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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 *September 10, 2003*

Fire Fighter Suffers Sudden Cardiac Death At His Fire Station - Oregon

SUMMARY

On February 20, 2003, at 0730 hours, a 53-year-old male career Captain (the deceased) began his 24-hour shift at his fire station. During his shift, the Captain was performing normal duties including checking fire extinguishers and participating in training exercises of emergency egress during aircraft rescue operations. He was last seen alive by crew members at 2030 hours as he was preparing for sleep. He was found the next morning in his private quarters at 0700 hours by two crew members. The Captain was unresponsive, wearing the previous night's uniform, laying diagonally on top of his bed. One crew member ran from the room to call 911 (medical emergency) and retrieve an automated external defibrillator (AED) from the station's ambulance. The other crew member checked the Captain's vital signs and found no pulse and no respirations. As he prepared to perform cardiopulmonary resuscitation (CPR), he noted the Captain was stiff and cool to the touch. Since the Captain had obviously been expired for some time, CPR was not begun. The AED showed no heart beat (asystole), and this lack of a heart beat was confirmed by the arriving Advance Life Support ambulance team. He was pronounced dead at the station by the county coroner. The death certificate completed by the county medical examiner, listed "ischemic heart disease" as the immediate cause of death due to "atherosclerotic coronary heart disease." The autopsy, conducted under the supervision of the county medical examiner listed "arteriosclerotic cardiovascular disease" as the cause of death.

A number of agencies have developed preventive measures to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. This strategy consists of: 1) minimizing physical stress on fire fighters; 2) screening to identify and subsequently rehabilitate high risk individuals; and 3) encouraging increased individual physical capacity. This strategy has not been evaluated by NIOSH, but represents research presented in the literature, consensus votes of Technical Committees of the National Fire Protection Association (NFPA), or labor/management groups within the fire service. Issues potentially relevant to this FD include:

- ***Consider slightly modifying FD medical evaluations to be consistent with NFPA 1582.***
- ***Consider adding exercise stress tests to the medical examination on a periodic basis.***
- ***Consider more strenuous physical fitness testing.***
- ***Phase in a <u>mandatory</u> wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***

Fire Fighter Suffers Sudden Cardiac Death At His Fire Station - Oregon

INTRODUCTION & METHODS

On February 20, 2003, a 53-year-old male Captain lost consciousness sometime after 2030 hours while on-duty at his fire station. The victim was pronounced dead by the county coroner at the station the next morning. On March 4, 2003, NIOSH contacted the affected Fire Department (FD) to gather more information on the fatality. On August 3, 2003, an occupational physician from the NIOSH Fire Fighter Fatality Investigation Team traveled to Oregon to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met and/or interviewed the

- Fire Chief
- Crew members of the deceased
- Deceased's family including his wife, sister, and sons
- FD contract physician

During the site-visit NIOSH personnel reviewed

- FD log book
- Death certificate
- Autopsy report
- The deceased's medical records
- FD pre-employment/pre-placement medical evaluation
- FD run reports for 2003

INVESTIGATIVE RESULTS

Incident. On February 20, 2003, at 0730 hours, a 53-year-old male career Captain (the deceased) began his 24-hour shift at his fire station. No emergency calls were received that day, and the day was spent checking fire extinguishers and training for emergency egress during aircraft rescue operations. The Captain was the apparatus Driver during this training session and he was wearing his turnout jacket, but not the rest of his turnout gear or his self-contained breathing apparatus (SCBA). According to crew members, the apparatus Driver duty during this training exercise was not a physically demanding position.

At approximately 1830 hours, the crew had dinner and then retired to the television area to relax. At approximately 2030 hours, the Captain said good night to crew members and retired to his sleeping quarters. Not at that time, nor at anytime during his shift, did the Captain report to crew members any symptoms suggestive of cardiac problems (e.g., chest pain, shortness of breath, dizziness, palpitations, syncope, etc.). If fact, several crew members noted that he looked better than he had for weeks. During the night several crew members noted the Captain's room light was on, but they did not inquire because they thought he was reading in bed.

