Working Alone and/or in Remote Locations

Opportunities to Prevent the Risk of Fatality From Cardiovascular Events in Oil and Gas Extraction Workers

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Objective: The aim of the study is to explore personal and work factors related to fatal cardiac events among oil and gas extraction (OGE) workers. **Methods:** The National Institute for Occupational Safety and Health Fatalities in Oil and Gas Extraction database was reviewed to identify fatal cardiac events among OGE workers from 2014 through 2019. A case series design was used to review case files, provide descriptive statistics, and summarize the findings. **Results:** There were 75 fatalities identified, including 55 (73%) with sufficient information for review. Of the 55 workers, 18 (33%) worked alone. Thirty-six fatal cardiac events (66%) were unwitnessed by a coworker. Toxicology findings suggested some possible exposures to hydrogen sulfide or hydrocarbon gases or vapors. Missing data were common. **Conclusions:** This study identified the need for cardiovascular disease prevention and treatment, emergency preparedness, lone worker programs, medical screening, and enhanced exposure control in the OGE industry.

Keywords: oil and gas industry, cardiovascular diseases, occupational health, emergency medical services, rural health services

Cardiovascular disease (CVD) is the leading cause of death among US adults.[1] Men are at increased risk and develop the condition 10 years earlier than women on average.[2,3] Cardiovascular disease includes conditions of the heart and vessels such as atherosclerosis, heart attacks, heart failure, heart rhythm disturbances, strokes, and peripheral arterial diseases.[3] Personal risk factors for these conditions can be divided into nonmodifiable and modifiable. The nonmodifiable risk factors include older age, male sex, and a family history of premature CVD death. The modifiable risk factors include diabetes, high blood pressure (hypertension), high blood cholesterol, tobacco use, obesity, and a sedentary lifestyle.[2,4] A recent study reported that oil and gas extraction (OGE) workers were more likely than nonmanual workers to drink alcohol excessively, smoke or use smokeless tobacco, and have obesity.[4,5] In a separate survey administered between 2017 and 2019, among 498 OGE workers,[6] the mean age was 36.9 years with nearly half of the respondents (48.4%) older than 34 years, the oldest reported was 70 years. The vast majority were men and more than one third (35.5%) used tobacco daily. High blood pressure (16.5%) and high cholesterol (11.6%) were the most common modifiable CVD risk factors. Obesity was not addressed in this survey. Obesity was not addressed in this survey (NIOSH (2017–2019). NIOSH Oil and Gas Worker Survey, Unpublished raw data).

LEARNING OUTCOMES

- After reading this article, readers should be able to describe at least two challenges workers who are alone or in remote areas may face when in need of medical care for a cardiac event or other health emergency.
- After reading this article, readers should be able to identify toxicology panels that can help assess for exposure to hydrocarbon gases and vapors or hydrogen sulfide.

In addition to the personal risk factors cited previously, CVD and sudden cardiac events have been associated with working conditions, including shift work,[7,8] physical work demands,[9] and occupational chemical exposures[10]—all of which are prevalent in the OGE industry. A multidisciplinary team investigated the sudden cardiac deaths of nine OGE workers from 2010 to 2015 concluding that the fatalities were caused when workers opened storage tank hatches that released hydrocarbon gases and vapors (HGVs). It was suspected that the sudden releases of HGVs displaced air and resulted in low-oxygen (O_2) environments.[10] Low-O_2 could have resulted in temporary asphyxia contributing to the fatality by decreasing the oxygen supply to the heart and precipitating cardiac arrhythmias.[10] At least one worker's death was initially attributed to cardiovascular disease, suggesting that HGV-related deaths have the potential to be misclassified as nonoccupational when toxicological data are not evaluated during the death investigation.[10]

