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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 *August 2008*

Captain Suffers a Fatal Heart Attack While Participating in Fire Department Physical Fitness Training Program—California

SUMMARY

On May 14, 2007 the Captain reported to duty at his fire station at 0800 hours. About an hour later, the Captain and the other crewmember assigned to his station (Engineer), changed into gym clothes and drove their Engine to a paved walking/jogging trail to participate in their Fire Department fitness program. The temperature was 80° Fahrenheit and sunny. The two began walking a ½ mile flat section of the trail followed by walking another ½ mile steep section (approximately 8% grade). At the top of the steep section, the Captain rubbed his chest and complained "my heartburn is killing me today." Shortly thereafter, the two started jogging on the flat portion of the trail, when the Captain collapsed. The Engineer notified dispatch and then began performing cardiopulmonary resuscitation (CPR) including the use of an automated external defibrillator (AED) from the Engine. About eight minutes after his collapse, ambulance paramedics arrived on-scene and administered advance life support which was continued in the hospital emergency department. Despite these resuscitation efforts, the Captain died. Both the death certificate and the autopsy report listed "acute myocardial infarction" (otherwise known as a heart attack) as the immediate cause of death due to "coronary artery disease." NIOSH investigators agree with these reports, and that the heart attack was probably triggered by the moderate to severe physical exertion associated with his fitness training.

NIOSH investigators offer the following recommendations to reduce the risk of on-duty heart attacks and sudden cardiac deaths in this and other fire departments across the country. It is unlikely, however, that implementation of any of these recommendations would have prevented the Captain's sudden cardiac death.

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. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. 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 Web site at

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- Provide annual medical evaluations to ALL fire fighters to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.
- Conduct symptom-limiting exercise stress tests on some fire fighters based on their risk for a coronary heart disease event.
- Discontinue biannual chest X-rays for the Hazmat team unless specifically indicated for an individual.
- Conduct annual respirator fit testing. Secure funding from the governing municipality to upgrade the current fitness-wellness program.

INTRODUCTION AND METHODS

On May 14, 2007, a 53-year-old male, career Captain suffered an on-duty fatal heart attack while participating in a Fire Department physical fitness training program. On May 16, 2007 NIOSH was notified of this fatality by the United States Fire Administration and NIOSH contacted the Fire Department to gather additional information about the death. On June 10, 2008, an occupational medicine physician from the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to the Fire Department to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met with or interviewed the following people:

- Fire Chief
- Fire Captain
- President of the local chapter of the International Association of Fire Fighters (IAFF)
- Crew member who was on duty with the Captain
- Crew members and the Battalion Chief who responded to the dispatch request for medical assistance
- Son of the Captain
- City Personnel Analyst who administers contracts for Fire Department medical services
- Forensic pathologist who conducted the autopsy

During the site visit NIOSH personnel reviewed the following documents related to this incident:

- Fire Department investigation file of the incident
- Dispatch tape
- Death certificate
- Autopsy report
- Captain's medical records maintained by the Fire Department
- Captain's medical records maintained by his primary care provider
- Components of the Fire Department's wellness and fitness program
- Components of the Fire Department's medical evaluation program

- National Climatic Data Center weather report

INVESTIGATIVE RESULTS

Incident. On May 14, 2007 the Captain reported to duty at his fire station (Station 3) at 0800 hours to begin his 24-hour shift. The Captain was assigned to Engine 3 (E-3) along with E-3's Engineer (Driver/Operator). The shift began with the Captain and the Engineer checking their personal protection equipment [turnout gear, helmet, gloves, boots, wildland fire gear, self-contained breathing apparatus (SCBA) and mask], and then placing this gear onto E-3. This was followed by a conference call with the City's fire fighters on-duty that day. At about 0900 hours, the Captain and the Engineer changed into gym clothes and drove E-3 about a mile from their station to begin a jog as part of the Fire Department's physical fitness program.

