1000 FREDERICK LANE, MORGANTOWN, WV 26508 · 304.285.5916

35-year-old Volunteer Firefighter Dies from Smoke Inhalation Injury Sustained During Initial Fire Attack – Kansas

Executive Summary

On June 20, 2022, at about 2253 hours, a building fire was reported in a small rural city in Kansas. Personnel from two jurisdictions, the City and County Volunteer Fire Departments (FDs), were dispatched and arrived to find moderate smoke conditions in a commercial building. A 35-year-old firefighter (FF1) responded to the fire and was assigned to be part of the initial attack crew.

Fire origin was thought to be on the 2nd floor, which was accessible by interior stairs. However, due to heavy smoke, the attack team had difficulty finding the stairs. The team exited the structure and received detailed directions to the stairs, retrieved a thermal imaging camera, and reentered the building at approximately 2319. FF1 fell backwards down the stairs and experienced a catastrophic loss of air pressure at 2322. Shortly afterwards, a Mayday was called for firefighter down. The rapid intervention team (RIT) found FF1 face down and unresponsive on the floor near the base of the stairs.

FF1 was removed from the building and placed in the waiting ambulance. Once outside, it was noted that his mask was off. He had a pulse but was not breathing, so CPR was initiated. Soot was noted in his airway when he was intubated. Intraosseous access was obtained during EMS ground transport to a rendezvous location with EMS air transport at 2349. On the way to the emergency department (ED), he went into cardiac arrest. However, with resuscitation efforts, he regained spontaneous circulation. On arrival at the ED, at 2352, he was still unresponsive. Imaging done at the time of his admission to the ICU showed a severe anoxic brain injury. He did not exhibit any brain stem reflexes. A brain perfusion scan done the following day showed no cerebral blood flow. He was pronounced dead at 1205 on June 22, 2022.

Key Recommendations

NIOSH offers the following recommendations to reduce the risk of smoke inhalation injuries and sudden cardiac arrest among firefighters at this and other fire rescue agencies across the country.

- *Key Recommendation #1: Reinforce self-contained breathing apparatus (SCBA) training to include equipment familiarization and use in Immediately Dangerous to Life or Health (IDLH) environments, such as structure fires. Ensure firefighters keep their mask on when operating in IDLH environments to reduce the risk of inhaling hot gases and combustion products.*

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- *Key Recommendation #2: Firefighters wearing full face masks should groom facial hair as to not impede the seal formed by the mask. This requirement is outlined in OSHA 29 CFR 1910.134 and NFPA 1404 Standard for Fire Service Respiratory Protection Training. Fit testing should also occur, at minimum, once per year, following guidelines from the NFPA 1500 Standard on Fire Department Occupational Safety, Health, and Wellness Program and OSHA 29 CFR 1910.134(k).*
- *Key Recommendation #3: Adopt and comply with OSHA mandatory record keeping components of a respiratory protection program and regular SCBA maintenance and recordkeeping.*
- *Key Recommendation #4: Encourage training of all firefighters on NFPA 1407 Standard for Training Fire Service Rapid Intervention Crews to promote safety and survival.*

For further information, visit the program website at www.cdc.gov/niosh/firefighters/fffipp/about.html or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Introduction

On June 20, 2022, a 35-year-old volunteer firefighter (FF1) suffered a cardiac arrest following the inhalation of combustion products while attempting to extinguish a structural fire. The National Institute for Occupational Safety and Health (NIOSH) received notification of this fatality through the U.S. Fire Administration email updates service. NIOSH contacted the affected fire department (FD) to gather additional information and initiate the investigation.

A medical officer and a firefighter safety specialist with the NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) conducted the investigation. NIOSH staff conducted a site visit August 21–26, 2022. During the investigation, the NIOSH investigators interviewed the following people:

- *County FD Chief*
- *Other volunteer FFs from the same FD*
- *FF1's parents (father is also a volunteer FF with this FD)*
- *Police Chief*
- *City Attorney*
- *Three Dräger staff (SCBA manufacturer)*
- *State Fire Marshal*

The NIOSH investigators reviewed the following documents:

- *Emergency medical service (EMS) and inpatient hospital records*
- *Autopsy and postmortem toxicology reports*
- *Self-contained breathing apparatus (SCBA) data*
- *Video capture from police body cameras the night of the fire*

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Fire Department

At the time of this investigation, this county volunteer FD consisted of approximately 65 members. The FD serves a population of about 10,000 in an area of approximately 605 square miles. About 1,250 residents live in the central town/city in whose jurisdiction the fire occurred. The FD's seven stations have a variety of apparatus including engines/pumpers, a ladder truck, and rescue squads. A contracted private ambulance service provides transport.