Subsequent National Institute for Occupational Safety and Health (NIOSH) surveillance has identified other work activities, including the transfer of oil and gas process fluids, that have resulted in fatal exposures to HGVs.[11] Industrial hygiene data collected during fluid transfer activities have confirmed exposure to HGVs can occur at high levels including levels immediately dangerous to life or health.[12] Efforts to raise awareness of these hazards throughout the industry and related professions (e.g., death investigators) are ongoing and necessary.[12,13–15]

The NIOSH Fatalities in Oil and Gas Extraction (FOG) database includes detailed information about worker fatalities in the US OGE industry.[14] Six of the nine deaths mentioned previously were

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identified through FOG. The FOG includes information on workers who experience a fatal cardiac event that began at work or was believed to be triggered by work activities. Precipitating work activities may include chemical exposures, vigorous activity, or excessively hot conditions. Analysis of the case series presented hereinafter characterizes the cardiac deaths identified through the FOG database and highlights the challenges of preventing cardiac deaths among OGE workers while providing suggestions for prevention. This article summarizes an exploratory analysis of fatal cardiac events identified through FOG between 2014 and 2019 to help inform health and safety practices in OGE so that similar fatalities can be prevented.

METHODS

This study used a case series design to analyze data from the NIOSH FOG database, including data abstracted from formal investigation reports produced by governmental agencies including the Occupational Safety and Health Administration (OSHA) and the Bureau of Safety and Environmental Enforcement.[16] Reports included inspectors' hand-written notes, medical examiner or coroner reports, toxicological findings, and other related documents. Because formal governmental investigations were not completed for all fatalities in FOG, the NIOSH supplemented the database using public records including media reports, press releases, obituaries, or death certificates.[15] Data were abstracted from these diverse data sources and data formats by researchers with knowledge of the OGE industry using a systematic data collection and quality review process. Each decedent's case file was reviewed by at least two reviewers. The FOG database includes workers from the OGE industry for both land and offshore-based locations, classified using the North American Industry Classification System (NAICS).[17] Most workers were employed by companies supporting exploration and preparation of crude oil and natural gas wells (NAICS 211—operators, 213,111—drilling, 213,112—servicing), although some were employed by companies providing other ancillary services, such as transportation. Additional details about FOG are described elsewhere.[14]

Fatalities in oil and gas extraction were included as cardiac events if the death was coded as a cardiac event or otherwise met either of the following two FOG case definitions[14]:

> *Cardiac Event (Possible Work Exposure): Workers whose cause of death or diagnosis was determined to be a heart attack, heart arrhythmia, sudden cardiac death, or other heart-related episodes where symptoms of the cardiac event began at work, and a specific workplace event, exposure, or practice is suspected to have contributed to the worker's death.*
>
> *Cardiac Event (No Known Work Exposure): Workers whose cause of death or diagnosis was determined to be froma heart attack, heart arrhythmia, sudden cardiac death, or other heart-related episodes where symptoms of the cardiac event began at work and are not attributable to a specific workplace event, exposure, or practice.*

Three variables derived from the underlying case file data were used to describe cardiac events. A cardiac event was classified as having a delayed response if there was evidence in the case file an individual who was experiencing symptoms (e.g., chest pain) remained at work after the onset of these symptoms or if there was a clearly stated delay in bystander or medical response to the cardiac event. Unlike other variables in FOG, delayed response was derived from primary documents specifically for this study. Some case files lacked the details necessary to evaluate response delays. A cardiac event in which another worker was present on the job site but did not observe the event was defined by FOG as unwitnessed. This is an important distinction because this results in a delayed response even while working in the presence of others. Lastly, a lone worker was an individual who was working without any other worker or person present at the worksite or in the vehicle. All three derived variables have the ability to impact medical response time, an important determinant of cardiac event survival,[18] although different actions may be required to address delayed response, whether an event is witnessed, or whether the worker is alone.