The Fire Department has an on-duty and an off-duty component of their fitness program. Both components are voluntary. The on-duty component consists of time during the shift, typically between 0800-0100 hours, when members are encouraged to "work out." The workout could consist of weight training with weights available in most fire stations, or aerobic activity. The aerobic activity could occur outdoors (walk/jog/run) or inside the station using machines (treadmills, stationary bikes, stairs). Only a few stations, however, are equipped with aerobic machines. This workout time is not "protected," meaning that crewmembers must respond to all emergency calls received during this time.

The off-duty component provides a $25 monthly subsidy for belonging to, and using, a local fitness center. If a member fails to use the fitness center an average of two times per week, the subsidy is discontinued.

At about 0915 hours, the Captain and the Engineer parked E-3 alongside the paved trail where they typically jog. The temperature was 80° Fahrenheit and sunny [CDEC 2008]. They began by walking along the flat portion of the trail for ¼ mile then turned around and walked back to the Engine (Photo 1). They walked another ¼ mile before reaching a very steep hill (approximately 8% grade) which peaked after about 250 yards (Photo 2). Close to the top of the hill, the Captain rubbed his chest and complained "my heartburn is killing me today." In a effort to get comfortable and rest, he took a deep breath and bent over his knees. After resting about 60 seconds, the two walked back down the hill and returned to the Engine. When they returned to E-3, they dropped off their hat and collar microphone, prior to beginning their jog.

The two started jogging on the flat portion of the trail, with the Engineer running a little ahead of the Captain. They jogged away from and back to the E-3 for about a total of one mile when the Engineer came around a corner and saw the Captain lying on his back (approximately 0938 hours). Initially, the Engineer thought the Captain was joking, but soon realized the Captain not responding. He sprinted to the Captain's location and found the Captain in a semi-conscious state (very sweaty, rapid breathing with a pulse, but unresponsive). Using the Captain's

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Photo 1. Flat section of the paved trail

Photo 2. Steep section of the route

radio, the Engineer called Dispatch requesting Engine-2 and a life support unit (private ambulance company), and that the Battalion Chief be notified (0939 hours). He then ran back to E-3 about 50 yards away to retrieve the oxygen tank with a bag-valve mask.

The Engineer placed the mask over the Captain's face and asked one of the civilians walking on the trail to provide bagged ventilations while he updated Dispatch on the situation. When he returned to provide bagged ventilations, the Captain's pulse became weaker and faster. At this point the Captain stopped breathing. The Engineer had the civilian continue the bagged ventilations while he retrieved E-3's AED. The AED leads were attached to the Captain's chest and a shock (defibrillation) was advised and delivered with no change in the Captain's clinical status. The AED advised no shock be given and 2-person CPR was initiated. The Battalion Chief arrived at approximately 0943 hours and took over the bagged ventilations for the civilian.

At about 0947 hours, the ambulance and Truck-1 (Engine-2 was in training in District 5 and Truck-1 was the closest Fire Department apparatus) arrived at the same time. The paramedic from the ambulance company inserted a breathing tube into the Captain's trachea on the first attempt. At the time of this report ambulance records were not available to determine if a secondary technology test was performed to ensure the tube was properly placed in the Captain's trachea [AHA 2005]. Two intravenous lines were placed through which advance life support medications were administered. Two-person CPR was continued as the Captain was lifted into the ambulance which departed the scene at approximately 0952 hours.

En-route to the hospital, the Captain's condition did not change and 2-person CPR continued. The ambulance arrived at the hospital approximately 3 minutes later (0955 hours). Advance life support continued for about 9 minutes in the emergency department with no

change in the Captain's clinical status. He was pronounced dead at 1004 hours and all resuscitation measures were discontinued.