Membership and Training

In 2008, FF1 completed Federal Emergency Management Agency (FEMA) Incident Command System (ICS) 100, 200, and 700. He completed an 8-hour Kansas State FF Association training on farm extrications in 2018. The FD's policy document stated the following requirements for membership: must be at least 18 years of age, no felony convictions, maintain themselves in proper physical and mental condition in order to carry out the demands of the job, completed driver's license check, completed application for employment, completed probationary period before final approval granted by the FD Captain and the County Fire Chief, and filing of an application for insurance through the County.

Preplacement/Periodic/Return to Work Medical Evaluations

FF1 began volunteering as a firefighter with this FD at age 18. He had a break in service before he reapplied for a position as a volunteer firefighter on March 14, 2016. A preemployment medical examination was conducted as part of his application. The duration of the break in service is unknown by the investigative team. On May 5, 2016, he was sworn in as a volunteer firefighter with this FD. His last recorded fit test was February 2, 2010, with the Dräger Panorama Nova® SCBA. The FD stopped doing its own respirator fit testing in 2020. The current process for FD respirator fit testing is unknown.

Wellness/Fitness Programs

The FD provides fitness equipment at its station for the volunteers to use, but there is no formal wellness/fitness program.

Investigation

On June 20, 2022, a call came into the county dispatch center at 2253 hours reporting a commercial building fire in a small rural city in Kansas. The two-story building's primary use was a healthcare provider office with exam- and procedure-type rooms. The rear of the building's first floor was a small open gymnasium used for exercise classes and physical training. The building had a second floor that

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ran the length of the entire building. It was used for storage and not regularly occupied by people. The caller advised they did not see flames, but smoke could be seen coming from the top of the building. The caller reported seeing no parked cars near the building.

The initial response consisted of personnel and apparatus from two volunteer fire departments. The first, and the authority having jurisdiction, was the single city volunteer station. The second station was a county station also within city limits. FF1 was a member of the county station. A county firefighter (FF1) responded to the county station and drove a pumper to the scene. A second county firefighter (FF2) responded to the county station, noticed the pumper was gone and responded to the scene in his personal vehicle. The fire chiefs from both the county (Chief 1) and city (Chief 2) departments responded to the scene directly from their homes. These were the first four personnel to arrive on the scene. The dispatch center was responsible for electronically recording marked time events, but none of these four personnel had a marked arrival time.

Chief 1 was the first to arrive on scene, at an estimated time of 2258, and completed a 360 of the building. Chief 1 reported to dispatch observing smoke-stained first-floor glass windows and white smoke coming out of the building's west side. Chief 2 arrived shortly after Chief 1, at an estimated time of 2259, and completed his 360. Chief 2 assumed command of the incident and became the Incident Commander (IC).

The west side (A-side) of this building was the main entrance to the healthcare provider's office and faced the main street (Photo 1). The south side (D-side) of the building contained an entry door and a parking lot that was completely open to the side street (Photos 2a, 2b). The IC selected the D-side as the entry point. The parking lot allowed for easier apparatus placement, and the D-side door provided better access to the stairs. The upstairs storage area was only accessed by one set of interior stairs and had a large set of triangle windows that matched the roof line pitch on the A-side.

The IC believed the fire origin was on the 2nd floor. FF1 and FF2 arrived at approximately 2300 and 2302 (respectively), donned their fire gear and SCBAs, and reported to the D-side entry door. EMS was called to the scene at 2301. The IC command post was just outside the entry door. The IC decided that FF1 and FF2 would be the initial fire attack crew. FF1 turned on his SCBA at 2303 and went on air at 2306. A 250-foot, 1¾-inch pre-connect hose line was pulled by FF1 and FF2 (the attack crew) off the first arriving engine. The next county firefighter (FF3) to arrive was initially assigned to the Rapid Intervention Team (RIT) but was moved into pump panel and prepared to charge the line and assist with hose advancement as more firefighters arrived.

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Multiple interviews with FF personnel and the IC reported that neither FF1 nor FF2 were wearing Nomex hoods on initial entry into the structure. It is unclear why they did not have hoods upon arrival. FF1 and FF2 made entry with a charged hose line at 2309, but due to heavy smoke, they had difficulty finding the stairs. The building owner arrived on the scene and notified the IC that the building should not have anyone in it.