Descriptive statistics were used to summarize all cardiac events identified through the FOG database, which spanned 2014–2019. Decedent characteristics were summarized according to the workers' demographics, industry (NAICS), documentation of potential occupational exposures, as well as geographic location. Preexisting cardiac risk factors and cardiac disease were identified in the case files using information provided by individuals familiar with the decedents (e.g., coworkers, supervisors, primary care physicians, family members, etc.) or contained in autopsy reports. Risk factors identified through autopsy reports included evidence of prior heart disease, hypertension, hyperlipidemia, diabetes, overweight or obesity, older age, stroke history, and tobacco use.

In addition to these summary statistics, selected worker deaths were described using brief narratives to present the types of free-text data that were abstracted from FOG case files, including qualitative data on hazards not typically documented in structured fields, such as whether the cardiac event was witnessed by a coworker and whether the worker was alone at the time of death. All available narrative descriptions were reviewed for FOG fatal cardiac events meeting the case definitions hereinabove. A convenience sample of five case files were chosen for the article. These cases are typical descriptions of FOG cardiac case files. They are included in the article to illustrate the value and limitations of FOG data sources.

RESULTS

Between 2014–2019 FOG captured data on 526 OGE worker fatalities, including 75 cardiac event fatalities (14% of total; Table 1). Of the 75 cases, 39 (52%) were reported to OSHA, documented with an OSHA Preliminary Report, and not fully investigated. Of the 39 cases that were not investigated, none reported the decedent's sex, 1 had documentation of the decedent's age, and many narratives lacked details on the circumstances of the death (e.g., "Employee passed away due to natural causes"). Results summarized hereinafter, however, do include data extracted from OSHA Preliminary Reports' incident narrative if deemed pertinent for FOG. Incident narratives included information related to preexisting health conditions (e.g., "worker had a bypass 2 months prior"), as well as working conditions and environmental characteristics (e.g., "worker was at an tank gauging at an oil collection site which consisted of an earthen dike around six tanks positioned from North to South").

The population consisted of 35 men and 1 woman and 39 cases with unknown sex. Individuals ranged in ages from 20 to 68 years with the mean age of 51 ± 12.8 years. Of the 75 cases, 39 were missing age data (the same cases were missing sex and age). Texas had the most cardiac deaths of any state (n = 38, 51%). The basins with the most deaths were the Permian and Western Gulf (n = 18, 24%; n = 18, 24%, respectively). Among all cardiac fatality case files, 55 (73%) contained enough information to determine whether the worker was alone, the event was unwitnessed, or the medical response was delayed. Of the 55 decedents, 20 (36%) were alone at the time of death, 31 (56%) experienced unwitnessed cardiac events, and 16 (29%) experienced events observed by coworkers. Of the 16 cardiac events observed by coworkers, 6 (38%) had documented delayed response (8 were unable to be determined). The 2 remaining cardiac events that were observed and considered to not have a delay in care had documentation of immediate bystander cardiopulmonary resuscitation (CPR) response by a coworker and immediate contact with emergency services. It is uncertain how long the response time was for the medical team to arrive.

Of the 75 case files, 18 (24%) noted the possibility of exposure to chemical hazards such as volatile organic compounds or hydrogen

TABLE 1. Characteristics[a] of Fatal Cardiac Events Among Oil and Gas Workers, NIOSH FOG Database; 2014–2019 ($N = 75$)

Variable	No. Cases Unless Otherwise Specified	% of Total
Age		
Known	36	48
Mean age in years	51	
Median age in years	54	
Age range in years	20–68	
Unknown	39	52
Sex		
Female	1	1
Male	35	47
Unknown	39	52
Company type by NAICS[b] code		
211—Operator	4	5
213,111—Drilling operations	16	21
213,112—Well servicing	52	69
4842—Specialized freight	1	1
Unknown	2	3
Unwitnessed cardiac event		
Yes	31	41
No	16	21
Delayed response	6	8
Response not delayed	2	3
Unknown	8	11
Unknown	28	37
Working alone at time of cardiac event		
Yes	20	27
No	27	36
Unknown	28	37
Risk factors for a cardiac event[c]		
Yes	30	40
No	0	0
Unknown	45	60
Possible occupational chemical exposure		
Yes	18	24
Unknown	57	76
Autopsy		
Autopsy conducted	34	45
Autopsy not conducted	5	7
Unknown	36	48
Oil and gas basin[d]		
Permian	18	24
Western Gulf	18	24
Other	39	52
State[d]		
Texas	38	51
Other	37	49