The Captain was usually the first to arise in the morning, typically around 0500 hours. He would make coffee for the crew and begin the chores of cleaning the station. In the morning, the Captain typically dressed in civilian clothes for the last few hours of the shift. By 0700 hours the entire crew had awoken, and all wondered why the Captain was sleeping so late. Two crew members went to awaken the Captain and found him lying on his back, diagonally across his bed with his head pressed against the wall. He was still in the previous night's uniform with his shoes unlaced and his pants unbuckled. He was unresponsive.

One crew member ran from the room to call dispatch (911) for a medical emergency, and then ran to the station's ambulance to retrieve their AED. The other crew member checked the Captain's vital signs and found no pulse and no respirations. He noted his purple/black appearance and, as he moved the body to perform CPR, he noted the Captain was stiff and cool to the touch. Since the Captain had obviously been expired for some time, CPR was not begun. The AED showed no heart beat (asystole), and this lack of a heart beat was confirmed by the arriving

Advance Life Support ambulance team. He was pronounced dead at the station by the county coroner at 0700 hours.

Medical Findings. The death certificate, completed by the county medical examiner, listed "ischemic heart disease" as the immediate cause of death due to "atherosclerotic coronary heart disease." Pertinent findings from the autopsy, conducted under the supervision of the county medical examiner, showed:

- Moderate calcification and atherosclerotic narrowing of the coronary arteries
  - "70-80% stenosis of the right coronary artery"
  - "95% stenosis of the proximal left circumflex coronary artery with the plaque showing central disintegration and liquefaction"
  - "Substantial stenosis of the left anterior descending coronary artery"
- Softening and dark discoloration of the left ventricle, more toward the apex" [a finding suggestive of a recent myocardial infarct (MI) (otherwise known as a heart attack)]
- No scars suggestive of old/remote heart attacks
- No evidence of a blood clot (embolus) in the pulmonary arteries
- Microscopic examination of the heart muscle showed no inflammation, necrosis, or scarring [again these finding suggest no old/remote heart attacks]

His blood carboxyhemoglobin level (a test of carbon monoxide exposure) was not checked due to no exposure to fire smoke during his shift, and no drug screen was performed.

Although the Captain had four risk factors for CAD (male gender, age over 45, family history, and smoking), he had no known history of CAD. In 1999, during his annual medical evaluation, his resting EKG was suggestive of a new anteroseptal MI (heart attack). Subsequent medical evaluations included an echocardiogram and an exercise stress test (EST). The echocardiogram showed normal heart structures, size, and motion. His EST was conducted using the Bruce protocol. The Captain exercised for 12 minutes reaching 12.9 (METS) and a maximum heart rate of 156 beats per minute (93% of his maximum predicted heart rate). He reported no symptoms suggestive of angina, showed no EKG signs of ischemia (no ST segment changes), and had a good blood pressure response. He did show ventricular couplets at peak exercise which resolved during recovery. There were no sustained dysrhythmias (abnormal heart rhythms). An imaging study conducted at rest and at peak exercise showed normal and uniform tracer uptake throughout all areas of the heart. There were no distribution discrepancies between the resting and exercise images. In addition, the scan calculated a normal left ventricular function (ejection fraction of 56%).

This negative stress test resulted in the occupational medicine clinic re-evaluating the June 1999 EKG. Subsequent questioning of the technician performing the EKG strongly suggested electrode lead placement was responsible for the tracing being suggestive of a new anteroseptal MI. Correct lead placement during the resting EKG just prior to the EST (July 13, 1999), and during subsequent EKGs at the occupational medicine clinic (July 15, 1999) were entirely normal. His last annual physical evaluation was conducted in June 2002 and he was cleared for unrestricted full-duty.

The Captain never mentioned any heart symptoms to family members. He did have occasional episodes of heartburn, but the symptom characteristics were not suggestive of angina (e.g. the heartburn typically started after a late, spicy meal and was unrelated to exertion). Approximately six weeks prior to his death, the Captain went hunting with his son and successfully climbed very hilly and rugged terrain for several hours without any heart symptoms. About three weeks

prior to his death, the Captain had an upper respiratory illness which he attributed to a "cold." The Captain did not seek medical care for this illness, and it resolved after about two weeks, although he complained of some residual tiredness. A few days before his death, the Captain had a few instances of chest musculoskeletal pain. Again, the pain characteristics made it unlikely to be angina (the pain was sharp, unrelated to exertion, and lasted only 10 to 20 seconds).