Medical Findings. The cause of death listed on the death certificate was completed by the County's Deputy Coroner after the forensic pathologist completed the autopsy report. Both the death certificate and the autopsy report listed "acute myocardial infarction" (otherwise known as a heart attack) as the immediate cause of death due to "coronary artery disease." Pertinent findings from the autopsy include:

- Atherosclerotic coronary artery disease
  - — 95-99% narrowing of the left anterior descending artery by atherosclerotic plaque
  - — No significant narrowing of the right or circumflex coronary artery
  - — No blood clots (thrombus) in the coronary arteries
- A large heart of 496 grams (the coroner's office noted that the normal heart size for someone of the Captain's his weight was 275-478 grams)
  - — Four chamber enlargement
  - — Mild dilation of both ventricles
  - — Right ventricular hypertrophy [5 millimeters (mm) at the mid posterior wall]
  - — Left ventricular hypertrophy [16 mm at the mid lateral wall]
- No blood clots in the pulmonary arteries (e.g., no pulmonary embolus)
- Negative blood testing for alcohol or illicit drugs (amphetamines, barbiturates, benzodiazepines, cocaine metabolites, methadone, methamphetamines, opiates, phencyclidine, and propoxyphene).
- Histology (microscopic) sections of the heart showed:
  - — hypertrophic myocytes (enlarged cardiac muscle cells) in both ventricles
  - — increased interstitial fibrosis in some sections of the left ventricle.

The Captain had a family history of cardiac disease with his father dying at age 52 due to congestive heart failure. The Captain also had a history of being overweight from 1984 to 2007 with body mass indexs (BMI) ranging from 28 to 31 [CDC 2008]. In 2003 the Captain was diagnosed with high blood triglycerides with a level of 606 milligrams per deciliter (mg/dL) (normal 0-149), but this total cholesterol was normal (195 mg/dL with normal <200) while his HDL ("good") cholesterol was slightly low at 31 mg/dL (normal 38-65). His total cholesterol/HDL ratio was slightly high (6.3) indicating an increased risk for coronary artery disease (CAD). Over the next 4 years he was unable to bring down his triglycerides or raise his HDL cholesterol by decreasing his intake of fatty foods or increasing his exercise, respectively.

In 2001, as part of the Fire Department's medical surveillance program for hazardous materials (Hazmat), the Captain underwent

an exercise stress test. The purpose was to determine his exercise capacity and to screen for CAD. The Captain exercised for 9 minutes 51 seconds using the El Camino protocol reaching 97% of his target heart rate and 14.7 metabolic equivalents (METS), which is considered excellent exercise tolerance. Throughout the test he was asymptomatic, had a good blood pressure response, and had no arrhythmias. However, his electrocardiogram (EKG) showed significant ST segment depression [2.6 millimeter (mm)] with upsloping ST segments in the inferior and lateral leads at peak exercise. These ST segment changes returned to baseline after he stopped exercising. The most commonly used criteria for a positive exercise test from an EKG perspective is "≥ 1 mm horizontal or downsloping ST segment depression or elevation for at least 60 to 90 milliseconds after the end of the QRS complex" [Gibbons 2002]. The contract Fire Department physician considered the Captain's exercise test "borderline" and referred the Captain for an imaging [gated cardiac single-photon emission computed tomography (SPECT) scan] exercise stress test. The SPECT scan is a more sensitive and more specific test to screen for CAD [Blumenthal 1996].

Four days later the Captain underwent an imaging exercise stress test. He exercised for 16 minutes reaching 89% of his target heart rate. Again, he was asymptomatic with a good blood pressure response. The SPECT scan read by a nuclear medicine radiologist showed no wall motion abnormalities, a normal estimated left ventricular ejection fraction (63%), and "…essentially uniform distribution of tracer with no significant perfusion defects, although there is some probable diaphragmatic and anterior wall attenuation artifact." The report went on to conclude, "Today's study shows no definitive evidence for exercise induced ischemia…." With this additional information, the Fire Department contract physician cleared the Captain for unrestricted duty.