Photo 1. Commercial structure from A-Side. [Photo by NIOSH]

Photo 2a. Commercial structure from D-Side. [Photo by NIOSH]

Photo 2b. D-Side, firefighter entry point. [Photo by NIOSH]

FF1 and FF2 exited the structure at 2318 to gain detailed directions to the stairs from the IC and building owner and to get a thermal imaging camera. FF1 and FF2 were given Nomex hoods at this time by other firefighter personnel who arrived on scene. The attack team donned the hoods and reentered the building at 2319. Three additional firefighters arrived and were assigned positions around the time of reentry. One firefighter (FF3) was initially assigned backup hose line and RIT but changed assignment after more firefighters arrived and made entry with FF1 and FF2 to assist with hose

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advancement. Two firefighters (FF4 and FF5) staged at the door with a back-up hose line and served as the RIT.

Upon reentry, FF1 and FF2 quickly found the stairs and made their way to the second floor. The stairwell had a closed door on the first floor that the attack crew had passed on the initial entry. The staircase was concrete and consisted of 16 stairs with a small landing at stair nine (Photo 3a, 3b). The crew made it to the landing with their hose line and encountered a large volume of fire on the second floor.

Photo 3a. Base of stairwell. [Photo by NIOSH]

Photo 3b. Base of stairwell and hallway. [Photo by NIOSH]

The crew worked the hose line together to knock down the fire when FF1 fell backwards down the stairs. FF1 had a catastrophic loss of air pressure at 2322, but a return of air pressure occurred at 2324. FF1's pre-alert for non-motion occurred at 2324 and was off 9 seconds later (still at 2324 hours). FF1's SCBA lost all pressure a second time at 2326. FF2 heard this commotion and initially thought that FF1 had dropped a hand tool, but when he looked to his side, he noticed that FF1 was not there. FF2 heard

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FF1 asking for help from the bottom of the stairs, and he made his way down to FF1. FF2 checked FF1 and found that he was no longer speaking and was not moving. FF2 believed that FF1 was facedown and had his SCBA face mask on at this point and called for help from FF3, telling him that FF1 was down.

FF3, who was on the interior of the building, on the first floor around a corner assisting with the hose advancement, heard FF2's call for help as "FF1 down" and called a Mayday over the radio for a firefighter down. The fireground channel is not recorded and the exact wording of the Mayday is not known, but several firefighters, including the IC, confirm hearing the Mayday, and noted that the message was clearly understood.

FF3 made his way to FF1 and FF2, still at the base of the stairs. FF4 and FF5 (the RIT crew) made entry and followed the hose line to the stairs. FF3, FF4, and FF5 found FF2 with FF1, who was face down and unresponsive on the floor near the stairs to the attic. One of the rescuers stated FF1 was exhibiting agonal breathing with his SCBA mask displaced. It is possible that the facepiece was disturbed when the FF fell down the stairs; additionally, facial hair that interferes with the seal could make a facepiece less secure. Through interviews, there appeared to be no attempt to correct the mask placement nor confirm airflow to it as recommended by NFPA *1407 Standard for Training Fire Service Rapid Intervention Crews* [NFPA, 2020] and NFPA 1404 Standard for Fire Service Respiratory Protection Training [2018]. He was removed from the building at 2330, and once outside, it was noted that his mask was off. FF4 reported grabbing FF1 by the left SCBA shoulder strap to drag him out of the building while keeping his other hand on the hose line for orientation due to smoke conditions. There is no recollection of hearing an SCBA alarm alerting. Once FF1 was removed and the fire attack resumed, the origin of the fire was found to be in one of the first-floor examination rooms. Crew estimated FF1 was removed from the building 5 minutes after being located. FF1's helmet and thermal imaging camera were found on the ground inside the building.

A schematic of the first floor of the building is shown in Figure 1.