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the Captain's death, the FD consisted of 23 career fire fighters manning one fire station serving a population of 8,000 residents in a geographic area of five square miles. The primary responsibility of the FD is emergency incidents at the Air National Guard and civilian airport. When the Air National Guard is not flying, the FD responds to community mutual aid calls for support of structure and wildland fires. For the first six months of 2003, the FD responded to 204 incidents, with 107 (52%) being runway barrier changes.

Fire fighters are State employees and work a 24-hour shift (Day 1), followed by 24 hours off-duty (Day 2). This sequence is repeated on Days 3-4 and Days 5-6. Days 7-9 are days off prior to the sequence repeating (this averages to a 56-hour work week). Shifts begin at 0730 hours. The Captain was on "Day 3" of his work sequence, and had agreed to work an upcoming overtime shift on "Day 6." The Captain had 23 years of experience as a fire fighter and was promoted to Captain in 1990. He was certified as a National Fire Protection Association (NFPA) Fire Fighter I, Fire Fighter II, Fire Officer, Driver/Operator, Hazardous Materials, and a Wildland Fire Fighter.

Candidate Evaluations. When vacancies in the FD become available, applications are taken for those already certified as NFPA Fire Fighter I, Emergency Medical Technician (EMT)- basic, and Department of Defense International Fire Service Accreditation Congress (IFSAC). The applicant then takes a written and a physical ability test followed by an interview conducted by a board composed of members of the FD and Officers stationed at the Air National Guard base. The top candidate(s) is hired as a three month probationary employee, and the rest of the ranked candidates are kept on a hiring list for one year.

Preplacement Evaluations. All probationary employees are required to undergo a preplacement medical evaluation conducted by a contractor hired by the FD. The FD specifies the components of the medical evaluation which includes:

- Complete medical history and questionnaire
- Height, weight, and vital signs
- Physical examination
- Vision test
- Audiogram
- Urinalysis
- Urine drug screen
- Blood tests: Complete blood count, chemistry panel (SMA 6) which includes a serum glucose measurement
- Spirometry (lung function tests)
- Chest X-ray (one view - PA)
- Resting electrocardiogram (EKG)
- Skin test for tuberculosis (PPD)
- Hepatitis B & C screen
- Immunizations administered if proof of vaccination cannot be provided [hepatitis B, measles, mumps, & rubella (MMR), and varicella].

After reviewing this information, the contractor decides whether the candidate is medically cleared to perform fire fighting duties. Qualitative respirator fit testing is currently performed by the FD.

Periodic Evaluations. The FD requires annual medical evaluations for **all** fire fighters. This evaluation is the same as the pre-placement evaluation without the Chest X-ray, and urine drug screen. However, the contractor also administers a random urine drug test on one random fire fighter per month. In addition, for FFs above the age of 50, the contractor checks PSA and gives stool testing kits for occult blood. The FD Physician contractor also administers a physical ability test consisting of walking on a treadmill at a pace of 2 miles per hour (mph) with elevations of 0° for three minutes, 3.5° for three minutes, and 7° for three minutes (nine minutes total). The participant's heart rate is taken at three minute intervals. This test achieves approximately 6.9 METS. Fire fighters whose pulse exceeds 85% of the maximum heart rate (220 minus their age) is put in a light duty position and a physical conditioning program is prescribed.

Medical Clearance, and Fitness/Wellness Programs. If a fire fighter is injured at work, emergency medical care can be administered by any physician, however this must be followed-up by the State's program for workers compensation issues and clearance for return to work. A fire fighter who misses work for three shifts because of an illness (work-related or not), must also be cleared for "return-to-work," by either the State physician or the FD's contract physician.

The fire station has exercise (strength and aerobic) equipment purchased by, or donated to, the FD. The FD has a voluntary fitness program where fire fighters can have protected time during non-Air National Guard flying hours to use the exercise equipment. Approximately 20% of the fire fighters take advantage of the opportunity to use the exercise equipment.

The FD contracts with the local occupational health clinic to provide health maintenance/wellness information during their annual medical evaluation. In addition, any fees for classes on smoking cessation, weight reduction, or dietary habits, are covered by the FD.