[a]"Unknown" indicates that there was insufficient information in the FOG case files to measure a given characteristic. The FOG case files included formal government inspection reports containing inspectors' handwritten notes, medical examiner or coroner reports, toxicological findings, and other related documents. Because formal governmental investigations were not completed for all fatalities in FOG, the NIOSH supplemented the database using public records including media reports, press releases, obituaries, or death certificates. 15

[b]NAICS: North American Industry Classification System.17

[c]Evidence of cardiac event risk factors included autopsy findings or bystander-reported evidence of prior heart disease, hypertension, hyperlipidemia, diabetes, overweight or obesity, older age, stroke history, or tobacco use.

[d]The FOG database includes cases from 14 geologic regions where OGE occurs (Anadarko, Appalachian, Ardmore, Arkoma, Cherkoee Platform, Denver-Julesberg, Fort Worth, Permain, Powder River, San Joaquin, TX-LA-MS Salt, Uinta-Piceance, Western Gulf, Williston). All basins other than the Permian and Western Gulf basins, and all states other than Texas, had fewer than 9 fatal cardiac events identified through FOG.

sulfide (H_2S), although direct exposure measurements were unavailable. In addition, 34 of the 75 files included documentation that an autopsy was performed (45%), 5 that an autopsy was not performed (7%), and 36 had no documentation of an autopsy being conducted (48%). One case file indicated that the autopsy was not performed because the coroner's office only had capacity for certain types of autopsies (i.e., infants and homicides). In addition, 22 of the 75 case files (29%) had documentation that toxicology tests were performed, including 1 case file without an autopsy and 1 case file where only an external examination was performed. The type and frequency of toxicology tests performed are summarized in Table 2. Toxicology tests were often reported without specific test numbers (e.g., NMS Labs). Of the 9 documented thiosulfate tests, 5 were positive (56%). Of the 3 hydrocarbon and oxygenated volatiles tests, 2 were positive (67%). After reviewing the FOG case files, 30 decedents (40%) had evidence of cardiovascular risk factors, 11 of which had documentation that the individual would have been aware of these (known medical history whether treated or not). The remaining 60% of case files did not have enough documentation to determine if cardiovascular risks were present.

CASE NARRATIVES

Case File 1: Lone Worker

Summary

This was a female truck driver in her mid-50s at an oil wellsite. She was found unresponsive in the cab of the company truck with the engine running, which had drifted off the side of the road and was found parked. This was the only information noted in the OSHA investigation report.

Risk Factors

This individual was a lone worker with no evidence of chemical exposure and negative toxicology report. The autopsy was available, and the medical examiner noted heart disease, thickened and prolapsed mitral valve, vascular disease, cardiomyopathy, and emphysema of the lungs. The cause of death was reported by the medical examiner as valvular heart disease and dilated cardiomyopathy.

Evidence of lone work was documented in the OSHA case file. There was no evidence of an autopsy being performed.

Case File 2: Lone Worker

Summary

This was a male pumper in his mid-60s who was found by a passerby in a field near a highway. The worker was noted to be gasping for air at the time. Emergency services were contacted, but he died before they were able to arrive on-scene. The location where the pumper was found was about one mile from his vehicle that was parked on a lease road near an oil wellsite. It is suspected that the pumper walked toward the road from his vehicle seeking help.

