structure fire with smoke showing. The victim, responding in his personal vehicle, was one of the first fire fighters to arrive at the fire scene and was notified by plant employees that the fourth-floor fire was out but that smoke was still present. The victim, accompanied by his Fire Chief and a two-man entry team, climbed up four flights of stairs to a fourth-floor landing area. While the entry team was wearing full turnout gear and SCBA, the Chief and the victim were in street clothing and no SCBA. Upon entering the interior of the fourth floor, fire fighters encountered no active fire, light smoke, and a few remaining plant employees. The victim, along with another officer, entered the fire area soon afterward and toured the area. After a total of approximately 15 minutes on the fourth floor, the victim descended the stairs, exited the plant, and was organizing a debriefing for fire fighters when he collapsed. Prior to his collapse, the victim did not display any signs or symptoms of discomfort.

Immediate assessment found him to be unresponsive, with a carotid pulse but no respirations. An oral airway was inserted and assisted respirations were initiated with a bag-valve-mask. Approximately 9 minutes later, the victim's pulse was no longer present, and an automatic external defibrillator (AED) was attached to the victim's chest. A heart rhythm consistent with ventricular fibrillation was present and a shock (electrical cardioversion) was delivered but resulted in asystole (no heart beat). Cardiopulmonary resuscitation (CPR) was administered by Emergency Medical Technicians (EMTs) for a total of 21 minutes, followed by advanced life support (ALS), which was administered by Paramedics, for 25 minutes en route to the hospital. Once in the hospital's emergency department, the endotracheal tube was checked for proper placement and ALS was continued for 2 minutes before the victim was pronounced dead, and resuscitation measures were discontinued. The death certificate listed the immediate cause of death as "a: probably myocardial infarction" [heart attack], due to "b: coronary artery disease," due to "c: diabetes." No autopsy was performed and no carboxyhemoglobin levels were measured.

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. These recommendations have not been evaluated by NIOSH but represent research presented in the literature, regulations passed by enforcement agencies such as the Occupational Safety and Health Administration (OSHA), consensus votes of technical committees of the National Fire Protection Association (NFPA), or products of labor/management technical committees

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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within the fire service. This preventive 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 (fitness). Steps that could be taken to accomplish these ends include

- ***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.***
- ***Provide fire fighters with medical evaluations to wear self-contained breathing apparatus (SCBA).***
- ***All personnel entering a potentially hazardous atmosphere must wear a SCBA.***
- ***Carboxyhemoglobin levels should be tested on symptomatic or unresponsive fire fighters exposed to smoke.***
- ***Perform an autopsy on all fire fighters who were fatally injured while on duty.***
- ***Collaborate with the affected plant to develop a fire safety program, including an employee evacuation protocol.***
- ***Attach automatic external defibrillator (AED) leads immediately to all unconscious victims.***
- ***Reduce risk factors for cardiovascular disease and improve cardiovascular capacity by offering a wellness/fitness program for fire fighters.***

INTRODUCTION & METHODS

On October 11, 1998, a 51-year-old male fire fighter collapsed at the scene of a commercial structure fire. Despite CPR and ALS administered by the fire fighters, emergency medical technicians/paramedics, and hospital emergency department personnel, the victim died. On January 25, 1999, NIOSH contacted the affected Fire Department to initiate the investigation. On March 29, 1999, NIOSH investigators from the Fire Fighter Fatality Investigation Team, Cardiovascular Disease Component, traveled to Pennsylvania 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
- Family members
- Emergency medical technicians/paramedics providing treatment

During the site visit NIOSH personnel also reviewed

- Fire Department Incident Report
- Fire Department policies and operating procedures
- Fire Department training records
- Fire Department annual report for 1998
- Fire Department administrative records
- Hospital Emergency Department records related to this incident
- Past medical records of the deceased
- Death certificate of the deceased

Finally, the fire scene and the area where the victim collapsed were surveyed.

INVESTIGATIVE RESULTS

<u>*Emergency Scene Response*</u>. On October 11, 1998, at 0217 hours, Central Dispatch dispatched a

SECOND alarm response, including the involved fire department, to a commercial structure fire with smoke showing. This volunteer fire department responded with three vehicles (one Engine, one Tanker, and one Utility truck) staffed by 10 members of their department. This department also had six of their members respond directly to the fire scene in their privately owned vehicles. Four neighboring volunteer fire departments also responded with eight additional fire suppression vehicles and 52 additional personnel, including another Fire Chief. All neighboring units were placed in staging.

