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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 *May 11, 2000*

Fire Fighter Dies as a Result of a Cardiac Arrest at the Scene of a Brush Fire - Maryland

SUMMARY

On February 15, 1999, a 50-year-old male volunteer Fire Fighter responded to a brush fire. The victim, serving as Driver/Operator, was operating the pump controls on his engine, assisting in pulling and moving hose, and connecting supply lines. Approximately 46 minutes into the incident, the victim collapsed. Prior to his collapse, the victim did not display any signs or symptoms suggestive of heart problems, although he had remarked to his Fire Chief that his "lunch had not agreed with him." Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) administered on scene, en route to the hospital, and in the emergency department, the victim died.

The death certificate, completed by the County Coroner, listed the immediate cause of death as "a: occlusive coronary artery disease" due to "b: hypertensive cardiovascular disease." The autopsy, also completed by the County Coroner, listed "occlusive coronary artery disease with ischemic cardiomyopathy" as the cause of death.

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 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.***

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

INTRODUCTION AND METHODS

On February 15, 1999, a 50-year-old male Fire Fighter collapsed at the scene of a brush fire. Despite CPR and ALS administered by fire fighters, emergency medical technicians, paramedics, and hospital emergency department personnel, the victim died. NIOSH was notified of this fatality on February

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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16, 1999, by the United States Fire Administration. On February 17, 1999, NIOSH contacted the affected Fire Department to initiate the investigation. On December 6, 1999, a NIOSH investigator from the Fire Fighter Fatality Investigation Team, Cardiovascular Disease Component, traveled to Maryland to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met with the

- Fire Chief
- Fire Department personnel involved in this incident
- Family members

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
- Ambulance reports
- Hospital Emergency Department records related to this incident
- Past medical records of the deceased
- Death certificate
- Autopsy

INVESTIGATIVE RESULTS

Emergency Scene Response. On February 15, 1999, at 1216 hours, County Dispatch notified the involved Fire Department of a brush fire. Brush Truck 66 (Chief, Driver/Operator, and two Fire Fighters), Car 6 (four Fire Fighters), Brush Truck 65 (Driver/Operator and two Fire Fighters), and Engine 64 (Driver/Operator [the victim] and one Fire Fighter) responded at 1220 hours. Brush Truck 66 and Brush Truck 65 arrived on scene at 1224 hours and found a large brush pile and approximately one-fourth acre of woodland on fire. Car 6 arrived on scene at 1225 hours. Fire fighters removed two, 1¾-inch hoselines and a 1-inch booster hose from Brush Truck 66 and began to extinguish the fire. Engine 64 arrived on scene at 1227 hours. A 2½-inch supply hose was connected from Engine 64 to Brush Truck 66 to supply water to the Brush Truck. A booster hose was also pulled off Engine 64 and placed in service. The victim assisted in connecting and moving these hoselines. By 1241 hours, additional units previously dispatched, including mutual aid units, had arrived on scene. Ultimately six Engines, one Tanker, and 25 fire fighters were on scene.

At this incident, the victim was wearing full bunker gear but no self-contained breathing apparatus (SCBA). He was conversant and not reporting any symptoms or signs suggestive of heart problems, although he remarked to the Fire Chief that his "lunch had not agreed with him."

At approximately 1302 hours, the victim was discussing the operation of the front-mount pump on Engine 64 when he had a witnessed collapse. Nearby fire fighters immediately assessed the downed Fire Fighter and found him to be unresponsive, with an intermittent carotid (neck) pulse but no respirations. Cardiopulmonary resuscitation (CPR) was begun. An oral and a nasal airway were inserted, and assisted respirations were initiated with a bag-valve-mask supplemented with oxygen while the Chief notified Dispatch that a man was down with a suspected cardiac arrest.

Ambulance 269 (Driver and two Emergency Medical Technicians [EMTs]), Medic 4 (two EMT-Paramedics), and Medic 28 (two EMT-Paramedics) (mutual aid) were dispatched at 1303 hours. Ambulance 269 arrived on scene at 1307 hours and found the victim to be unconscious, pulseless, and without spontaneous respirations. An automated

external defibrillator (AED) was attached to the victim's chest. Monitor tracings of his heart rhythm revealed ventricular fibrillation (V. Fib.), and the AED unit advised a shock (electrical cardioversion), which was successfully administered at 1312 hours. Three more shocks were delivered prior to ALS arrival, each being unable to convert the victim's heart rhythm out of V.fib.

