Heart Disease in the Fire Service: Cause for Concern

By: Thomas Hales, MD, MPH

A little over a year ago NIOSH published a document titled, “Preventing Fire Fighter Fatalities due to Heart Attacks and Other Sudden Cardiovascular Events.” The document presented the “lessons learned” from over 175 on-duty fire fighter fatalities due to sudden cardiac death. Specifically, the document described the magnitude of the problem, provided some background on the personal and occupational risk factors for coronary heart disease (CHD), and provided 35 recommendations to prevent or reduce these tragic deaths [NIOSH 2007]. This paper summarizes that document and provides some possible explanation for why, since 1992, the number of on-duty sudden cardiac deaths has not significantly declined.

Magnitude of the Problem

The umbrella term cardiovascular disease encompasses heart attacks (myocardial infarctions), cardiac arrest, and CHD. Since the National Fire Protection Association (NFPA) began collecting fire fighter fatality data in 1977, cardiac arrest and heart attacks have been the number one cause of on-duty fire fighter fatalities, killing between 40 and 50 fire fighters every year. However, not all sudden cardiovascular events result in sudden cardiac death. In 2006, an estimated 1000 fire fighters suffered an on-duty cardiovascular event that did not result in sudden death [Karter 2007]. Therefore, approximately 1045 fire fighters suffer an on-duty cardiac event every year. This

number, however, does not include off-duty events, thus underestimating the larger problem of heart disease in the fire service.

Skeptics question whether the “problem” of heart disease truly exists in the fire service. These skeptics point to the 25 or so cohort studies that have examined the rates of heart disease among fire fighters compared to rates of heart disease in the general population. Results of these studies conflict (i.e., some studies report a higher rate among fire fighters while others do not). In 1995, Guidotti published a review of the fire fighter mortality literature. He concluded, “Sudden death, myocardial infarction, or fatal arrhythmia occurring on or soon after near-maximal stress of the job are likely to be [work] related…” [Guidotti 1995].

The “healthy worker effect” presents one inherent limitation of cohort studies [Choi 1992]. For example, most fire departments screen candidates for CHD and CHD risk factors (e.g., diabetes and hypertension). If fire departments cannot accommodate candidates with these conditions, the candidates would be precluded from employment as a fire fighter. Without these candidates in the fire service, one would expect the CHD rates among fire fighters to be lower than the general population, because all of them are “healthy” (i.e., they have no CHD or CHD risk factors), thus the term healthy worker effect.

In 2000, Choi reassessed 23 standardized mortality ratio studies addressing the relationship between fire fighting and heart disease after attempting to control for the

healthy worker effect. He concluded that, "(1) there is strong evidence of an increased risk of death overall from heart disease among firefighters; …. (3) there is insufficient evidence, even after considering the healthy worker effect, for a relationship between firefighting and any heart disease subtype, such as acute myocardial infarction" [Choi 2000].

Personal and Occupational Factors Associated with CHD

CHD among fire fighters is due to a combination of personal and workplace factors. The personal factors are well known: age, gender, family history, diabetes mellitus, hypertension, smoking, high blood cholesterol, obesity, and lack of exercise [AHA 2008]. Not as widely known, however, is that fire fighters have exposures to workplace factors that are associated with adverse cardiovascular outcomes.

Cardiac and Cardiovascular Effects Associated with Fire Smoke

Fire smoke is a complex mixture of heated gases, vapors, and particulate matter. The composition of the smoke is determined not only by the fuel source, but also by fire conditions (oxygen availability, temperature, etc.) [Levin 2005]. While hundreds of decomposition products are found, two of the more common and well known gases with cardiovascular effects are carbon monoxide and hydrogen cyanide.

Carbon Monoxide. Carbon monoxide, a byproduct of incomplete combustion, is present in virtually all fire environments. A number of studies have quantified a fire fighter's

exposure during various phases of fire suppression [Gold 1978; Brandt-Rauf 1988; Jankovic 1991]. High levels of carbon monoxide have been documented not only during knockdown, but also during overhaul when fire fighters frequently remove their self contained breathing apparatus (SCBA) [Bolstad-Johnson 2000]. If inhaled, carbon monoxide disrupts the blood's transport of and intracellular use of oxygen [Ernst 1998]. The resulting hypoxia can cause myocardial injury [Satran 2005].

Hydrogen Cyanide. Hydrogen cyanide forms during the incomplete combustion of substances containing carbon and nitrogen (paper, cotton, wool, silk, plastics, etc.). Hydrogen cyanide frequently has been detected in structure fires, and levels have exceeded established exposure limits [Gold 1978; Brandt-Rauf 1988; Jankovic 1991]. Like carbon monoxide, hydrogen cyanide disrupts the intracellular use of oxygen, resulting in intracellular hypoxia with cardiac manifestations [Purser 1984].

