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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 *January 2010*

Fire Fighter/Operator Suffers Sudden Cardiac Death While Operating a Fire Engine at a Structure Fire – Louisiana

SUMMARY

On September 11, 2009, a 44-year-old male career Fire Fighter/Operator (FF/O) responded in his privately owned vehicle to a two-story structure fire. On scene while wearing full turnout gear, he connected the engine to a hydrant, assisted on a 2½-inch hoseline to protect exposures, and, after additional fire fighters arrived, operated the pump panel on the fire engine. As the FF/O went to the rear of the engine, he suddenly collapsed. The Deputy Police Chief, standing nearby, saw the FF/O collapse and notified the Fire Chief, who notified the on-scene ambulance. Ambulance paramedics treated the FF/O and transported him to the local hospital's emergency department (ED). Despite advanced life support for a total of 39 minutes (at the scene, during transport, and in the ED), the FF/O died. The death certificate and the autopsy, completed by the assistant coroner, listed "hypertensive atherosclerotic cardiovascular disease with coronary insufficiency" as the cause of death. NIOSH investigators conclude that the FF/O's underlying heart condition, coupled with the stress of responding to the alarm and performing fire suppression tasks, probably triggered either a heart attack or a cardiac arrhythmia, resulting in his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear if the recommended programs would have prevented the FF/O's sudden cardiac death had they been in place.

- **Provide preplacement and annual medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.**
- **Ensure fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.**
- **Phase in a comprehensive wellness and fitness program for fire fighters.**
- **Perform an annual physical performance (physical ability) evaluation.**
- **Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the Fire Department's annual medical evaluation program.**

- **Conduct annual respirator fit testing.**
- **Discontinue lumbar spine x-rays as a screening test administered during the preplacement medical evaluation.**

INTRODUCTION & METHODS

On September 11, 2009, a 44-year-old male career FF/O suffered sudden cardiac death during fire suppression operations. Despite cardiopulmonary resuscitation (CPR) and advanced life support administered on scene, during transport, and in the hospital's ED, the FF/O died. The U.S. Fire Administration notified NIOSH of this fatality on September 15, 2009. NIOSH contacted the affected fire department (FD) to gather additional information on October 6, 2009, and on October 23, 2009, to initiate the investigation. On November 2, 2009, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Louisiana to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- The FF/O's daughter
- Crew members

NIOSH personnel reviewed the following documents:

- FD policies and operating guidelines
- FD training records
- FD annual report for 2008
- FD incident report
- Emergency medical service (ambulance) report
- Hospital ED records
- Death certificate
- Autopsy report

RESULTS OF INVESTIGATION

Incident. On September 11, 2009, the FF/O worked a 10-hour overtime shift from 0800 hours until 1800 hours. During this shift the FF/O performed station duties of apparatus checks and cleanup, but the FD did not receive any emergency calls. The FF/O remained at the fire station until about 2030 hours then went home.

At 2136 hours, the FD was dispatched to a fire in a dwelling. Engine G1, Engine C3, and Engine C8 responded. An ambulance was automatically dispatched because the call involved a structure fire. Weather conditions at this time included a temperature of 76 degrees Fahrenheit and 87% relative humidity [NOAA 2009].

The FF/O (driving his privately owned vehicle) responded, arriving at 2141 hours. Off-duty fire fighters are subject to recall during structure fires and other large scale operations. Fire fighters found a two-story dwelling with fire emitting from the windows on the "B" side. The FF/O connected a water supply line from

G1 to a hydrant as other fire fighters stretched a 2½-inch hoseline to protect exposures and a 1¾-inch hoseline to perform interior fire attack. The FF/O manned the 2½-inch hoseline for a time then served as engine operator of G1 after additional fire fighters arrived. Fire suppression continued until approximately 2205 hours, when overhaul began.

At approximately 2209 hours, the FF/O was walking to the rear of G1 when he collapsed. The Deputy Police Chief witnessed the collapse and notified the Fire Chief, who alerted the ambulance paramedics. The paramedics found the FF/O unresponsive with weak pulse and shallow respirations. He was moved to the ambulance for further evaluation and treatment. He took a large breath and began to vomit. Cardiac monitoring revealed ventricular fibrillation, and a shock (defibrillation) converted his heart rhythm to asystole (no heart beat). CPR was begun as an unsuccessful intubation was attempted. An intravenous line was placed through which resuscitation medications were administered. The FF/O's heart rhythm reverted to ventricular fibrillation and a second shock was delivered. Again, his heart rhythm converted to asystole. A CombiTube® (breathing tube inserted into the trachea) was placed, and the ambulance departed the scene en route to the ED at 2223 hours. No improvement in the FF/O's condition occurred during the transport.