Medic 28 arrived on scene at 1316 hours and assumed control over patient care. The victim was unconscious, pulseless, and without spontaneous respirations. CPR continued, and the victim was intubated. Ambulance 269 (with Paramedics onboard) departed the scene at 1323 hours en route to the nearest hospital. An IV line was placed, and medications were administered consistent with ALS protocols. Over the ensuing 12 minutes, the victim's heart rhythm was continuously reassessed, found to be in V. Fib. each time, and a total of five shocks were delivered. CPR was administered by Fire Fighters and EMTs for a total of 14 minutes, followed by ALS, administered by Paramedics, for a total of 19 minutes on scene and en route to the hospital.

The victim arrived at the hospital's emergency department at 1335 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 heart rhythm was again found to be in V. Fib., and four additional shocks were administered. The heart rhythm degraded to asystole. ALS measures continued for an additional 12 minutes in the emergency department until 1347 hours, when he was pronounced dead and resuscitation measures were discontinued.

Medical Findings. The death certificate was completed by the County Coroner on February 17, 1999. The immediate cause of death was listed as "a: occlusive coronary artery disease," due to "b: hypertensive cardiovascular disease." Blood obtained in the emergency department had a carboxyhemoglobin level of 0.2% (suggesting the victim was not exposed to significant levels of carbon monoxide) and a blood test for alcohol was negative. No heart enzyme tests (cardiac isoenzymes) were done in the hospital or at autopsy. Significant findings from the autopsy included

1. Atherosclerotic coronary artery disease:
   - Moderate (50%) narrowing of the left main coronary artery
   - Severe (95%) narrowing of the right coronary artery
   - Severe (90%) narrowing of the left anterior descending coronary artery
   - Severe (95%) narrowing of the first diagonal branch of the left anterior descending coronary artery
   - Severe (95%) narrowing of the left circumflex artery
   - Evidence (fibrosis) of a previous (old) heart attack (myocardial infarction) involving the apex, anterior, and posterior wall of the left ventricle
   - Marked left ventricular dilatation
   - No evidence of a thrombus formation in any of the coronary arteries.
2. Cardiomegaly with biventricular hypertrophy
3. Diffuse pulmonary edema

The victim had several risk factors for coronary artery disease (CAD), including high blood pressure (hypertension), obesity, family history (sibling), and physical inactivity. The hypertension was controlled with several medications prescribed by his personal physician. During his periodic Fire Department Driver/Operator physical examination in 1996, an electrocardiogram (EKG) revealed a ST and T wave abnormality and possible anterolateral ischemia. This was not accompanied by angina, and there was no diagnostic testing or further treatment. He was

cleared for fire fighting duty. In 1997, the victim suffered an acute fall and went to the emergency department. A chest X-ray was performed to identify any rib fracture. No definite heart abnormality was identified. In March 1998, a chest X-ray was performed as part of a periodic Fire Department Driver/Operator physical examination and revealed mild cardiomegaly (enlarged heart). No other abnormality was identified, and he was cleared for fire fighting duty. He went to his personal physician in January 1999, because of right-sided chest pain. A chest X-ray, performed to rule out rib fracture, revealed that his heart was somewhat enlarged, but no other problems were identified. No EKG was performed at this time. He was placed on a low-calorie diet due to his weight. Otherwise, he did not report any other symptoms of chest pain, palpitations, or shortness of breath 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 67 volunteers in one station and served a population of approximately 6,000 in a geographic area of 45 square miles. In 1998, the department responded to 612 calls: 275 medical calls, 82 structure fires, 69 rescue calls, 26 investigations, 25 brush fires, 23 hazardous condition calls, 23 fill-in calls, 14 vehicle fires, 10 helicopter standby, and 10 miscellaneous calls.

