



36-Year-Old Probationary Firefighter Suffers Cardiac Arrest After Completing SCBA Drill—Arizona

Executive Summary

On October 17, 2018, a 36-year-old probationary firefighter (PF) participated in a joint multi-agency search and rescue training evolution. The training evolution consisted of searching for a rescue mannequin in a house while wearing full turnouts and self-contained breathing apparatus (SCBA). After successfully completing the evolution, the PF went for a walk. Minutes later, a fellow firefighter noticed the PF sitting in the rear of the cab of one of the fire engines and asked him if everything was ok. The PF responded that he was not feeling well. Concerned about the PF's health, the firefighter notified the incident commander (IC) who directed a medic/firefighter at the drill to assist with the ill PF. The medic/firefighter spoke with the PF and asked him to step out of the engine so he could assess him. The PF was helped to the ground and placed on his back at which time he became unresponsive. The PF was breathing, had a weak radial pulse and was cold and clammy to the touch. As an IV and oxygen were administered, the PF went into cardiac arrest. Chest compressions and ventilation via bag valve mask (BVM) were initiated. There were no basic life support/advanced life support (BLS/ALS) units on standby during the training exercise so staff called dispatch. A BLS ambulance was closest and arrived approximately 25 minutes later. An automatic external defibrillator (AED) cardiac monitor was placed on the PF. Cardiopulmonary resuscitation (CPR) continued en-route to the hospital where the PF was pronounced dead after approximately two and one-half hours of resuscitation efforts. The death certificate listed the cause of death as coronary artery atherosclerosis with dilated cardiomyopathy and obesity as significant contributing conditions.

Key Recommendations

NIOSH investigators offer the following recommendations to prevent similar deaths, and to address general health and safety issues among firefighters at this and other fire departments across the country:

- *Provide pre-placement and annual medical evaluations consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, which include a baseline electrocardiogram (EKG) in all individuals prior to engagement in any strenuous physical activity to rule out any underlying cardiac anomalies.*
- *Ensure all firefighters are cleared for duty by a healthcare provider knowledgeable about the physical demands of firefighting, the personal protective equipment used by firefighters and the various components consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.*

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The following recommendations may not have prevented the Probationary Firefighter's death, but NIOSH investigators include them to address general safety and health issues:

- *Fire departments should have ALS with automatic external defibrillators (AEDs) and all ALS-required medications on board during training exercises.*
- *Implement a mandatory wellness and fitness program for fire department members consistent with NFPA 1583, Standard on Health-Related Fitness Programs for Firefighters, and the International Association of Fire Fighters/ International Association of Fire Chiefs (IAFF/IAFC) Wellness-Fitness Initiative.*
- *All formal training exercises, especially those involving multiple agencies, should utilize a written Incident Action Plan (IAP).*

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Introduction

On October 17, 2018, a 36-year-old Probationary Firefighter (PF) collapsed during a training evolution and subsequently died. On May 31, 2019, a firefighter safety specialist from the National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) conducted an onsite investigation of the incident.

During the investigation, the FFFIPP safety specialist interviewed the following personnel:

- *Fire District Fire Chief*
- *Fire Chief from neighboring department*
- *Members from neighboring fire jurisdictions*

NIOSH personnel reviewed the following documents:

- *Emergency medical service (ambulance) report*
- *Autopsy and toxicology reports*

Investigation

On October 17, 2018, the PF was participating in a joint training exercise which involved several fire agencies from the surrounding area. A single-family, two-story home was offered to the fire district for training purposes. The fire district invited neighboring departments to participate in a nighttime search and rescue exercise. The exercise included approximately 20 members from four agencies. The exercise included members wearing full personal protective equipment (PPE) (turnout pants, jacket, hood, helmet and gloves) and self-contained breathing apparatus (SCBA). A 165-lb rescue mannequin was placed on the first floor of the home that was filled with simulated smoke. In teams of two, fire department members would conduct a primary search for the mannequin while remaining on supplied air with 30-minute SCBA bottles. If found before their SCBA ran out of air, members would work as a team to remove the mannequin from the house. There was no departmental requirement for basic life support/advanced life support (BLS/ALS) standby units during training exercises.



Home used for live fire exercise [Photo by TJ Welch]

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The exercises began at 1900 hours with a briefing by the incident commander (IC). After multiple evolutions by other teams, the PF and his team member successfully completed the exercise by finding the rescue mannequin and removing it from the house. After completing the exercise, the PF removed his SCBA and, according to witnesses, went for a walk before returning to the fire engine cab to rest. A fellow firefighter went to check on the PF and found him sitting in the rear of the engine cab. When the PF said he was not feeling well, the firefighter requested help from the IC. A medic/firefighter was sent to help, and a transport unit was requested from dispatch.