The ambulance arrived at the ED at 2235 hours. Inside the ED, the FF/O's heart rhythm remained in asystole and advanced life support continued. The CombiTube® was removed and the FF/O was intubated. Resuscitation efforts continued with no change in the FF/O's condition. At 2248 hours the FF/O was pronounced dead by the attending physician, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy, completed by the assistant coroner, listed "hypertensive atherosclerotic cardiovascular disease with coronary insufficiency" as the cause of death. Specific findings from the autopsy are listed in Appendix A.

The FF/O was 74 inches tall and weighed 289 pounds, giving him a body mass index (BMI) of 37.1. A BMI > 30.0 kilograms per meter squared is considered obese [CDC 2009]. The FF/O's risk factors for coronary artery disease (CAD) included male gender, smoking, and obesity. He last visited a physician in May 2009 for influenza symptoms. His blood pressure reading at that time was normal. It is unclear if the FF/O had a primary care physician. The FF/O had never reported episodes of shortness of breath on exertion or any other cardiac problems to his family or the FD.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the combination FD consisted of four fire stations with 18 uniformed personnel that served a population of 17,000 residents in a geographic area of 3.5 square miles.

In 2008, the FD responded to 352 calls: 72 structure fires, 29 vehicle fires, 25 trash/grass fires, and 226 other calls.

Membership and Training. The FD requires all new career fire fighter applicants to be 18 years of age, have a valid state driver's license, pass a background check, pass an interview with the First Assistant Chief, and pass a post offer/preplacement medical evaluation. Once hired, recruits must attend "rookie school" for Fire Fighter I training and training on fighting interior structure fires. Recruits are placed on probation until they pass a practical fire fighter skills test (similar to the International Fire Service Accreditation Congress program) administered by the First Assistant Chief.

Volunteer fire fighter applicants must be 18 years of age, pass a background check, be approved by the FD board, and attend three meetings and three training sessions within 6 months. The applicant is then voted on by the FD membership. The new member must also attend "rookie school" for Fire Fighter I training and to fight interior structure fires. The State of Louisiana has no mandatory minimum training for fire fighters. The FF/O was certified as a Fire Fighter I, Driver/Operator, HazMat operations, and Technical Rescue, and had 20 years of fire fighting experience.

Preplacement and Periodic Medical Evaluations. The FD currently requires a preplacement medical evaluation for career members only. Components of this evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)
- Hearing test
- Vision screen
- Urinalysis
- Urine drug screen
- Back (lumbar-sacral) x-ray

These evaluations are performed by a physician contracted with the City. Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for fire fighting duties. This decision is then sent to the FD. At the time the FF/O applied for membership, the FD did not have a preplacement medical evaluation.

Annual medical evaluations are not required for either career or volunteer members.

Health and Wellness Programs. The FD does not have a wellness/fitness program, and no exercise (strength and aerobic) equipment is available in the fire station. No health maintenance programs are available from the City. No annual physical ability test is required.

DISCUSSION

Atherosclerotic Cardiovascular Disease. In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age over 45, male gender, family history of CAD, smoking, high blood cholesterol, high blood pressure, obesity/physical inactivity, and diabetes [AHA 2009]. The FF/O had three of these risk factors (male gender, smoking, and obesity/physical inactivity).

Narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. 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 et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques.

Establishing the occurrence of a recent heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. In the FF/O's case, he never had a heart rhythm on which an EKG could be performed, cardiac enzymes were not tested, and the autopsy did not reveal a coronary artery thrombus. Therefore, it cannot be concluded definitively the FF experienced a heart attack, although this is the most likely clinical scenario.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Siscovick et al. 1984; Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks in fire fighters have been associated with emergency response and fire suppression [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The FF/O had responded to the structure fire, connected the water supply line to the engine, manned a 2½-inch hoseline applying water to the exposure, and performed driver/operator duties while wearing full bunker gear. These activities expended at least 10 metabolic equivalents (METs), which is considered heavy physical activity [Gledhill and Jamnik 1992; AIHA 1971]. Given the FF/O's autopsy findings of CAD, cardiomegaly, and left ventricular hypertrophy (LVH), it is probable that the physical stress of emergency response and driver/operator duties triggered a heart attack or a cardiac arrhythmia, resulting in his sudden cardiac death.