Particulate Matter. Fire fighters have significant exposure to fire smoke particulate matter during fire suppression [Treitman 1980; Brandt-Rauf 1988]. Studies in the general population suggest particulate matter, as a component of air pollution, has cardiovascular effects [Brook 2004]. For example, long-term repeated exposure to elevated concentrations of particulate matter has been associated with cardiovascular mortality and the initiation/progression of atherosclerosis [Dockery 1993; Pope 2002, 2004]. In addition, short-term exposure to fine particulates has been associated with triggering heart attacks, particularly among people with pre-existing heart disease

[Peters 2001; Pope 2006]. These findings have implications for the fire service given fire fighters' exposure to fire smoke particulate matter.

Cardiac and Cardiovascular Effects Associated with the Work Environment

Increased Heart Rates and Heavy Physical Exertion. A significant portion of the fire fighters' work day is spent at rest or doing light work around the fire station. However, the station's alarm may sound at any time, and fire fighters are expected to rapidly deploy to the incident scene. Fire fighters react to these emergency calls with increased heart rates, probably due to a surge in sympathetic nervous system activity (the flight or fight response) [Barnard 1975; Kuorinka 1981]. The increase in heart rate frequently persists through the course of fire suppression activities, a finding not surprising given the heavy physical demands of structural fire fighting [Smith 2001]. The pattern of sedentary periods interrupted by catecholamine surges and heavy physical exertion has been suspected to put fire fighters at increased risk for acute heart attacks. Epidemiologic studies in the general population report that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Willich 1993; Mittleman 1993; Albert 2000].

Heat Stress. Heat stress and heat illnesses are well-recognized hazards of fire fighting. Fire suppression can increase body temperature, resulting in sweating and fluid loss that can cause serum electrolyte changes, lower stroke volume (the volume of blood pushed during each contraction of the heart), or lower cardiac output [Smith 2001; Rossi

2003]. Heat stroke has been reported to increase the risk of myocardial ischemia, arrhythmias, and conduction abnormalities [Akhtar 1993].

Noise Exposure. Fire fighters' noise exposures are obvious: sirens, air horns, diesel engines, and the roar of a large structure fire itself. Researchers have measured sound levels exceeding 120 decibels during emergency operations [Tubbs 1995]. Studies of community and occupational groups have found an association between noise exposure and hypertension and possibly an association with ischemic heart disease [Van Kempen 2002; Davies 2005; Willich 2006; McNamee 2006]. Fire fighters' noise exposure (short duration, high intensity) differs from noise exposures studied in the community and in other occupational groups (lower intensity for a longer duration [e.g., full-shift]). However, given the extent of the noise-induced hearing loss found in fire fighters, it is plausible that noise exposure increases the risk of hypertension and possibly ischemic heart disease among fire fighters [Tubbs 1995].

Shift Work and Overtime. Several studies suggest a modest association between "rotating" shifts (e.g., a week of days, a week of evenings, a week of nights, with weekends off) and heart disease [Steenland 2000]. Because most career fire departments work 24-hour shifts, and volunteer fire fighters do not work shifts at all, these findings may have limited application to the fire service. A 24-hour shift, however, is long, stressful, and fatiguing. The literature also suggests long hours can increase blood pressure and lead to increased heart disease independently of other stressful conditions at work [Steenland 2000].

Environmental Tobacco Smoke. In 2006, the Surgeon General confirmed a causal relationship between exposure to secondhand smoke and increased risks of coronary heart disease morbidity and mortality [USDHHS 2006]. An estimated 46,000 cardiac deaths occur each year due to secondhand smoke in the United States [Cal/EPA 2005]. Because not all fire stations are smoke free, involuntary exposure to tobacco smoke continues to present cardiovascular risks for fire fighters.

Work-relatedness

In 1999, NIOSH presented evidence from its fatality investigations suggesting that fire fighter CHD fatalities were triggered by work activities [Hales 1999]. The majority of on-duty fire fighter CHD fatalities occurred in the afternoon or evening hours. This starkly contrasts with the circadian rhythm of CHD deaths in the general population, where most deaths occur in the early morning hours [Elliott 2001]. An analysis of fire fighters' activities immediately preceding their sudden deaths showed that over 75% of the deaths occurred while traveling to or from an incident, at an incident, or during training activities. These activities are known to produce high heart rates and elevated blood pressures, which can be attributed to alarm response or performing physically demanding tasks.

These findings led to a formal analytic epidemiologic study [Kales 2003]. Using data from the NIOSH-investigated CVD fatalities, Kales and his colleagues at the Harvard School of Public Health reported a statistical difference in the temporal pattern of sudden cardiac deaths in fire fighters compared to the general population. These

researchers also conducted a case-control study using cases from the NIOSH-investigated CHD fatalities and two control groups. Compared to non-emergency duties, fire fighters involved in fire suppression were 64 times more likely to die from an on-duty CHD event. Fire fighters engaged in physical training were 8 times more likely to die from CHD. Fire fighters responding to an alarm were 6 times more likely to die from CHD. A subsequent more extensive study by Kales et al. found similar findings [Kales 2007]. These findings suggest that fatal heart attacks suffered by fire fighters while on-duty didn't "just happen" at work, but rather that work activities triggered them.