The victim, traveling via his personal vehicle, was one of the first fire fighters to arrive at the fire scene, at approximately 0230 hours. Employees on the fourth (top) floor of the plant opened a garage-style door to ventilate the smoke and shouted down to the victim that the fire was out but that smoke was still present. At 0232 hours, the Chief of the involved Fire Department arrived at the fire scene and was advised of the situation by the victim. After assessing the situation, the Chief assembled an "entry" team of two fire fighters to enter the interior of the fourth floor, where the fire had originated and smoke was still present. The victim, being an employee of the plant, had keys to the interior doors and led the entry team and the two Chiefs up a series of stairs to the fourth-floor landing. The entry team, in full turnout gear and SCBA, prepared to enter the interior of the fourth floor. At this time, the victim was wearing street clothes and no SCBA. He was conversant and was not displaying any signs or symptoms of discomfort.

Both Chiefs entered the fire room to do "size-up." They encountered light smoke conditions and a few remaining employees of the plant. The plant employees reported that combustible material had caught fire in the ovens, and they had extinguished the material and removed it from the ovens. The entry team entered the oven area of the fourth floor and found burned food which had been shoveled out of the ovens into a nearby aisle. Another officer from the involved Fire Department entered the fourth floor and was apprised of the situation by the victim. At this time, the entry team and the two Chiefs descended the stairs and exited the structure while the victim toured the fire area with the remaining officer to identify the emergency shutoffs (e.g., electrical power sources) in the event of a future fire department response. At 0303 hours, the victim and the officer exited the plant, and the Chief declared the fire under control.

At approximately 0312 hours, while the victim was organizing fire fighters for debriefing in front of the plant, he collapsed. He collapsed facedown onto a steel drainage grate sustaining a severe laceration (cut) down his nose with a moderate amount of bleeding. Nearby fire fighters immediately assessed the downed fire fighter and found him to be unresponsive with a carotid (neck) pulse but no respirations. It is this county's policy to send an EMS ambulance staffed with emergency medical technicians (EMT) to all fire alarms. These vehicles are equipped with automatic external defibrillators (AEDs) but no other advanced life support (ALS) equipment [such as endotracheal tubes for intubation, intravenous lines, or medications]. An oral airway was inserted and assisted respirations were initiated with a bag-valve-mask while the Chief notified Dispatch that a man was down with a suspected cardiac arrest.

At approximately 0321 hours, the victim's carotid pulse stopped, and an automatic external defibrillator (AED) was attached to his chest. Monitoring tracings of his heart rhythm showed ventricular fibrillation (V. Fib.), and the AED unit advised a shock (electrical cardioversion), which was successfully administered at 0322 hours. Unfortunately, the victim's heart became asystolic (no heart beat). Cardiopulmonary resuscitation (CPR) including chest compressions was reinitiated and the victim was loaded onto the

volunteer EMS ambulance and departed (0333 hours) for transport to the nearest hospital. An ALS unit was requested to be met en route.

At 0343, the EMS ambulance was met by another EMS vehicle staffed by a paramedic with ALS equipment. At this time the victim was intubated, an IV line was placed, and medications consistent with ALS protocols were administered. The victim arrived at the hospital's emergency department at 0408 hours. The victim was unconscious, pulseless, and without spontaneous respirations. The placement of the endotracheal tube was rechecked and found to be in the proper position. His initial heart rhythm was asystole. ALS measures were continued for an additional 2 minutes until 0410 hours, when he was pronounced dead.

Several of the plant employees never exited the fourth floor of the plant, and four of these employees reportedly experienced some respiratory symptoms. Two employees considered their symptoms minor and refused medical evaluation. The other two employees were transported to the nearby hospital's emergency department, where they were assessed, briefly observed, and released. Neither employee had elevated levels of carboxyhemoglobin reported. (Elevated carboxyhemoglobin levels suggest significant carbon monoxide exposure, a hazardous product of fire.) Neither the two Fire Chiefs nor the one Officer, all of whom entered the fourth floor without respiratory protection, reported symptoms consistent with smoke inhalation.

Medical Findings. The death certificate was completed by the coroner on October 14, 1998. The immediate cause of death was listed as "a: probably myocardial infarction" [heart attack], due to "b: coronary artery disease," due to "c: diabetes." No blood was sent for laboratory analysis; therefore, no carboxyhemoglobin levels, cardiac isoenzyme levels, or drug tests were available. No autopsy was performed.