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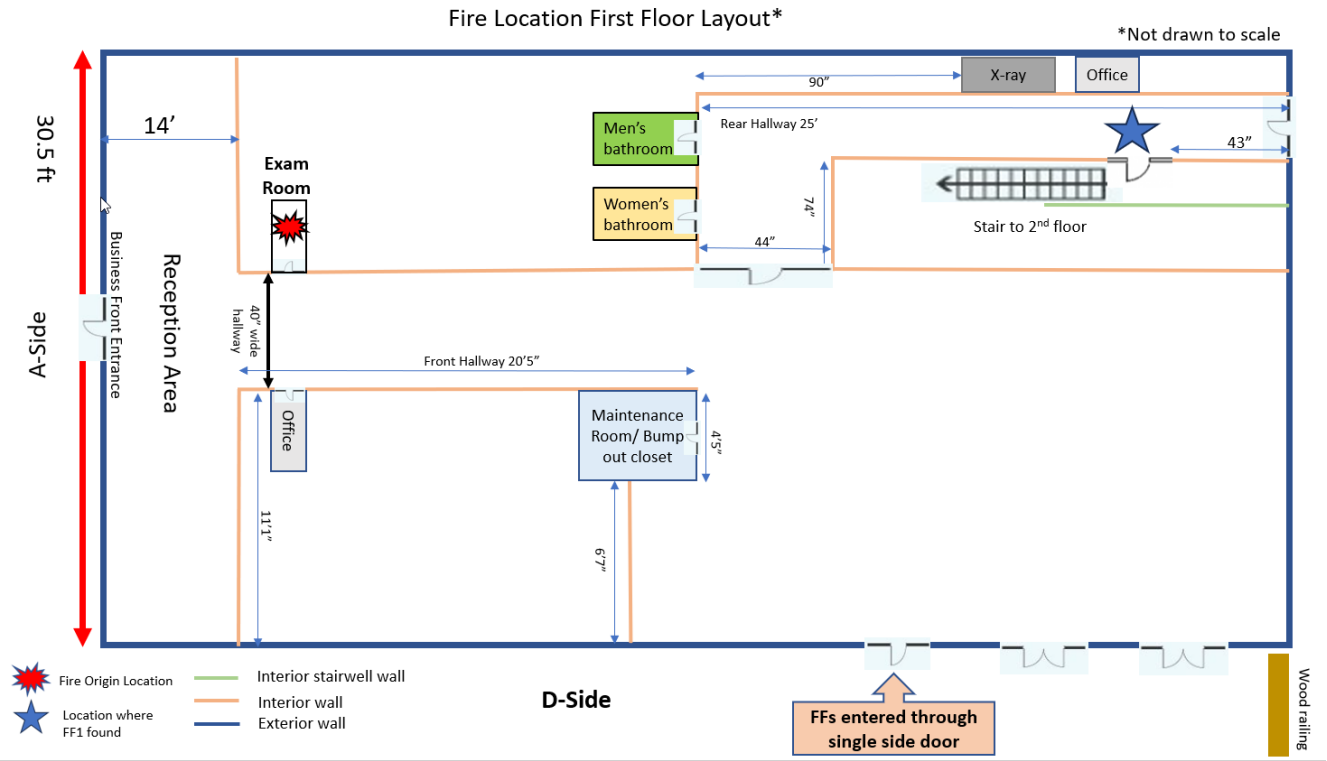

Figure 1. Layout of first floor of structure fire. The blue star indicates the location where FF1 was found.

EMS assumed care of FF1 at approximately 2335. FD staff noted that the ambulance was already present when they exited the building with FF1. EMS records indicate that FF1 was in cardiac arrest on their initial assessment while other firefighters present reported he was in respiratory arrest when found and went into cardiac arrest shortly after removal from the building. EMS noted immediate initiation of CPR. Soot was noted in his airway when he was intubated. The Paramedic also noted singeing of nose hairs and first-degree burns on the external nares. No other signs of external trauma noted. Initial pulse oximetry showed 80% saturation, which increased to 98% as he was ventilated with a bag valve mask prior to intubation. Intraosseous access was obtained during EMS ground transport to a rendezvous location with EMS air transport at 2349. EMS records note initial rhythm was asystole, which converted to ventricular fibrillation after one dose of epinephrine. FF1 received one shock, and the rhythm changed to pulseless electrical activity (PEA). A second dose of epinephrine was given, and a pulse was regained with an unspecified rhythm. When FF1 went into PEA again, CPR was resumed. A third dose of epinephrine was given resulting in return of spontaneous circulation. FF1 was placed on a

dopamine infusion. A single dose of methylprednisolone was administered before he was transferred to the flight crew.

On arrival to the emergency department (ED) at 2352, FF1 was still unresponsive. Endotracheal tube placement was confirmed by chest X-ray. Wheezes and rales were heard in all lung fields bilaterally. While in the ED, FF1 was administered a Cyanokit®, which is a cyanide antidote kit containing hydroxocobalamin. He was admitted to the Burn ICU at 0120 on June 21, 2022. His initial carboxyhemoglobin saturation was high at 11.4% (normal is < 2%) from a blood sample collected at 0203. A head CT performed due to his unresponsive state showed findings consistent with a severe anoxic brain injury. FF1 did not exhibit any brain stem reflexes and a brain perfusion scan done the following day showed no cerebral blood flow. He was pronounced dead at 1205 on June 22, 2022.

An autopsy was conducted by a pathologist located in Kansas City under the authority of the County Coroner's Office on June 24, 2022. The cause of death was determined to be "smoke inhalation with inhalation of hot gases and debris," with sulfhemoglobin and methemoglobin intoxication as contributory factors. It was also noted in the autopsy report that FF1 had a moustache and beard.