As part of his Hazmat physical evaluation, the Captain had exercise stress tests every 2 years conducted by the Fire Department contract physicians group. Each test showed similar EKG findings: significant ST segment depression (2.7 mm at peak exercise) but the ST segments in the 2005 and 2007 tests appear to be horizontal or possibly downsloping in the inferior and lateral leads. In each instance (2003, 2005, and 2007) the contract physicians compared the series of exercise stress tests and felt the tests were essentially unchanged and cleared the Captain for unrestricted duty. However, in 2005 and 2007 the Fire Department contract physicians asked the Captain's cardiologist to review the tests or asked the Captain to be seen by a cardiologist. It is unclear if the Captain ever saw a cardiologist or if a cardiologist ever reviewed the exercise stress test results.

About 2-3 months prior to his death the Captain began having symptoms of heartburn. The symptoms typically increased with running or drinking wine late at night, and were relieved with antacids or over-the-counter Prilosec®. Two weeks prior to his death, his primary care physician became aware of the symptoms, diagnosed gastroesophageal reflux disorder (GERD), and gave the Captain a trial

of Nexium®. About 10 minutes before his collapse and after walking up a very steep hill, the Captain complained, "My heartburn is killing me today." Other than these "heartburn" symptoms, the Captain never reported symptoms suggestive of heart disease at home, during leisure activities, during exercise, or while performing fire fighter duties.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the Fire Department consisted of 92 uniformed personnel and served a population of 95,000 residents in a geographic area of 70 square miles. The department has eight fire stations (eight engines and one truck), where fire fighters work 24 hours on duty from 0800 to 0800 hours, and are off duty for 24 hours. This cycle of 24-hours on / 24-hours off is repeated four times and then the fire fighters have four days off. Four of the engines are staffed with three personnel (an officer, an engineer, and a fire fighter), while the remaining four engines are each staffed with two personnel (an officer and an engineer). The Fire Department's only truck is staffed with three personnel (an officer, and engineer, and a fire fighter).

Hiring Procedure. Applicants for the position of fire fighter are required to complete an application. Applicants that are not currently NFPA certified fire fighters are excluded from the applicant pool. The candidates then complete a written examination. Candidates scoring >70% are allowed to take the Candidate Physical Ability Test (CPAT). Those passing the CPAT, or those who had passed the CPAT in the previous year, are then interviewed and ranked by members of the Fire Department. The top ten candidates are then interviewed by four senior Captains of the Fire Department. The top 2-3 candidates have background checks, a psychological evaluation, a medical evaluation, and a drug screen. If the candidate passes these evaluations he/she is hired as a probationary employee for one year.

The Captain had 23 years of fire experience, 21 of those years as a full time fire fighter with this Fire Department. He was certified as Fire Fighter I & II, Fire Officer, Apparatus Operator, Hazmat responder at level I & II, wildland fire fighter I-IV, fire service instructor, fire inspector, emergency medical technician, received live-fire training, and training in search and rescue.

Pre-employment/Pre-placement Medical Evaluations. The Fire Department requires a pre-employment/pre-placement medical evaluation for all new hires, regardless of age. Components of this evaluation for all applicants include the following:

- A complete medical history (including respiratory questionnaire)
- Height, weight, and vital signs
- Physical examination
- Urinalysis (dipstick)
- Audiogram
- Chest X-ray (one view)

- Blood test (complete blood count with platelets)
- Resting EKG
- Exercise stress test
- Spirometry
- Urine drug test for illicit drug use (amphetamines, barbiturates, benzodiazepines, cannabinoid, cocaine metabolites, methaqualone, opiates, phencyclidine), and alcohol.

These evaluations are performed by a physician group at a local clinic under contract with the city. Once the evaluation is complete, a physician makes a decision regarding medical clearance for fire fighting duties which is eventually forwarded to the personnel department. The Captain was cleared for duty during his candidate medical evaluation in 1986.