Recommendations

Fire departments have a responsibility to implement effective prevention programs for not only workplace risk factors, but also personal risk factors for cardiovascular disease. These include:

- Providing medical evaluations to ensure that candidates and members are capable of performing job tasks with minimal risk of sudden incapacitation

- Ensuring that physicians conducting the medical evaluations are knowledgeable about the physical demands of fire fighting, the essential jobs tasks of fire fighting, and the consensus guidelines developed by the fire service

- Implementing a comprehensive wellness/fitness program for fire fighters to reduce risk factors for CVD and improve cardiovascular capacity

- Controlling exposure to carbon monoxide and other fire contaminants through proper management of the fire scene and proper use of respiratory protection

- Ensuring adequate staffing levels for operations to prevent overexertion

- Providing on-scene rehabilitation to monitor vital signs for indication of excessive cardiovascular strain, and to cool and hydrate the fire fighter

- Implementing a comprehensive hearing conservation program

Trends in On-Duty Fire Fighter Deaths

Since 1977 the NFPA has been tracking the number of fire fighter on-duty cardiovascular deaths. It reports a 37% reduction in on-duty sudden cardiac death from the first 5 years (1977–1981) compared to the last 5 years (2003–2007) [Fahy 2008]. As in the general population, the reasons for this decline are probably a result of improved prehospital care, improved medical and surgical interventions, and a reduction in major CHD risk factors (reduction in cholesterol, blood pressure, etc.) [Ford 2007]. Another factor relevant for the fire service is the probable reduction in occupational exposures due to the use of personal protective equipment (e.g., SCBA use) since the late1970s.

Unfortunately, since 1992 the number of fire fighter on-duty cardiac deaths seems to resist further decline [Fahy 2008]. The following considerations provide some possible explanation for this observation.

Fitness and Wellness. Despite efforts by NIOSH and other fire service organizations to highlight the problem and provide guidance, most fire departments have not implemented appropriate screening and health promotion programs. In 2005, the U.S. Fire Administration (USFA) estimates that only 24% of fire departments had a program to maintain basic fitness and health, an 11% decline from 2001 [USFA 2006, 2008]. In fire departments where NIOSH investigated an on-duty cardiovascular death, only 57% conducted periodic medical evaluations. Only 21% required exercise stress tests for fire fighters at risk for CHD. Only 39% of fire departments had wellness programs such as smoking cessation and cholesterol and blood pressure checks, and only 9% had mandatory fitness programs. This occurred despite published guidelines for screening and prevention programs such as NFPA 1582 and 1583, and the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) wellness and fitness program. Implementing these guidelines should make significant progress in reducing the number of on- and off-duty CHD deaths.

However, even if fire departments implemented health promotion programs and fire fighters were able to reduce their CHD risk factors it would take a decade for the number of sudden cardiac deaths to decline. Why? Plaque (atherosclerosis) build-up

inside the coronary arteries accumulates over decades. Preventing and reducing plaque formation will also take years or even decades.

Occupational Exposures. Although much progress has been made with the use of SCBA during the knockdown phase of fire suppression, most fire departments do not have policies regarding respiratory protection during overhaul. Industrial hygiene studies have documented exposure to a number of cardiotoxins during overhaul including carbon monoxide, cyanide, and particulates [Bolstad-Johnson 2001].

Finally, the NIOSH fire fighter program has uncovered a small but significant number of on-duty sudden cardiac deaths that were not related to CHD. Rather, these deaths were related to arrhythmias associated with an underlying damage to the heart muscle known as a cardiomyopathy. All three forms of cardiomyopathy (dilated, hypertrophic, and restrictive) are associated with sudden cardiac death. NIOSH found that over 50% of the on-duty sudden cardiac death cases among fire fighters under the age of 35 were due to an arrhythmia associated with a cardiomyopathy. Unfortunately, sudden cardiac death is often the first clinical indication of a cardiomyopathy, and screening tests (e.g., echocardiograms) are not practical to administer to all fire fighters. Therefore, while much remains to be done to reduce the number of on-duty fire fighter fatalities from sudden cardiac death, the goal should be to reduce the number of cases rather than to eliminate all cases.

To help the fire service reduce the number of on-duty fire fighter deaths from CHD, additional research is needed on the:

- Effectiveness of health promotion programs to reduce the incidence of heart disease among fire fighters
- Barriers to implementing health promotion programs (both wellness and fitness)
- Effectiveness of on-scene rehabilitation to reduce cardiovascular strain
- Risk posed to the fire fighter's cardiovascular system due to occupational exposures

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