Discussion

In this incident, the apparent precipitating event was FF1's fall or possible collapse from the stairs. Although we can determine the sequence of events, the described event of the fall is an assumption based on the timeline data sources and the SCBA data log. FF1's fall and mask displacement or removal resulted in the thermal inhalational injury that contributed to his cardiac arrest. Disruption of blood flow carrying needed oxygen to the brain often results in irreversible brain damage called anoxic brain injury, which was FF1's cause of death. The following is a discussion regarding these relevant issues.

Timeline of Events

There were four sources of information used to establish a relatively accurate timeline of events: SCBA data log, dispatch information, police officer body worn camera footage, and time-stamped pictures taken at the scene by a local media photographer. FF1 had the only working SCBA data log, and all other pertinent SCBA data loggers had dead batteries. The following timeline was established:

Incident Timeline

Event	Time (date)
911 call and dispatch:	2253 (June 20, 2022)
Chief 1 arrival (estimated):	2258

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Event	Time (date)
Chief 2 arrival (estimated):	2259
FF1 arrival (estimated):	2300
EMS called:	2301
FF2 arrival (estimated):	2302
FF1 turns on SCBA:	2303
FF1 goes on air:	2306
FF1 forces entry:	2306–2308
FF1 and FF2 make entry:	2309
FF1 and FF2 exit building for better directions:	2318
FF1 and FF2 reenter the building:	2319
FF1's SCBA has a catastrophic loss of air pressure:	2322
FF1's SCBA has a return of air pressure:	2324
FF1 pre-alert for non-motion on:	2324
FF1 pre-alert for non-motion off:	2324 (9 seconds after turning on)
FF1's SCBA loses all pressure a second time, believed to be time of fall:	2326
FF1 pulled from building and all gear removed:- CPR initiated:	2330
EMS makes contact with FF1:	2335
EMS ground transport arrival to air crew location:	2349
FF1 arrival to ED:	2352
FF1 pronounced dead:	1205 (June 22, 2022)

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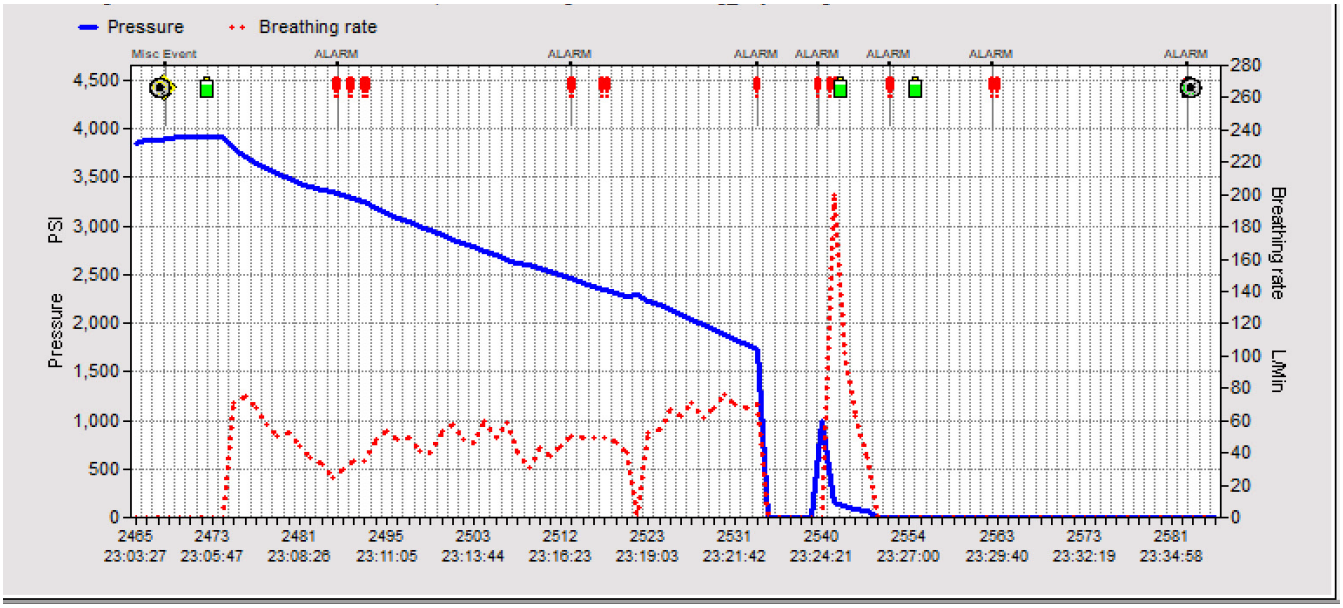

Figure 2. FF1's SCBA pressure and breathing rates.