Periodic Medical Evaluations

Medical evaluations for Fire Department members are position dependent. Hazmat fire fighters undergo a medical evaluation every 2 years with the same components as the Candidate medical evaluation (listed above) with the exception of the urine drug test. Fire fighters who drive the apparatus undergo a medical evaluation every 2 years. The components include a California Department of Motor Vehicles Medical Examination report for Commerical Driver Fitness Determination (health history, pulse, blood pressure, dipstick urinalysis, hearing test, vision [Snellen] screen), audiogram, respiratory questionnaire, spirometry, and a respiratory fit test every other year. Regular fire fighters do not have a physical evaluation unless they are engineers, become promoted, or become part of the Hazmat team. As mentioned previously, the Captain's last medical evaluation was of the Hazmat variety 3 months prior to his death.

Fitness and Wellness Programs

The Fire Department has a fitness program with an on-duty and an off-duty component. Both components are voluntary, but the Chief estimates approximate 95% of the fire fighters participate. The Captain participated in the on-duty exercise program, typically by jogging. The Captain also participated in the off-duty program by exercising for about an hour during most of his off days.

Members are also required to pass an annual physical ability test. If the member fails the test within the required timeframe, they are given weeks/months to rehabilitate and re-take the test. Members are allowed three chances to pass the physical ability test before disciplinary action is considered.

If a member suffers a work-related injury or illness, they must be cleared for return to duty by the Fire Department contract physician group. If a member misses four shifts due to a non-work related injury or illness, they also must be cleared for return to duty by the Fire Department contract physician group.

DISCUSSION

Coronary Artery Disease and the Pathophysiology of Heart Attacks. In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death. Risk factors for its development include age over 45, male gender, family history of coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2008]. The Captain had three of these risk factors (male gender, age, family history), and severe localized narrowing of one of his major coronary arteries (95-99% blockage of his left anterior descending artery) at autopsy.

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 [Fuster 1992]. This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. At autopsy, the Captain was not found to have a thrombus in his coronary arteries.

Establishing the occurrence of an acute heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus/plaque rupture. In the Captain's case, he never regained a heart rhythm on which an EKG could reveal characteristic changes, cardiac enzyme testing was not performed (but we would not expect the enzymes to become positive for at least 4 hours post-heart attack), and no coronary artery blood clot/plaque rupture was found at autopsy. However, occasionally (16-27% of the time) post-mortem examinations do not reveal the coronary artery blood clots/plaque rupture during acute heart attacks [Davies 1992; Farb 1995]. NIOSH investigators agree with the coroner's office and the forensic pathologist that, despite the absence of a thrombus in one of his coronary arteries on autopsy, the clinical scenario of the Captain's death is most consistent with a heart attack [Libby 2005; Thaulow 1993].

Symptoms of angina (chest pain due the heart muscle not getting enough oxygenated blood through the coronary arteries) are one of the best indicators of CAD. Up to 20% of patients, however, are asymptomatic or have "atypical" angina [Selwyn 2005]. The Captain did experience "heartburn" a few months prior to his death. Could the patient's heartburn have been atypical angina or his "angina equivalent?" Two weeks prior to his death the Captain mentioned these symptoms to his private physician. Although the medical record did not describe the symptoms, it did say that the symptoms increased with running, a finding consistent with atypical angina. However, the Captain also said the symptoms increased with drinking wine late at night and were relieved with antacids and Prilosec®, findings more consistent with heartburn.

Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death [Willich 1993; Mittleman 1993; Tofler 1992, Albert 2000]. 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 response activities [Barnard 1975; Kuorinka 1981; Lemon 1977; Hurley 1980; Manning 1983; Guidotti 1992; Smith 1995]. Therefore, it should not be surprising that recent epidemiologic studies report that fire suppression, training, alarm response, and strenuous physical activity on the job in the preceding 12 hours, all increase the risk for a sudden cardiac event [Kales 2003, Kales 2007, Hales 2007].