DISCUSSION

In the United States, coronary artery disease (CAD) due to atherosclerosis (plaque) is the most common risk factor for cardiac arrest and sudden cardiac death.[1] Risk factors for its development include increasing age, male gender, heredity, tobacco smoke, high blood cholesterol, high blood pressure, physical inactivity, obesity and overweight, and diabetes.[2] The deceased fire fighter had four 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. In this case, no thrombus was found at autopsy.

Establishing the occurrence of a heart attack requires any of the following: coronary artery thrombus, characteristic EKG changes, and elevated cardiac enzymes. Since the latter two could not be performed prior to his death, and no definitive thrombus was found, it cannot be determined if his sudden cardiac death was precipitated by a heart attack. On the other hand, a 95% blockage (stenosis) of one of the main coronary arteries (proximal left circumflex) with central disintegration and liquefaction is suggestive of a thrombus which would have caused a heart attack and precipitated his sudden cardiac death.

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.[5] Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased heart rate, increased catecholamines, and shear forces, which occur during heavy exercise.[6,7] Although firefighting is a very physically demanding occupation, by all accounts, the Captain was not engaged in heavy physical exertion during his shift.

Prior to this event, the victim had no symptoms of angina (heart muscle pain). Unfortunately, sudden cardiac death is often the first overt manifestations of ischemic heart disease.[8]

To reduce the risk of sudden cardiac arrest and heart attacks among fire fighters as well as other medical causes of incapacitation, NFPA has developed its "Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians," otherwise known as NFPA 1582.[9] NFPA 1582, in its appendix for "informational purposes only," recommends that fire fighters over the age of 35 with risk factors for CAD be screened for obstructive CAD by an Exercise Stress Test (EST). Unfortunately, EST have problems with both false negatives (inadequate sensitivity) and false positives (inadequate specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of CAD).[10,11] This has led other expert groups to not recommend EST for asymptomatic individuals without risk factors for CAD.[12-14]

When asymptomatic individuals have risk factors for CAD, recommendations for EST vary by organization. NFPA 1582 recommends biannual EST for fire fighters with CAD risk factors beginning at age 35.[9] Medical certification for a commercial drivers license issued by the U. S. Department of Transportation (DOT) recommends EST for drivers over the age of 45 with more than two CAD risk factors.[12] The American College of Cardiology/ American Heart Association do not think that "there is evidence and/or general agreement that [EST] is useful and effective" in asymptomatic persons without known CAD, but they identify four groups of such persons for which "there is conflicting evidence and/ or a divergence of opinion about the usefulness/ efficacy" of EST. In these groups, EST's "usefulness/ efficacy is less well established by evidence/opinion" (as opposed to the "weight of evidence/opinion [being] in favor of usefulness/efficacy)."[13]

- Group 1:Persons with multiple risk factors. Five risk factors for CAD are defined: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic blood pressure greater than 140 mm Hg or diastolic pressure greater than 90 mm Hg), smoking, diabetes, and family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

- Group 2:Men over the age of 40 and women over the age of 50 (especially if sedentary) who plan to start vigorous exercise.

- Group 3:Men over the age of 40 and women over the age of 50 who are at high risk for CAD due to other diseases (e.g., chronic renal failure).

- Group 4:Men over the age of 40 and women over the age of 50 who are involved in occupations in which impairment might impact public safety.

Finally, 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).[14] The USPSTF indicates that there is insufficient evidence to recommend screening middle age and older men or women in the general population but notes that "screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety."[14]

Four years prior to his death, the Captain had an EST. All aspects of the EST were negative with one exception: a ventricular couplet [two premature ventricular contractions (PVCs) occurring sequentially]. The medical literature is unclear whether a ventricular couplet during peak exercise is suggestive of ischemic heart disease, and therefore a positive EST.[15] Given how well the Captain performed on other aspects of his EST, however, it was reasonable to conclude his EST was negative.