SCBA Discussion

FF1 was assigned a Dräger AirPack SCBA. At the time of the incident (2322), there was a catastrophic loss of air from the SCBA (Figure 2). Air pressure to the SCBA returned at 2324 when a pre-alert sounded for non-motion for 9 seconds. The SCBA lost all pressure for a second time at 2326. When FF1 was located, it was noted the SCBA mask was displaced.

After the incident, the SCBA unit along with all other personal protective equipment (PPE) were secured by the local police department. Upon testing, the SCBA performed as designed and no fault was found with the unit. The unit was labeled with the last test date, which was over a year prior. NFPA *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services* recommends an established practice for annual inspection of SCBA [NFPA 1981, 2019].

Hot Gas Inhalation Injury

Firefighters utilize SCBAs during fire suppression activities to protect themselves from toxins created as products of combustion and to prevent thermal injuries to their airways from breathing in hot gases. Heat rises, and this is the basis for public safety messaging that when in a house fire to stay low beneath smoke and crawl to an exit to remain in cooler air to breathe while escaping [Commonwealth of Massachusetts, no date]. Air temperatures inside a fire can rise sharply with distance from the

ground. In a house fire, the air temperature at floor level may reach up to 100°F, increase to 600°F at eye level, and may exceed 1500°F at ceiling height [Firefighter Insider, no date].

Thermal injury to the upper airway can quickly result in swelling of those structures, leading to complete airway obstruction. Any evidence of burns to the upper airway such as soot in the mouth or nose, singeing of nasal hair, burns on the skin around the mouth and on the nose, etc., are indications for immediate intubation to maintain a patent airway. This swelling can be compounded by subsequent required fluid resuscitation in burn patients [Chao et al. 2019; Foncerrada et al. 2018]. The EMS crew that made initial contact with FF1 quickly noted the soot in his airway and burns on his nose. These would have prompted immediate intubation even if he had not already been in respiratory arrest.

Inhalation of Toxic Smoke Compounds

In addition to direct thermal injury to the airways, inhaling smoke produced by a live fire can expose individuals to other hazardous substances generated as products of combustion. Carbon dioxide, carbon monoxide (CO), and cyanide are the most common. CO may be formed by the combustion of any carbon-containing fuel such as gasoline, propane, etc. Cyanide products may be released by a variety of products such as polyurethane (foam upholstery stuffing), polyacrylonitrile (appliances and engineered plastics), polyamide nylon products (carpets and clothing), melamine resins (household and kitchen goods), etc. [Alarie 2002; Bizovi and Leikin 1995].

Both CO and cyanide are classified as chemical asphyxiants because they block oxygen distribution at a cellular level. Substances like carbon dioxide, a part of normal exhaled air, can also create a hazard when it is formed in excess during a fire. Simple asphyxiants are gases that can “crowd out” oxygen in the local environment when they are produced in excess or in a closed environment without adequate ventilation. This can result in a personal breathing zone dangerously deficient in oxygen content. Aside from carbon dioxide, other simple asphyxiant gases include methane, nitrogen, and helium [Prien and Traber 1988]. Removing or displacing a SCBA facepiece in an immediately dangerous to life or health (IDLH) environment could result in loss of consciousness due to lack of adequate oxygen in the immediate breathing zone and/or exposure to high levels of CO and/or hydrogen cyanide.

FF1 showed high levels of carboxyhemoglobin on arrival to the ED, which is consistent with being off his supplied air and breathing in smoke or fumes. There is no way to estimate how long of an exposure would result in a particular carboxyhemoglobin level because each fire produces its own unique mix of combustion products. Consequently, carboxyhemoglobin levels don’t always directly correlate with specific CO exposure amounts. Carboxyhemoglobin forms when CO is inhaled and binds to oxygen’s binding sites on hemoglobin, the molecule in red blood cells that carries oxygen to the tissues. Since CO has a binding affinity over 200 times greater than that of oxygen to hemoglobin, the body is

starved of oxygen, even when it is present, because there is no space for it on the hemoglobin molecule [Bennett and Mitchell 2022].

Medical providers are encouraged to consider cyanide toxicity in a patient with inhalation injury from an enclosed space fire with persistent hypoxia, hypotension, metabolic acidosis, and/or cardiac arrest despite appropriate resuscitation efforts. In these cases, empiric treatment with a cyanide antidote is recommended. Hydroxocobalamin was approved by the FDA in 2006 [FDA 2006]. This cyanide antidote is delivered in a single dose intravenously, has a rapid onset of action (first dose is infused over 15 minutes and may not need second dose depending on clinical response), and binds with cyanide to form cyanocobalamin, also known as vitamin B12, which is excreted by the kidneys. In 2023, the American Heart Association recommended hydroxocobalamin as the antidote of choice in suspected cyanide toxicity. It is available commercially as Cyanokit®. [Lavonas et al 2023; Anseeuw et al. 2013; O'Brien et al. 2011; Serb Pharmaceuticals 2024; Sheridan 2016].