Left Ventricular Hypertrophy/Cardiomegaly. On autopsy, the FF/O was found to have left ventricular hypertrophy (LVH) and an enlarged heart. Both conditions increase the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure (hypertension), a heart valve problem, or chronic cardiac ischemia (coronary artery disease) [Siegel 1997]. The FF/O was not known to be

hypertensive, and the autopsy did not reveal a heart valve problem. Therefore, chronic cardiac ischemia, rather than hypertension, is the most likely cause of his LVH.

Carbon Monoxide, Carboxyhemoglobin Levels, and Carbon Monoxide Poisoning.

Carbon monoxide (CO) is a component of fire smoke. When inhaled, CO crosses the alveolar (lung) membrane and binds to hemoglobin, forming carboxyhemoglobin (COHb). The COHb reduces the availability of oxygen to other tissues and disrupts the intercellular use of oxygen, which can lead to hypoxia (inadequate oxygen supply) [Alonso et al. 2003]. The brain and the heart are the organs most vulnerable to hypoxia. Symptoms/signs associated with CO poisoning include headache, dizziness, weakness, nausea, confusion, fast heart rate, and shortness of breath [Ernst and Zibrak 1998]. The FF/O did not report any of these symptoms prior to his collapse.

COHb levels in the blood are used to assess CO exposure and CO poisoning. COHb levels, however, do not correlate well with clinical findings, and profound unconsciousness has been reported with levels less than 20% [Kindwall 1994; Piantadosi 2002]. CO levels in nonsmokers are typically less than 3.0% [Ernst and Zibrak 1998]. At autopsy, the FF/O's COHb level was 5.7%. This level is consistent with the FF/O's history of smoking, but is not at a level considered dangerous [Piantadosi 2002]. Resuscitation efforts (intubation and administration of 100% oxygen for 25 minutes) would be expected to accelerate the elimination of COHb and lower COHb level [Ernst and Zibrak 1998; Alonso et al. 2003]. However, the FF/O never regained a heartbeat; therefore, these resuscitation measures probably had minimal impact on lowering his COHb level.

There is some evidence that prolonged exposure to low levels of CO may have adverse health effects, particularly cardiovascular. The adverse cardiovascular consequences reported at COHb levels of 2%–5% include a decrease in exercise tolerance among healthy individuals and those with ischemic heart disease [Aronow and Cassidy 1975; Allred et al. 1989; Kleinman et al. 1989]. Some reports suggest that increased levels of CO might contribute to the development of coronary heart disease, possibly through its effect on platelet and endothelial functioning [Wald et al. 1973; Borland et al. 1983; Thom and Ischiropoulos 1997]. Other authors, however, consider this evidence speculative [Mennear 1993].

In summary, the FF/O had a slightly elevated COHb level. This could have been due to his smoking history or exposure to carbon monoxide during his fire suppression activities and driver/operator duties. It is not clear what role, if any, the CO exposure (from smoking or fire suppression) had in triggering his heart attack, his arrhythmia, or his sudden cardiac death.

Based on the findings discussed above, NIOSH investigators concluded that the FF/O

died from a heart attack or a cardiac arrhythmia due to a combination of his underlying cardiac abnormalities (LVH, CAD, and cardiomegaly) and heavy physical exertion during fire suppression operations.

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides medical requirements for candidates and current fire fighters. The FF/O had no known medical conditions that would have precluded his work as a fire fighter.

Exercise stress tests screen people at risk for CAD and sudden cardiac death. NFPA 1582 recommends an exercise stress test performed "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (e.g., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease
- two or more risk factors for CAD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter [mg/dL]), hypertension (diastolic blood pressure greater than 90 millimeters of mercury [mmHg]), 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). This exercise stress test recommendation is similar to that recommended by the American College of Cardiology/American Heart Association (ACC/AHA) and the U.S. DOT [Gibbons et al. 2002; Blumenthal et al. 2007].