If the FD was conducting EST on a biennial (every two years) basis, his EST would have been repeated in 2001. Therefore, it is possible the Captain's underlying CAD may have been identified and he could have been referred for further evaluation and treatment. However, just six weeks prior to his death, the Captain participated in a very physically demanding hunting activity. According to his son, the Captain gave no indication of any heart problems (chest pain, excessive shortness of breath with exertion, or exercise intolerance). Thus, even if an EST had been performed, the Captain may have been one of the unfortunate 5% of individuals with CAD that have a false negative EST.[13]

RECOMMENDATIONS AND DISCUSSION

A number of agencies have developed preventive measures to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. This strategy consists of: 1) minimizing physical stress on fire fighters; 2) screening to identify and subsequently rehabilitate high risk individuals; and 3) encouraging increased individual physical capacity. This strategy has not been evaluated by NIOSH, but represents research presented in the literature, consensus votes of Technical Committees of the NFPA, or labor/management groups within the fire service. Potentially relevant issues applicable to this FD include:

Recommendation #1: Consider slightly modifying the FD medical evaluations to be consistent with NFPA 1582.

The FD has an excellent medical screening program. When comparing this program to NFPA 1582, there are a few differences. Extra components currently being conducted by the FD include a comprehensive medical EXAMINATION done annually, rather than an annual medical evaluation and a periodic comprehensive medical examination based on the age of the fire fighter.

The 2000 Edition of NFPA 1582 recommends a yearly physical evaluation to include a medical history, height, weight, blood pressure, and visual acuity test.[9] NFPA 1582 also recommends a comprehensive examination to include vision testing, audiometry, pulmonary function testing, a complete blood count, urinalysis, and biochemical (blood) test battery be conducted on a periodic basis according to the age of the fire fighter (less than 30: every 3 years; 30-39: every 2 years; over 40 years: every year). Extra laboratory tests conducted by the FD, but not included by NFPA, in their comprehensive medical examination include: a) the hemocult test for occult blood, b) cholinesterase levels, c) hepatitis-B titers, and d) a resting EKG. The FD should be aware that the revised 2003 edition of NFPA 1582 has passed their Standards Council Committee and should be issued this fall. We recommend the FD review the

revised edition and modify preplacement and periodic physical examinations accordingly.

The majority of fire fighters in this FD are certified as Hazardous Materials (HAZMAT) responders. NIOSH has published guidelines for, and examples of, HAZMAT pre-employment and periodic medical evaluations.[16] Reviewing these guidelines, it would appear this FD's medical evaluations are based more on HAZMAT guidelines, rather than the voluntary NFPA 1582 standard. However, both guidelines provide the physician administering the evaluation/ examination broad latitude in determining testing components. The selected components should be based on the fire fighter's work and their exposure.

Recommendation #2: Consider adding exercise stress tests to the medical examination on a periodic basis.

As mentioned in the discussion section of this report, conducting EST in asymptomatic individuals is controversial. After considering the pros and cons of conducting EST every two years, the FD has decided not to include this test. The NIOSH publication on HAZMAT medical examination states, "a 'stress test' (graded exercise) may be administered at the discretion of the examining physician, particularly where heat stress may occur."[16] Given the temperature of the area during the summer months, and the use of PPE during training exercises, heat stress could be a significant concern.

Recommendation #3: Consider more strenuous physical fitness testing.

As mentioned in the annual medical evaluations section of this report, the contract physician also conducts physical fitness testing. Fire fighters are exercised on a treadmill test for nine minutes achieving approximately seven METS or a $VO_{2\,max}$ of approximately 24 $ml \cdot kg^{-1} \cdot min^{-1}$. Since fire suppression activities can require a $VO_{2\,max}$ up to 45 $ml \cdot kg^{-1} \cdot min^{-1}$, this suggests a more rigorous physical fitness testing might be appropriate.[17-19]

Recommendation #4: Phase in a <u>mandatory</u> wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Additionally, physical inactivity, or lack of exercise, is associated with other CAD risk factors, namely obesity and diabetes.[20] NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[21] NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, provides the minimum requirements for a health-related fitness program.[22] In 1997, the International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (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. They produced a manual and a video detailing elements of such a program.[23] The Fire Department could review these materials to identify applicable elements for their department. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[24-26] A similar cost savings has been reported by the wellness program at the Phoenix Fire Department, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.[27]

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INVESTIGATOR INFORMATION

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