Particulates found in soot can act as irritants and initiate a severe inflammatory response in the lungs. This is one reason why corticosteroids are administered to patients with evidence of smoke inhalation [Chao et al. 2019; Toon et al. 2010] and why it was given in the form of methylprednisolone to FF1 by the EMS crew. One study of 529 burn patients over a 4-year period showed that 73% of those with evidence of inhalation injury developed respiratory failure, and 20% developed acute respiratory distress syndrome (ARDS). ARDS has a poor prognosis and a 50% mortality rate. Once respiratory failure occurred, the mortality rate was 40% compared with 3% in patients who did not progress to respiratory failure [Hollingsed et al. 1993].

The significance of the presence of methemoglobin and sulfhemoglobin in the postmortem samples is unclear as the laboratory report states that both these compounds may be present in decomposed specimens and that both of these saturation levels "must be interpreted with extreme caution." The report also stated these tests were run on postmortem femoral blood samples collected on June 24, 2022, resulting in methemoglobin at 54% saturation and sulfhemoglobin at 14% saturation. FF1 was not given the cyanide antidote that would have formed methemoglobin, and his admission record did not record use of any medications that could produce it as a metabolite. There is some evidence in the literature that fire victims may have methemoglobin in their blood due to inhalation of nitrogen oxides that could be produced by burning plastics [Ferrari and Giannuzzi 2015].

Anoxic Brain Injury

Due to their high metabolic activity, the brain and heart are very sensitive to a lack of oxygen. Loss of consciousness can result if oxygenated blood flow to the brain is interrupted for just 20 seconds. It is unknown exactly how long FF1 was in respiratory and/or cardiac arrest prior to being removed from the building where CPR was immediately initiated. He was intubated shortly after by the waiting EMS

providers. Crew reports estimate that FF1 was down for about 5 minutes before he was found. This correlates with the timeline that showed 8 minutes elapsed between the catastrophic loss of air pressure evident from FF1's SCBA data and when FF1 was removed from the building Even that short amount of time is enough to result in severe brain injury due to the lack of oxygen, and this damage is permanent. Anoxic brain injury is one of the reasons survival rates of cardiac arrest occurring outside of a medical facility remain low, approximately 10% [Ramiro and Kumar 2015].

Removal of SCBA While Inside an Involved Structure

Training of firefighters, including volunteers, should include how to handle various SCBA emergencies/failure scenarios. One tenet is that the facepiece should never be removed while inside an involved structure, and that the regulator should be removed only in very select circumstances [Rogers FD 2008]. Training consistent with NFPA 1001 may help proficiency with techniques for handling SCBA failure during emergency operations [NFPA 2019]. It is possible that the facepiece was disturbed when the FF fell down the stairs; additionally, facial hair that interferes with the seal could make a facepiece less secure.

SCBA and Facial Hair

The autopsy report stated that FF1 had a moustache and beard. OSHA is specific regarding the importance of having and maintaining a good seal with any type of respirator so that the full protective measure of that equipment is received by the wearer. CFR 1910.134(g)(1)(i)(A) and (B) state that "the employer shall not permit respirators with tight fitting facepieces to be worn by employees who have facial hair that comes between the sealing surface of the facepiece and the face or that interferes with valve function or any condition that interferes with the face-to-facepiece seal or valve function" [OSHA 2019]. This FD's Standard Operating Guidelines (SOG) states that "the firefighter shall not don a SCBA when facial hair or any other known factors are present that could prevent the facepiece to form a proper seal around their face. The firefighter shall not don the SCBA or enter a potentially hazardous environment if the SCBA appears to be working improperly or the facepiece is not making a proper seal."

Some volunteers we spoke with stated that FF1's case was not an isolated event as they had or were aware of others who had worn the SCBA while having a full beard. This would impair any seal being created or maintained with any efficacy between the wearer and the facepiece. The FD should prohibit this practice. NFPA 1401 also recommends annual training for respirator protection including how to perform seal checks and "consequences of an improper fit or poor maintenance impacting the protection being provided" [NFPA 2018].

Recommendations

Recommendation #1: Reinforce SCBA training to include equipment familiarization and use in IDLH environments, such as structure fires. Ensure firefighters keep their mask on when operating in IDLH environments to reduce the risk of inhaling combustion products.