At the time of his sudden death, the Captain was jogging which is considered moderate to heavy physical exertion. This activity occurred on duty as part of the Fire Department's fitness program. The NIOSH investigator concluded that the FF died from a probable heart attack due to his underlying CAD and triggered by the moderate to heavy exertion related to his jogging.

Other Cardiac Findings At Autopsy. On autopsy the Captain was noted to have mildly dilated ventricle cavities and thickened ventricle walls. These finding raise the possibility that, in addition to his atherosclerotic CAD, the Captain could have had some type of mixed dilated/hypertrophic cardiomyopathy. Dilated cardiomyopathy is characterized by dilatation of the heart chambers and impaired ventricular contraction (pumping). Although most cases of dilated cardiomyopathy are of unknown cause (idiopathic), a variety of acquired or hereditary disorders can cause the condition [Dec 1994]. It is unlikely the Captain had any of these disorders. Hypertrophic cardiomyopathy is a relatively common form of genetic heart disease [Maron 2006]. However the microscopic examination of the Captain's heart tissue was not consistent with the diagnosis of hypertrophic cardiomyopathy [Hughes 2004]. The more likely reason for the Captain's mild biventricular hypertrophy is chronic ischemia from his underlying atherosclerotic CAD [Selwyn 2005].

Screening Tests for Cardiac Disease – Exercise Stress Tests. Exercise stress tests are an appropriate screening test for CAD, however testing asymptomatic individuals is controversial. The National Fire Protection Association (NFPA) 1582 states, "Stress EKG with or without echocardiogram or radionuclide scanning shall be performed as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007]. Items in the Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends that sub-maximal (85% of predicted heart rate) stress tests be used as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (e.g., symptom limiting) stress tests with imaging should be use for fire fighters with:

- abnormal screening sub-maximal tests
- cardiac symptoms
- known coronary artery disease
- Males over the age of 45 and females over the age of 55 with two or more risk factors for coronary artery disease. Risk factors are defined as hypercholesterolemia

(total cholesterol greater than 240 mg/dL), hypertension (diastolic blood pressure greater than 90 mm Hg), smoking, diabetes mellitus, or family history of premature coronary artery disease (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The American College of Cardiology / American Heart Association (ACC/AHA) has also published exercise testing guidelines [Gibbons 2002]. The ACC/AHA states that the evidence to conduct stress tests in asymptomatic individuals with diabetes mellitus is "Class IIa" which is defined as "conflicting evidence and/or a divergence of opinion about the usefulness/efficacy but the weight of the evidence/opinion is in favor." The ACC/AHA goes on to say the evidence is "less well established" (Class IIb) for the following groups:

1. Evaluation of persons with multiple risk factors as a guide to risk-reduction therapy with the risk factors essentially the same as the NFPA listed above.
2. Evaluation of asymptomatic men older than 45 years, and women older than 55 years:
    - Who are sedentary and plan to start vigorous exercise
    - Who are involved in occupations in which impairment might jeopardize public safety [e.g., fire fighters]
    - Who are at high risk for coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation has also provided guidance for those seeking medical certification for a commercial drivers license. Their expert medical panel recommended exercise tolerance tests for asymptomatic "high risk" drivers [Blumenthal 2007]. They define high risk drivers as those with any of the following:

- Diabetes mellitus
- Peripheral vascular disease
- Person above the age of 45 with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart disease events. For individuals at increased risk for coronary heart disease events, they found "insufficient evident to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning…." Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [USPSTF 2004]. The USPSTF does note that "For people in certain occupations, such as pilots, and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than

the health benefit to the individual patient may influence the decision to screen for coronary heart disease."