Risk Factors

This individual was a lone worker with a history of heart disease and heart attacks who had possible H_2S exposure. Toxicology was positive for thiosulfate (1.8 μg/mL), although this was reported as noncontributory towards the cause of death. Autopsy report by the medical examiner was available and noted cardiomegaly, 40% stenosis of right coronary artery, multiple remote infarcts (heart attacks), thrombosis to the left anterior descending coronary artery, and chronic obstructive pulmonary disease. The cause of death was reported as coronary artery disease with thrombosis of the left anterior descending coronary artery.

Evidence of lone work was documented in the OSHA case file and media reports. The autopsy report was included in the OSHA case file, including toxicology results for thiosulfate (NMS number not provided). There was no evidence of toxicology testing for HGVs.

TABLE 2. Frequency of Postmortem Toxicology Tests Among 22 Oil and Gas Worker Fatalities Attributed to Cardiovascular Disease by Coroners, Forensic Pathologists, and Medical Examiners, NIOSH FOG Database, 2014–2019

Compounds	NMS[a] Numbers (Where Available)	No. Cases Tested (%)	No. Positive Results (% of Tests)
Drugs[b]	8051B 8052B 8092B	20 (91)	1 (5)
Alcohol	NA	10 (45)	0 (0)
Thiosulfate	7757SA 4472SP	9 (41)	5 (56)
Carbon monoxide	1002B	8 (36)	0 (0)
Hydrocarbons and oxygenated volatiles	NA	3 (14)	2 (67)
Electrolytes and glucose	1919FL	3 (14)	1 (33)

[a]NMS Labs, formerly National Medical Services Labs, is a company that provides analytic toxicology testing services and catalogs toxicology tests using internally developed codes. The NMS numbers were not always included in autopsy reports even when tests were conducted and/or results were documented. The NMS numbers are listed if they were documented in at least one case file. This column, therefore, includes all unique NMS numbers appearing in FOG cardiac event case files.

[b]Descriptions of postmortem toxicology tests were variable and largely unstructured. Some autopsy reports only indicated testing for "drugs" without further specification. The NMS numbers 8051B, 8052B, and 8092B correspond to basic, expanded, and expert postmortem forensic panels that test for 17, 211, and 258 analytes, respectively. The panels include tests for illicit drugs, prescription drugs, alcohol, controlled substances, and over-the-counter drugs.

Case File 3: Delayed Response

Summary

This was a male in his late-50s who was supervising a crew that was pulling tubing out of an oil well. When the crew took a break, the decedent reported not feeling well so he went into his air-conditioned truck cab. He placed his oxygen mask on due to his oxygen-dependent chronic obstructive pulmonary disease, and when a coworker came to check on the individual "a few minutes" after the break had started at 9:10 AM, he was noticeably short of breath and could not speak. The supervisor became unresponsive, so CPR was initiated. Emergency medical services (EMS) were contacted and arrived at 9:35 AM. He was transported to the hospital where he was pronounced dead.

Risk Factors

This individual was a worker with an observed cardiac event. He had a known history of oxygen-dependent chronic obstructive pulmonary disease, heart disease, history of two heart attacks, pacemaker, significant tobacco use, and high cholesterol. The medical examiner noted that the death was consistent with a history of heart disease and heart attacks with 95% occlusion of the left anterior descending coronary artery and that the cause of death was arteriosclerotic cardiovascular disease.

Evidence of delayed care was documented in the OSHA case file as the reported EMS arrival time relative to estimated time of CPR initiation (approximately 25 minutes). The autopsy report was included in the OSHA case file, including toxicology test results. The toxicology report included NMS panel 8052B (Postmortem Toxicology – Expanded, Blood [Forensic]). There were no tests reported for HGVs or H_2S.

Case File 4: Lone Worker

Summary

This was a male truck driver in his mid-40s who was pumping water brine using a self-contained apparatus alone at a site. He had completed the task and secured the hoses to his tanker. He was later found unresponsive on the well pad next to his truck. This was his first nightshift working alone for the company.