At approximately 2016 hours, the medic/firefighter approached the PF who confirmed he was not feeling well. The medic/firefighter noted the PF was pale in color and had a far-off gaze. The PF was able to get out of the fire engine but vomited as he was doing so. He was helped to the ground and placed on his back. At this point, he became unresponsive, his jaw was clenched, and he had secretions in his mouth. He was breathing, had a weak radial pulse, and his skin was cold and clammy to the touch.

Oral suctioning was attempted but was not very successful due to his clenched jaw. The PF was placed on oxygen via non-rebreather mask at 15 liters per minute and an IV was started with normal saline (wide open). The PF then went into respiratory arrest. Ventilation was initiated via bag valve mask (BVM), but an oral airway adjunct could not be placed due to his clenched jaw. The PF was reassessed and found to be pulseless, so chest compressions were initiated. During cardiopulmonary resuscitation (CPR), the IV became dislodged so an intraosseous line was placed in the left tibia. When the PF's jaw relaxed, an Ambu© King airway was placed, and CPR was continued while they were waiting for transport.

There were four transport units on duty in the county: two BLS and two ALS units. At the time the transport unit was requested, only one BLS unit was available, and it was approximately 25 minutes away. . On arrival of the BLS unit, the PF was transferred from the ground to the gurney and placed in the ambulance on a cardiac monitor. His cardiac rhythm was interpreted as pulseless electrical activity. Transport was initiated with lights and siren. During transport, a second cardiac rhythm check found him to be in a shockable rhythm and he was shocked at 200 joules. CPR was resumed. The next rhythm check found the PF to be in normal sinus rhythm with ST elevation with a palpable pulse.

On arrival to the hospital, the PF once again went into cardiac arrest. Firefighters continued CPR for approximately one hour before death was pronounced at 2217 hours.

Medical Findings

The PF's height was 6'7" and he weighed 367 lbs. His body mass index (BMI) was 40.3.

The death certificate listed the cause of death as coronary artery atherosclerosis. Dilated cardiomyopathy and obesity were listed as significant contributing conditions. The toxicology tests were positive for cannabinoids. Carboxyhemoglobin was less than 10% saturation.

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Fire Department

At the time of the NIOSH investigation, the volunteer fire district had a total of nine members serving a community of approximately 1,700 residents. The district consisted of a fire chief, assistant chief, two fire officers and five firefighters including the PF.

The fire district covers approximately five square miles and typically responds to structure fires, vegetation fires, automobile accidents and fires. The district has one Type 1 (structure) engine and one Type 6 (brush) engines as well as a Type 1 water tender.

Employment and Training

Within one year, the volunteer fire district requires new members to complete National Incident Management System (NIMS) incident command system (ICS) 100, 200, 700, 800 and district task book. The PF had less than one year of active duty.

Preplacement/Periodic/Return to Work Medical Evaluation

Candidates applying for firefighter positions must successfully complete a physical exam with a healthcare provider prior to joining. Periodic and return-to-work medical evaluations for this agency are also performed by the members' healthcare provider.

Wellness/Fitness Programs

The volunteer fire district did not have a formal wellness/fitness program.

Discussion

Dilated Cardiomyopathy

Dilated Cardiomyopathy (DCM) is a disease of the heart muscle characterized by left ventricle dilation due to impaired systolic function. When the heart cannot pump efficiently, blood begins to back up resulting in stretching and thinning of the heart chamber walls due to the increased volume they must hold since each beat is not pumping out the volume it should. As the backup worsens, fluid (acellular component of blood) is pushed out of blood vessels and into surrounding tissues. Additionally, as the heart chamber walls are stretched, the nerves embedded within that are responsible for initiating each heartbeat at regular intervals may be damaged. This results in an increased risk of irregular and potentially fatal heart rhythms called arrhythmias.

The circulatory system is a loop. Used or deoxygenated blood is returned from the body into the right atrium, released into the right ventricle which then pumps it into the lungs for air exchange to replete the oxygen content. The oxygenated blood returns to the left atrium which sends it down to the left ventricle. The left ventricle pumps out this oxygenated blood to the rest of the body via the aorta. Valves between atria and ventricles, prevent backflow into the atria when the ventricle contracts ensuring one way blood flow through the loop. Congestive heart failure occurs in DCM when the backed-up fluid appears in the small airways in the lungs resulting in airway "congestion" causing

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shortness of breath, exercise intolerance, inability to lay flat, and cough. There may also be swelling or edema in the legs as the backup progresses further back into the system. The presenting manifestations can include arrhythmias, and sudden death can occur at any stage of the disease.