Training. New members receive training at the Fire Department and at local and regional fire schools. Members must attain Fire Fighter I, Hazardous Materials Operations, and Rescue Technician certifications within 2 years after becoming a member. Additionally, members must receive truck company operations training within 3 years of joining the Department. The victim had received certifications in Fire Fighter I, Hazardous Materials Operations, and Driver/Operator and had 32 years' fire fighting experience.

Preemployment/Preplacement Evaluations. The Department requires a preemployment/preplacement medical evaluation for all new volunteers. Components of this evaluation include

- A complete medical history
- Height, weight, and vital signs
- Physical examination
- Vision test
- Hearing test
- Complete blood count (CBC)
- "SMA 20" (a battery of blood tests)
- Cholesterol and triglycerides
- Urinalysis
- Urine drug test
- Pulmonary function tests (lung tests)
- Resting EKG
- Chest X-ray
- Tuberculosis Skin Test (PPD)
- Quantitative respirator fit test
- Hepatitis B immunization

These evaluations are performed by a clinic which is under contract with the County. The clinic makes a decision regarding medical clearance for fire fighting duties.

Periodic Evaluations. No routine annual/periodic medical evaluations are required by this Department for **all** fire fighters; however, medical evaluations are required every 2 years for those fire fighters assigned as Driver/Operator. The contents of the examination are the same as the preemployment/preplacement evaluation and the Department of Transportation physical examination. An annual medical clearance is required for respirator use. An employee who is injured at work must be cleared for "return to work" by the contract clinic. The victim had passed his periodic evaluation and respirator clearance in

January 1999 (prior to visiting his personal physician for right-sided chest pain).

Wellness/Fitness. This Fire Department does not require physical agility/fitness testing for new or current fire fighters; however, they have a contract with a local fitness center to provide a fitness program. Participation was voluntary, and the victim was not a participant. No wellness (smoking cessation or weight control) program was in place.

DISCUSSION

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 65-80% 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 age over 45, male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity, physical inactivity, and diabetes.[2] The victim had these risk factors: age over 45, male gender, high blood pressure, family history, obesity, and physical inactivity.

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. In this case, however, a blood clot was not a factor.

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 HR, 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, assisting in connecting hoselines and moving hoselines, operating the engine's pump controls, and his underlying atherosclerotic CAD, all potentially contributed to this fire fighter's probable acute heart attack, subsequent cardiac arrest, and sudden death. The term "probable" is used because the victim did not have an EKG or blood tests for cardiac isoenzymes, which would have provided evidence of an acute MI. An autopsy can only definitively diagnose an MI if a thrombus is present. As mentioned previously, not all acute MIs have a thrombus present on autopsy.

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.[15] 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 (inadequate sensitivity) and false positives (inadequate

specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of angina).[16,17] This has led other expert groups **not** to 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 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.[18] 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 under 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 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.[15] 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 EST should then be performed on a periodic basis, at least once every 2 years.[15] The ACC/AHA indicates that data are insufficient to justify periodic exercise testing in people involved in public safety; however, as mentioned previously, they recommend that men over age 40 with a history of cardiac disease be screened before beginning a strenuous exercise program.[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 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."[19]

Thus, disagreement remains regarding whether asymptomatic fire fighters should have ESTs. Had an EST been performed in this fire fighter, his underlying CAD **may** have been identified and, if so, he could have been directed toward further evaluation and treatment.[20]

The victim reported three instances of rib pain/chest pain (X-rays did not reveal any abnormality). During three most recent physical examinations, EKGs were performed and revealed a mildly enlarged heart and possible anterolateral ischemia. However, the victim was not referred for further medical evaluation. Other than the rib pain associated with the acute fall, he did not report any other episodes of chest pain during physical activity performed at work (driving a truck), off-the-job, 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% of heart attacks being "silent," i.e., painless.[21] In addition, this victim had evidence of a remote (old) heart attack on autopsy and never complained of angina.

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

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*[15], and in the report of the International Association of Fire Fighters/ International Association of Fire Chiefs Wellness/ Fitness Initiative.[22] 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. This standard (NFPA 1582) should be shared with physicians responsible for clearing individuals for fire fighting duties.

Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments to implement.

Recommendation #2: 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.[22] Fire departments should review these materials to identify applicable elements for their department. The Department involved in this incident had a voluntary fitness program.

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INVESTIGATOR INFORMATION

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