The victim had several risk factors for coronary artery disease (CAD), including family history of CAD, high blood pressure (hypertension), high blood cholesterol (hypercholesterolemia), diabetes mellitus, obesity, and physical inactivity. The hypertension, hypercholesterolemia, and diabetes were well-controlled with medications prescribed by his personal physician. He did not report symptoms of chest pain, palpitations, shortness of breath, or exercise intolerance to his personal physician, family, or coworkers.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the fire department was comprised of 40 volunteers in one station serving a population of approximately 3,000 in a geographic area of 48 square miles. In 1998, the department responded to 30 calls: 10 structure fires, 4 motor-vehicle accidents, 4 carbon monoxide alarms, 3 electrical wires downed, 3 automatic fire alarms, 2 brush fires, 2 vehicle fires, 1 dump fire, and 1 medical flight landing assistance.

Training. Although the victim had been a member of this fire department for 32 years and had received fire fighter training, there was no training documentation. There are currently no state requirements for fire fighter certification and individual fire departments are responsible for setting up their own training requirements.

Medical Clearance and Physical Fitness. The department does not require a medical evaluation prior to performing fire fighting duties, does not require medical clearance for respirator usage, and does not require physical agility/fitness testing for new or current fire fighters.

DISCUSSION

Some fire fighters at the fire scene thought this fatal event to be a primary respiratory (lung) failure because the victim maintained a carotid pulse during the first few minutes after his collapse, and because of his exposure to smoke in the building without use of a self-contained breathing apparatus (SCBA). This is unlikely for several reasons. First, the victim spent a short period of time in the area where the fire occurred. Second, other workers at the plant, who were more heavily exposed to smoke, for a longer period of time, experienced respiratory symptoms but apparently did not have elevated carboxyhemoglobin levels. Third, 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 his collapse. Finally, it would be unusual for primary respiratory failure to cause ventricular fibrillation in such a rapid manner. For these reasons, cardiac arrest due to myocardial infarction (heart attack) was the most likely cause of his collapse. The victim's carotid (neck) pulse while unconscious could have been an abnormal cardiac rhythm (e.g., slow ventricular tachycardia) that maintained enough pressure to generate a carotid (neck) pulse but not enough pressure to maintain consciousness.

Approximately 9 minutes after the victim's collapse, the AED rhythm strip documented V.Fib. V.Fib. is the most common type of arrhythmia associated with cardiac arrest, occurring in 65 to 80 percent 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 many of these risk factors.

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.

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.[4] 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] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes 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 emergency, climbing the plant's four flights of stairs, and his probable underlying atherosclerotic CAD, all contributed to this fire fighter's "probable" heart attack, subsequent cardiac arrest, and sudden death. The term "probable" is used because autopsy findings and/or blood tests (cardiac isoenzymes) are required to "confirm" a heart attack (myocardial infarction) and neither of these were performed. (If there is a heartbeat, an electrocardiogram [EKG] can also confirm a heart attack.)

The victim did not report any episodes of chest pain during physical activity performed at work (climbing two flights of stairs several times a day), off the job (softball coach), or while performing duties as a volunteer fire fighter. This is somewhat surprising since chest pain (angina) typically accompanies ischemic heart disease. On the other hand, some individuals may not experience angina with ischemia, as evidenced by up to 20 percent of heart attacks being "silent," i.e., painless.[15]

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 NIOSH 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 necessarily listed in order of priority. This preventive 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 (fitness). 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 frequency of periodic medical evaluations for fire fighters can be found in NFPA 1582, Standard on Medical Requirements for Fire Fighters,[16] and in the report of the International Association of Fire Fighters/ International Association of Fire Chiefs wellness/ fitness initiative.[17] If these medical evaluations diagnose a previously unidentified medical condition, the condition should be checked against the medical conditions that **should** (Category A) or **could** preclude (Category B) individuals from performing fire-fighter activities.[16] While none of this victim's known medical conditions were in Category A, given the physically demanding tasks of fire fighters and his risk factors for CAD, we would have recommended an exercise stress test. It is assumed that if an exercise stress test was performed on this Fire Fighter, his underlying CAD would have been identified and he would have been directed toward further evaluation and treatment.[18] This standard (NFPA 1582) should be shared with physicians responsible for clearing individuals for fire-fighting duties.

Recommendation #2: Provide fire fighters with medical evaluations to determine their fitness to wear self-contained breathing apparatus (SCBA).