An electrocardiogram (EKG) is a screening tool that can detect an abnormal heart size and/or abnormal rhythms leading to further evaluation. It is recommended that an abnormal EKG should result in a referral for a more thorough cardiological evaluation that may include imaging studies such as an echocardiogram. The echocardiogram can visualize the different structures of the heart allowing for them to be measured to determine if there is enlargement of the ventricles and if so, to what degree. The echocardiogram is also unique in that it can calculate the heart's overall pumping capacity and its Doppler function allows the technician to visualize blood flow through the chambers of the heart in real time which can highlight heart valve problems that can exacerbate backflow issues from pump dysfunction. Since DCM can develop gradually over time, a person may not realize they have this condition until the symptoms become disabling.

In summary, a baseline EKG should be ordered and completed in all individuals interested in becoming a firefighter, and those with abnormal results should be assessed by a cardiologist who can conduct further evaluations to determine the source of the abnormality which may include DCM.

Body Mass Index

BMI does not measure body fat directly, but research has shown that BMI is moderately correlated with more direct measures of body fat obtained from skinfold thickness measurements, bioelectrical impedance, densitometry (underwater weighing), dual energy x-ray absorptiometry (also known as a DEXA scan), and other methods. Furthermore, BMI appears to be as strongly correlated with various metabolic and disease outcomes as are these more direct measures of body fatness. In general, BMI is an inexpensive and easy-to-perform method of screening for weight category, for example underweight, normal or healthy weight, overweight and obesity.

As per the Centers for Disease Control and Prevention (CDC), “BMI does not measure body fat directly, but BMI is moderately correlated with more direct measures of body fat. Furthermore, BMI appears to be as strongly correlated with various metabolic and disease outcome as are these more direct measures of body fatness.” To determine if a high BMI is a health risk, a healthcare provider would need to perform further assessments that might include skinfold thickness measurements as well as evaluations of diet, physical activity, family history and other appropriate health screenings.

The standard weight status categories associated with BMI ranges for adults are shown in the following table.

BMI	Weight Status
Below 18.5	Underweight
18.5 – 24.9	Normal or Healthy Weight
25.0 – 29.9	Overweight
30.0 and Above	Obese

[CDC 2020]

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Recommendations

NIOSH investigators offer the following recommendations to prevent similar fatal events, and to address general health and safety issues among firefighters at this and other fire departments across the country.

Recommendation #1: Fire department ALS units should be on standby during training exercises and be fully stocked at all times to provide that level of care. This includes having an AED or more advanced cardiac monitor/defibrillator and all ALS mandated medications.

The apparatus at the training exercise did not have ALS medications or a manual defibrillator; only an AED was onsite. At the time of the training exercise, the base station hospital required the volunteer fire agencies to keep medications locked in a secure area in the fire station with a seal. The expectation was that when a fire agency received a medical call, the medic would unlock the station locker, retrieve the medication box, break the seal, conduct an inventory and then respond to the medical call as a passenger in a fire apparatus which would be met on scene by an ALS or BLS unit depending on the type of call. At the time of the investigation, the volunteer fire agencies depended on the ALS transport units to supply the ALS medications and manual defibrillator. Therefore, none of the fire apparatus at the training exercise had ALS medications or a manually operated defibrillator available. There were also no requirements for either an ALS or BLS unit to standby on-scene at training exercises. To exacerbate the situation, an ALS transport unit was not available and a BLS transport unit was 25 minutes away at the time of the incident.

Early BLS interventions such as CPR and defibrillation via AED can improve the odds in sudden cardiac arrest care and should be initiated as soon as possible. ALS fire apparatus should carry appropriate ALS equipment so appropriate ALS interventions can be started while awaiting an ambulance for transport. All these actions combined may improve the chances of successful resuscitation.

Recommendation #2: Provide preplacement and annual medical evaluations consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, which includes a baseline EKG in all individuals prior to engagement in any strenuous physical activity to rule out any underlying cardiac anomalies.

Guidance regarding the content and frequency of the medical evaluations for firefighters can be found in NFPA 1582 [NFPA 2022]. In this incident, the PF had been cleared for duty by his personal physician, but no record of an EKG or cardiologist evaluation was found prior to his start of cadet training as recommended by the standard.

Recommendation #3: Ensure all firefighters are cleared for duty by a healthcare professional knowledgeable about the physical demands of firefighting, the personal protective equipment used by firefighters and the various components consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

In accordance with NFPA 1582 [NFPA 2022], the fire department should require that healthcare professionals be familiar with the physical demands of firefighting and the hazards firefighters

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encounter and should guide, direct and advise members with regard to their health, fitness and suitability for duty. The department healthcare professional should understand the physiological and psychological demands of firefighting and the environmental conditions under which firefighters perform, as well as the personal protective equipment they must use during various types of emergency operations.