A maximal stress test was not indicated based on the FF/O's age of 44 years. However, if a submaximal stress test had been performed as recommended by NFPA, perhaps the FF/O's underlying cardiac condition would have been identified, and he would have been referred for further evaluation and treatment.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear if the recommended programs would have prevented the FF/O's sudden cardiac death had they been in place.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000; NFPA 2007a]. These guidelines help to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, the FD is not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small fire departments to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [USFA 2004; NFPA 2007b].

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians (EMTs) from the local emergency medical service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Ensure fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000]. According to these guidelines, the FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty as required by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2007b]. The physician should review job descriptions and essential job

tasks required for all FD positions and ranks, in order to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. This recommendation should prevent a physician from making an uninformed decision to release a fire fighter to return to the physically demanding stresses of full duty.

Recommendation #3: Phase in a comprehensive wellness and fitness program for fire fighters.

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the National Volunteer Fire Council (NVFC) Health and Wellness Guide [IAFF, IAFC 2000; USFA 2004; NFPA 2008]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of over $1 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 nonoccupational healthcare costs [Kuehl 2007].

Given the FD's structure, the NVFC program might be the most appropriate model for its volunteer component [USFA 2004]. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program. The FD has no exercise equipment in the fire stations nor a written wellness/fitness program. An issue facing volunteer fire departments is incorporating physical fitness training into their training program. Physical fitness could be performed at other times in the station or at other locations such as a local fitness center or the fire fighter's home.

Recommendation #4: Perform an annual physical performance (physical ability) evaluation.

NFPA 1500 recommends fire department members who engage in emergency operations be annually evaluated and certified by the fire department as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007b]. This is recommended to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting. The physical

ability test could be performed as part of the FD's annual training program.

Recommendation #5: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the Fire Department's annual medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection prior to being fit tested [29 CFR[1] 1910.134]. Employees must receive annual medical evaluations to determine fitness for duty to wear personal protective equipment (respirators), unless the physician believes a semiannual evaluation is appropriate [29 CFR[1] 1910.120]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans [OSHA 2009]. The clearances are completed as part of the fire department medical evaluation program. Louisiana does not operate an OSHA-approved State plan for the public sector; therefore, public sector employers (including volunteer/paid fire departments) are not required to comply with OSHA standards. However, NIOSH investigators recommend following this standard to ensure an increased level of medical fitness and safety.

Recommendation #6: 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 CFR1 1910.134]. As mentioned previously, Louisiana is not an OSHA-approved State plan; therefore, the FD is not required to follow OSHA standards [OSHA 2009].

Nonetheless, NIOSH investigators recommend following this standard to ensure an increased level of medical fitness and safety.

Recommendation #7: Discontinue lumbar spine x-rays as a screening test administered during the preplacement medical evaluation.

The FD currently performs preplacement physical evaluations, which include routine lumbar spine x-rays. While these x-rays may be useful in evaluating individuals with existing problems, the American College of Radiology, American College of Occupational and Environmental Medicine, and NIOSH have concluded that lumbar spine x-rays have no value as a routine screening measure to determine risk for back injuries [Present 1974; ACOEM 1979; Gibson 1998]. This procedure involves both an unnecessary radiation exposure for the applicant and an unnecessary expense for the FD.

[1]Code of Federal Regulations. See CFR in references.

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INVESTIGATOR INFORMATION

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM)

Appendix A

Autopsy Findings

- Hypertensive heart disease
  - — Cardiomegaly (enlarged heart) (heart weighed 660 grams [g]; predicted normal weight is 450 g [ranges between 341 g and 593 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
- Coronary artery disease
  - — Severe (95%) focal narrowing of the left anterior descending coronary artery
  - — Mild focal narrowing of the right coronary artery
  - — Mild focal narrowing of the left circumflex coronary artery
  - — No evidence of a thrombus (blood clot) in the coronary arteries
- Left ventricular hypertrophy
  - — Left ventricular wall thickened (2.0 cm; normal by autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]; normal by echocardiographic measurement is 0.6–1.1 cm) [Armstrong and Feigenbaum 2001]
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)

- Blood tests for drugs and alcohol were negative
- Carboxyhemoglobin (blood test for carbon monoxide exposure) 5.7% saturation

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