In 1997, OSHA published its revised respiratory protection standard.[19] This standard, among other things, requires that a medical evaluation of fire fighters wearing SCBA be performed by a physician or other licensed health-care professional. This evaluation could consist of a screening questionnaire (enclosed) to ascertain if additional medical evaluations or a medical examination is warranted. This standard also requires employees working in "atmospheres that are immediately dangerous to life or health," which includes structural fire fighting, to work in a double buddy system. This double buddy system, or 2-in/2-out rule, is designed to protect fire fighters conducting interior structural fire fighting operations. Because Pennsylvania does not have an Occupational Safety and Health Administration

(OSHA)-approved state plan, its state and municipal employees, such as fire fighters, are not covered under the Occupational Safety and Health Act, which governs OSHA. Therefore, State, County, or City fire departments in Pennsylvania are NOT required to comply with OSHA standards. Nonetheless, we recommend voluntary compliance with this aspect of the respiratory protection standard to ensure that fire fighters can safely wear SCBA.

Recommendation #3: All personnel entering a potentially hazardous atmosphere must wear SCBA.

SCBA must be worn when a fire fighter enters an area that is considered immediately dangerous to life or health (IDLH) or potentially IDLH or where the composition of the atmosphere is unknown. Smoke, vapor, or fumes from a fire or hazardous material incident may contain many toxic components. Some of these components will have immediate effects on the unprotected fire fighter (e.g., carbon monoxide poisoning), while others (e.g., smoke particulates) have cumulative effects, resulting from years of exposure. Since the victim did enter the interior of the fourth floor, he was at least exposed to light smoke conditions.

Recommendation #4: Carboxyhemoglobin levels should be tested on symptomatic or unresponsive fire fighters exposed to smoke.

Unfortunately, a carboxyhemoglobin level was not done at the hospital; this would have provided a good assessment of the victim's exposure to carbon monoxide. It is unlikely, however, that his carboxyhemoglobin level would have been elevated since plant workers with more intense smoke exposure for a longer period of time were reported not to have had elevated carboxyhemoglobin levels. Furthermore, knowledge of his carboxyhemoglobin level would not have affected his treatment or outcome since he was already receiving oxygen and was pronounced dead minutes after arrival at the hospital. Nonetheless, to assist the investigation of fire-related deaths, we recommend performing carboxyhemoglobin levels to rule out carbon monoxide poisoning.

Recommendation #5: Perform an autopsy on all fire fighters who were fatally injured while on duty.

In 1995, the United States Fire Administration (USFA) published the "Firefighter Autopsy Protocol."[20] This publication hopes to provide "a more thorough documentation of the causes of firefighter deaths for three purposes:

(1) to advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;

(2) to help determine eligibility for death benefits under the federal government's Public Safety Officer Benefits Program, as well as state and local programs; and

(3) to address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

The State Fire Commissioner's Office has left the decision on whether to perform an autopsy to the coroner of the county involved. Due to the victim's being an organ donor, the family was advised by the coroner that an autopsy could not be performed.

Recommendation #6: Collaborate with the affected plant to develop a fire safety program, including an employee evacuation protocol.

Fire Departments should "develop a pre-fire plan by performing an on-site survey of all commercial and industrial buildings (including type of construction, occupancies, and hazardous materials, within their jurisdiction to obtain the information needed to compute the minimum water supplies required for fire fighting operations,"[21] to identify hazards and emergency shut-offs, and for employee evacuation.[22] When the fire department arrived on the scene, several plant employees remained on the fourth floor. Four had symptoms of smoke inhalation, and two were evaluated in the hospital's emergency department. No pre-fire planning by the Fire Department had occurred at this plant.

Recommendation #7: Attach automatic external defibrillator (AED) leads immediately to all unconscious victims.

When this victim collapsed, he maintained a pulse but was not breathing. On-site EMTs appropriately initiated CPR (inserted an oral airway and, ascertaining the presence of a pulse, provided assisted respirations without chest compressions), while notifying Dispatch that a man was down. CPR procedures should be revised so that AED leads are attached to an unconscious victim, despite the presence of a pulse, to monitor his cardiac rhythm. If an abnormal cardiac rhythm is responsible for the unconscious state, the AED can determine if defibrillation is appropriate.

Recommendation #8: Reduce risk factors for cardiovascular disease and improve cardiovascular capacity by offering 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.[23] 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.[17] Fire departments should review these materials to identify applicable elements for their department.

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