Recommendation #4: Implement a mandatory wellness and fitness program for fire department members consistent with NFPA 1583, Standard on Health-Related Fitness Programs for Fire Department Members, and the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) Wellness-Fitness Initiative.

Although health and fitness levels have not been shown to reduce the risk for sudden death due to cardiomyopathy, health promotion programs for firefighters can reduce modifiable coronary heart disease risk factors and improve fitness levels, with mandatory programs producing the greatest benefit. Guidance for fire department wellness/fitness programs to reduce cardiovascular risk factors and improve aerobic capacity is found in NFPA 1583 Standard on Health-Related Fitness Programs for Fire Department Members [NFPA 2022] and the Fire Service Joint Labor Management Wellness-Fitness Initiative (WFI) [IAFF, IAFC 2018]. Under this guidance, an annual EKG and aerobic capacity assessment stress test is recommended as part of a fitness for duty evaluation.

Recommendation #5: All formal training exercises, especially those involving multiple agencies, should utilize a written Incident Action Plan (IAP).

Although training exercises of this kind do not require a written IAP, it is strongly recommended on all formal training exercises, especially those that include outside agencies. The depth and scope of the IAP will vary based on the complexity of the training exercise. At a minimum, it would provide objectives (Leaders Intent) for all participants and identify a specific plan of action in the event an emergency occurred for one or more participants during the course of the training exercise.

NFPA 1561 Standard on Emergency Services Incident Management System and Command Safety 4.4.8 states: *The Incident Management System shall be applied to drills, exercises and other situations that involve hazards similar to those encountered at actual emergency incidents and to simulated incidents that are conducted for training and familiarization purposes* [NFPA 2020].

Utilizing an IAP within the Incident Management System allows for all members to understand the objectives of the exercise with ICS Form 202, as well as providing a clear line of supervision and communication through an organizational chart ICS Form 203 and communications worksheet ICS 205. In addition, it utilizes a written safety plan ICS Form 208 and medical plan worksheet ICS 206 that identifies procedures. In the event of a medical or catastrophic incident that may occur in the course of the training exercise, the IAP will provide the necessary tools for proper notifications and response.

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Recommendation #6: Training exercises should have an emergency medical services (EMS) transport unit (at least a BLS unit if an ALS unit is not available) at the training location on standby.

Rapid initiation of medical care/resuscitation and transport to definitive care are important steps to take when a medical emergency occurs during a training exercise. Even if personnel on-site have first responder training or more advanced ALS certification, a vehicle with trained staff should be on-hand to quickly transport the patient once initial stabilization has occurred. Delays due to waiting for a transport unit (ALS or BLS) to arrive may be the factor that determines outcome.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac/Medical Team, in Cincinnati, Ohio. TJ Welch is a Firefighter Safety Specialist and co-authored the report. He worked in volunteer, industrial and municipal fire departments and retired as a Chief Officer. Mr. Welch is a State Certified Fire Officer, founding member of the California Incident Command Certification System (CICCS) and chaired the CICCS committee on Physical Fitness Standards. Dr. Robert Harrison MD, MPH (California Department of Public Health) provided medical consultation, and Laura Styles, MPH (Public Health Institute) also contributed to this report.

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Appendix A

Abnormal Cardiovascular Findings at Autopsy

Cardiovascular System

The heart weighs 660 grams. The epicardial surfaces are smooth. The coronary arteries arise normally and are distributed in a left dominant pattern. The proximal segment of the left anterior descending coronary artery is dilated with mild-to-moderate calcific atherosclerotic narrowing.

The proximal segment of the right coronary artery displays marked atherosclerotic narrowing. No thrombosis, plaque hemorrhage, or dissection is within the atherosclerotic segments. There is moderate-to-marked four-chamber dilation. The chambers and valves are proportionate. The valves are normally formed, thin, and pliable and free of vegetations and degenerative changes.

The myocardium is red-brown, firm, and free of gross fibrosis. The atrial and ventricular septa are intact, and the septum and free walls are free of muscular bulges. The left ventricle measures 1.3 centimeters (cm), the right ventricle 0.4 cm, and the interventricular septum 1.1 cm in thickness as measured 1.0 cm below the respective atrioventricular valve annulus. The aorta and its major branches arise normally and follow the usual course with no significant aortic atherosclerosis. The orifices of the major aortic vascular branches are patent. The vena cava and its major tributaries are patent and return to the heart in the usual distribution and are unremarkable.

Microscopic Description

Sections of the right ventricle, left ventricle, and interventricular septum show hypertrophic myocytes, perivascular fibrosis, and wavy fibers. Within the right ventricle are scattered foci of granulation tissue. Cross sections of the right coronary artery show marked calcific atherosclerotic narrowing of the vessel. A fragmented cross section of the left anterior descending coronary artery shows calcific atherosclerosis.