Discussion: Inhalation of CO can affect cognition and cause a firefighter to lose their ability to communicate and move efficiently. Survivability while inhaling combustion products and smoke toxins diminishes due to the lack of oxygen and high concentrations of CO in fire environments. Physiologically, CO binds to red blood cells and displaces oxygen from being properly transported throughout the body; these effects occur rapidly during physical activity such as firefighting [Basari and Bergman 2011].

In this incident, it is unclear how FF1's face mask was removed. FF2 reported that he believed the mask was on when FF1 was located, so FF1 may not have removed his own mask. However, in the event of an SCBA failure, training in accordance with *NFPA 1001 Standard for Fire Fighter Professional Qualifications* [NFPA 2019] can be beneficial for ensuring a firefighter can manage an SCBA failure and demonstrate proficiency in a standardized systems check. Training on SCBA failures may help the firefighter to resist the natural urge to remove an SCBA mask during actual emergency operations.

Recommendation #2: Firefighters wearing full face masks should groom facial hair as to not impede the seal formed by the mask. This requirement is outlined in OSHA 29 CFR 1910.134 and NFPA 1404 Standard for Fire Service Respiratory Protection Training. Fit testing should also occur, at minimum, once per year, following guidelines from OSHA and the NFPA 1500 Standard on Fire Department Occupational Safety, Health, and Wellness Program [NFPA 2021].

Discussion: Due to his facial hair, FF1 likely did not have the degree of protection from his face shield/SCBA that he could have had if there had been a good seal between his face and the shield. Although it is unknown if this partial seal played a role in the eventual loss of his face shield, it goes against FD policy as well as OSHA requirements to don a SCBA and face mask with facial hair that could interfere with the seal. The FD should ensure its volunteers wear their PPE properly and are fit tested annually following OSHA and NFPA guidelines for procedures and documentation.

Recommendation #3: Adopt and comply with a respiratory protection program that includes regular SCBA maintenance and recordkeeping.

Discussion: The fire department does not currently have a formal respiratory protection program. Implementing a respiratory protection program in accordance with NFPA standards, which specifically addresses training, care, maintenance, and use of respiratory protection equipment, would be prudent

and benefit all members. Guidance for a respiratory protection program can be found in the *NFPA 1500 Standard on Fire Department Occupational Safety, Health, and Wellness Program* [NFPA 2021].

In this incident, we found no documentation showing the firefighter had been fit tested or formally trained on this particular SCBA ensemble. In addition, this firefighter had the only working SCBA data log. All other pertinent SCBAs had dead batteries, so they had no data logs. The SCBA worn in this incident had not been flow tested in over a year. Although no malfunctions were found with the SCBA, a formal respiratory protection program would assist with scheduling of routine testing. It is recommended that annual flow testing and fit testing be implemented as part of the respiratory protection program. Training in different SCBA flow on/off mechanisms could also be beneficial as various manufacturers utilize differing knobs that could be unintentionally adjusted during emergency operations if the user is unfamiliar with the equipment. Consider training with mutual-aid partners or neighboring agencies to accomplish a robust training on SCBA types and models. Ensure all firefighters follow SCBA manufacturer recommendations to ensure operational effectiveness and optimal firefighter safety.

Recommendation #4: Encourage training of all firefighters on NFPA 1407 Standard for Training Fire Service Rapid Intervention Crews to promote safety and survival.

Discussion: Further education surrounding an initial response to a firefighter down in an IDLH environment is advised. Ensure a mask is on each interior firefighter and safe breathing air is provided via SCBA. Otherwise, immediate extrication is essential. *NFPA 1407 Standard for Training Fire Service Rapid Intervention Crews* provides basic training procedures for RIT operations to promote safety and survival.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program's Medical Team based in the Division of Field Studies and Engineering in Cincinnati, Ohio. This investigation was conducted and this report was coauthored by Judith Eisenberg, MD, MS; Rob Saunders; and Andrea Wilkinson, MS, ATC/LAT. Dr. Eisenberg is a board certified Emergency Medicine physician, Mr. Saunders is a former NIOSH Technical Information Specialist, and Ms. Wilkinson is a Health Scientist. Mr. Saunders retired after 31 years with the Pike Township Fire Department, Indianapolis, Indiana. In addition to having served as a firefighter, paramedic, heavy rescue technician, and rescue diver, he has held the positions of Company Officer, Division Chief of Emergency Medical Services, Deputy Chief of Operations, and Fire Chief. Ms. Wilkinson is a fire service researcher and exercise physiologist. She is also an honorary Lieutenant for the Hanover Park Fire Department in Illinois.

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