Risk Factors

This individual was a lone worker who OSHA reported as a possible exposure to hydrocarbons but was not wearing his H_2S gas monitor as required. The supervisor and trainer were unable to interpret or use a multi gas monitor when asked. Toxicology completed by the medical examiner was negative for thiosulfate, and the cause of death was arteriosclerotic heart disease.

Evidence of lone work was documented in the OSHA case file. The autopsy report was included in the OSHA case file, including toxicology results for NMS panel 4472SP (Thiosulfate, Serum/Plasma). There was no evidence of testing for HGVs.

Case File 5: Delayed Response

Summary

This was a male workover rig operator in his late-40s who began feeling light-headed and nauseated while controlling the rig at a wellsite. He requested being relieved of his duties. He then became confused. Coworkers suspected a heart attack so they transported him to the nearest hospital located approximately 34 miles and 44 minutes from the worksite. While enroute, he stated that he felt hot, began convulsing, then became unconscious. He arrived at the hospital in cardiac arrest and was pronounced dead an hour later.

Risk Factors

This individual experienced an observed cardiac event with no known workplace exposure. He began feeling ill and was not immediately transported from the worksite. His medical history is unknown. This was a remote location, and the worker was transported in a personally owned vehicle by coworkers to the nearest medical facility. The medical examiner indicated that the cause of death was hypertensive cardiac disease and atherosclerotic cardiac disease although autopsy report was not made available.

Evidence of delayed care was documented in the OSHA case file—well site latitude and longitude were used to determine the geographic distance and approximate travel time from the workplace to the hospital where the employee was pronounced dead. There was no evidence of an autopsy being performed.

DISCUSSION

This study highlights the complexity of cardiac deaths among OGE workers, including potential interactions between workers' preexisting conditions, occupational exposures, demographics, work arrangements (i.e., working alone or in remote areas), and access to emergency medical services. In the five worker deaths described qualitatively, workers were all noted to have personal risk factors that contributed substantially to the event, including risk factors acknowledged by fellow crew members. As expected by the increased CVD risk associated with age, most decedents with age data available were older than 50 years. The US workforce has had a steady increase in workers older than 54 years, a trend that is expected to continue.[19] As some OGE workers nearing traditional retirement age continue working into their 60s, a greater proportion of the OGE workforce will be at elevated CVD risk based on age alone. It is also worth noting the cardiac events among workers younger than 30 years (Table 2). Although rare and typically related to congenital heart conditions,[20] these deaths are a good reminder that anyone can be impacted by a health emergency. As with workers 30 years or older, younger workers may experience sudden cardiac events related to chemical exposures (occupational or drug use),[10,21] heat stress (Lin et al. FOG Database. Unpublished data, 2022), or coronary artery disease.[20] As chronic conditions affect a

growing number of adolescents (e.g., diabetes, fatty liver, high blood pressure, obesity), these concerns are expected to impact a greater proportion of the workforce.[22]

A mortality study from New Mexico's OGE industry reported on cardiac deaths attributed to work between 2008 and 2018. Faturos et al[23] reported that 22% of all deaths identified among OGE workers were cardiovascular in nature, second only to motor vehicle crashes. As with deaths identified through FOG, New Mexico decedents had a mean age in their 50s (54.56 [95% CI, 49.66–59.47]). The authors of that study did not report toxicology findings or analyses related to HGVs or other occupational exposures.

Another key finding from FOG was the frequency of lone workers. Many of the individuals were had no other worker or present at the worksite or in the vehicle at the time of the incident. This prevented the individual from receiving immediate medical attention that would have otherwise been expected in a traditional, populated work environment. Lone work, along with the distance required to obtain definitive care, prevented all but a few of the decedents from obtaining medical attention in a timely manner. Attempts at bystander CPR and emergency response from those individuals who were first on-scene were encouraging and indicate that OGE workers are often willing to act without warning to save a fellow worker.