In 2001, the Captain's positive exercise stress test was followed 4 days later by a more sensitive and more specific imaging exercise stress test. That test was read as normal by the nuclear medicine radiologist. This raises two possibilities. It is possible that the Captain's false negative results were due to an inherent limitation of the imaging test (a 95% test sensitivity will not detect 5% of people with CAD) [USPSTF 2004]. Or that the imaging exercise stress test was misread by the radiologist. In retrospect, the "probable diaphragmatic and anterior wall attenuation artifact" may have actually represented the Captain's inferior and lateral ischemia suggested by the EKG (2.7 mm depression of the ST segment with a horizontal pattern) during his non-imaging stress test.

Could the Captain's condition have been identified before his sudden death? Three interventions may have prevented the Captain's sudden cardiac death at this time by allowing for earlier diagnoses and treatment. One, if the Captain followed up on the Fire Department contract physicians' recommendation to see a cardiologist. Two, if the Fire Department contract physicians' had not cleared the Captain for duty until he received a cardiology consult. Three, the subtle change from upsloping ST segment in 2001 to horizontal ST segment in 2005 and 2007, could have led to a repeat imaging exercise stress test or directly to a cardiac catheterization and possible intervention.

RECOMMENDATIONS:

NIOSH investigators offer the following recommendations to reduce the risk of on-duty heart attacks and sudden cardiac deaths in this, and other fire departments across the country. It is unlikely, however, that implementation of any of these recommendations would have prevented the Captain's sudden cardiac death.

1. **Provide annual medical evaluations to ALL fire fighters to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.**

The NIOSH investigator applauds the Fire Department for implementing a comprehensive medical evaluation program. This program, however, has some discrepancies with the program recommended by various fire service organizations [IAFF/IAFC 2000; NFPA 2007]. Specifically, all three organizations recommend annual medical evaluations. Currently, the Fire Department conducts biannual medical evaluations for its Hazmat teams and its Engineers ("DMV evaluations"). Similarly, these organizations recommend annual blood lipid testing (triglycerides, cholesterol, etc) which is not part of the Fire Department's program. It is important to note, however, that the Fire Department is not legally required to follow the guidance provided by the NFPA, IAFF, or the IAFC.

2. **Conduct symptom-limiting exercise stress tests on some fire fighters based on their risk for a coronary heart disease event.**

As noted in the discussion section of this report, conducting exercise stress tests on asymptomatic fire fighters is controversial. Currently, the Fire Department is conducting biannual exercise stress tests on all Hazmat fire fighters, regardless of their risk for a coronary heart disease event. This represents an unnecessary expense for the Fire Department and is in contract to the recommendation of the NFPA and the AHA/ACC. The Fire Department should conduct exercise stress test only on fire fighters at increased risk of a coronary heart disease event.

3. Discontinue biannual chest X-rays for the Hazmat team unless specifically indicated.

The Fire Department seems to be conducting biannual screening chest X-rays for the Hazmat teams. This exposes incumbents to unnecessary radiation and represents an unnecessary expense for the Fire Department. Routine chest X-rays are not required by the Occupational Safety and Health Administration (OSHA) Hazmat standard and are not recommended for the Hazmat medical surveillance evaluation unless specifically indicated by the medical/occupational history (e.g., the fire fighter was having respiratory symptoms) [29 CFR 1910.120; NIOSH 1986].

4. Conduct annual respirator fit testing.

The OSHA respiratory protection standard requires employers whose employees are required to use a respirator (e.g., an SCBA) to have a formal respiratory protection program, including annual fit testing [42 CFR 1910.134]. California is an OSHA-approved State plan, and therefore the Fire Department is required to follow OSHA standards [OSHA 2008].

5. Secure funding from the governing municipality to upgrade the current fitness-wellness program.

Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, reducing the number of work-related injuries, and reducing the number of work-related lost work days [Maniscalco 1999; Stein 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce coronary artery disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Blevins 2006; Dempsey 2002; Womack 2005]. A recent study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future non-occupational healthcare costs [Kuehl 2007].

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