Of the 75 case files, 41 (55%) lacked an autopsy report either because an autopsy was not performed or because the report was unavailable to the NIOSH. Decisions not to conduct autopsies may have been multifactorial in nature. Death investigators may have lacked sufficient funds to pay for relevant toxicology tests or an understanding of the occupational exposures in OGE that could contribute to a fatal cardiac event. Some death investigators were limited to conducting autopsies for certain types of deaths (e.g., infant deaths) that did not include occupational fatalities. There may have been shortages of trained death investigators in areas where OGE worker deaths occurred. Finally, autopsy reports may have been unavailable to NIOSH investigators when data sharing was a barrier (e.g., legal agreements permitting OSHA to share complete case files had not been executed) or when the autopsy occurred after a case had been deemed not work related. Of the 75 case files, 53 (71%) lacked data on toxicology testing. Documented toxicology tests were most commonly administered for forensic purposes, such as detecting the presence of impairing substances (Table 2). OSHA has previously recommended[24] two toxicology panels be performed to help inform deaths' work relatedness:

- NMS 2413B—Inhalants panel for solvents and gases, BTEX, MEK, isobutane, methane, propane, pentane, N-hexane, and N-butane
- NMS 4472SP—Hydrogen sulfide exposure biouptake marker, which includes thiosulfate.

There may be reasons why a toxicology test was not performed. There may have been limited laboratory services in rural areas where autopsies were performed. An H_2S toxicology test may have been waived, for example, if a personal multigas meter or H_2S monitor had not registered H_2S. The calibration status (or history) of a monitor may be unknown to the OSHA investigator or company representatives. Without the appropriate toxicology tests, it is difficult to know how often H_2S or hydrocarbons are contributing to OGE worker deaths.

More than half of cardiac events identified through FOG (52%) were not investigated by OSHA. According to 29 CFR 1904.39(b)(5), employers are required to report work-related fatality or in-patient hospitalization caused by a heart attack.[25] The OSHA Area Offices then determine whether to investigate the events, based on individual cases' circumstances.[25] Toxicological tests for HGVs and H_2S administered to OGE workers who experience a cardiac event may assist OSHA in deciding and documenting why particular OGE cardiac fatalities are or are not investigated, given limited resources.

Occupational medicine providers use fitness for duty examinations to develop detailed knowledge of patients' working conditions and health risks, both of which are required to assess whether an individual is fit to perform his or her tasks without risk to self or others.[18] When evaluating for workers for safety-sensitive positions, occupational medicine providers serve a dual role—that of a healthcare provider serving individual patient needs and that of a public health official weighing potential harms to other workers and the general public. This tension is particularly acute when assessing workers in safety-sensitive occupations, such as professional drivers or firefighters,[26,27] for whom a sudden cardiac event may risk multiple lives. Fitness for duty examinations[26–28] often include cardiovascular risk assessment,[27] which may involve a medical history, pulse and blood pressure measurement, blood tests to screen for diabetes and high blood cholesterol, and baseline electrocardiograms. Fitness for duty examinations are not, however, routine for onshore OGE workers and industry-specific medical guidance is lacking.[29]

Limitations

The FOG database compiled and codified secondary data sources for OGE fatality surveillance. This report is limited to worker fatalities, and the cases did not contain detailed information on the time of symptom onset. Therefore, it is not clear for any given fatality whether CPR, EMS, or automated external defibrillator (AED) access would have prevented the death from occurring. Limitations of the fatality investigation reports, media reports, obituaries, and death certificates prevented reviewers from capturing all OGE fatalities during this period, and from capturing complete data for each case file. The fatalities identified through FOG may, therefore, not be a representative sample of all OGE fatalities during the same period. It was noted in a few of the initial OSHA reports beginning in 2019 that the events were labeled "not work related" without further considerations or details regarding the incident. For example, among several decedents the cause of death was listed as cardiovascular in nature or due to natural causes even when hydrocarbon and oxygenated volatiles or thiosulfate were later detected through toxicology. More often, case files lacked scientific evidence either implicating or excluding occupational chemical exposures as a cause of death. The data in this article and the original publication on HGV deaths[10] suggest that deaths from occupational exposures can be misclassified by death investigators and so their burden may be underestimated. Free-text descriptions in OSHA case files and media reports made it possible for NIOSH researchers to identify workers exposed to underrecognized hazards (e.g., working alone). Lack of standardized data collection also required several, relatively time-intensive approaches to identify potential exposures, such as relying on latitude and longitude or a close reading of free text to recognize delayed care. There are, therefore, inherent data quality limitations to using FOG's data sources. Some of these limitations might be addressable with informatics solutions, such as natural language processing.

In addition, in 2018, the OSHA began providing NIOSH reports of fatalities that OSHA had deemed not work related, which increased the number of FOG case files each year and included case files containing significantly less information than fatalities that were investigated by the agency. Adding these cases to the case series provided better understanding of the number of fatal cardiac events among OGE workers but added relatively little detail to examine the potential contributors to mortality risk, including whether an autopsy was conducted or any toxicology tests were administered. These cases from 2018 explain much of the missing data reported in Table 1. Lastly, to be included in this report, the presentation of the event had to be a workplace incident as defined by the OSHA and the employer or coworkers who reported the event. This is likely a limitation because some cardiac deaths may have occurred after individuals were no longer on duty, as has been reported among firefighters.[30,31] Noting these concerns identifies opportunities for process improvement during the monitoring and information gathering stages of workplace fatalities. This would include training the NIOSH and OSHA employees who are involved in these investigations on a standard protocol that would be practical and suitable for both organizations.

Implications for OSH Professionals

This study did not evaluate the effectiveness of any interventions; however, the cases identified through FOG raise implications for occupational medicine providers and other OSH professionals. Many of the implications described hereinafter could apply to many other industries and workplaces. There are various abatements and controls worth considering when seeking to mitigate the risks of fatality from a cardiac event encountered by OGE workers.

Individual Risks

This study revealed that OGE workers with chronic health conditions can work alone or in remote locations. Oil and gas companies could consider implementing medical fitness for duty evaluations for the OGE workers. Periodic medical evaluations, accounting for workers' age, may also be warranted after the initial evaluation. In the absence of established medical guidelines for onshore OGE workers, occupational medicine providers and, if applicable, their employers or practices, have the opportunity to design medical evaluations that identify and address potentially hazardous working conditions in OGE, including working alone or in remote locations, as well as exposures to other chemical and physical hazards. Guidelines established for drivers subject to US Department of Transportation regulations or offshore oil workers in the United Kingdom and Canada could offer useful benchmarks (Lin et al. FOG Database. Unpublished data, 2022).[20,21] Medical evaluations may have limitations. Access to trained healthcare providers able to perform medical evaluations or provide chronic disease care is challenging in rural areas, where OGE often occurs. A 2018 US study reported construction and extraction workers were less likely to have health insurance than workers in almost every other occupation.[32] Twenty-nine percent of construction and extraction workers were not insured, likely limiting those workers' adherence to evidence-based chronic disease management practices (e.g., blood pressure medication). Medical guidelines may also limit employment opportunities for individuals with chronic health conditions or disabilities. Even so, medical evaluations would offer the opportunity for the worker to learn about his or her risks, be appropriately assessed, and give the supervisor enough information to ensure the safety of the individual or crew being sent out to a remote site.

Access to evidence-based wellness programs and services could help workers identify and manage underlying health risks. These programs and services may include smoking cessation, weight management, diet and lifestyle choices, exercise, and activity modification, and understanding the signs and symptoms of cardiovascular disease. The Total Worker Health® program at NIOSH and The Community Guide® provide guidance for employers who are interested in implementing evidence-based health programs.[22–25] These programs should be tailored to the needs and demographics of the worker population being addressed.

Exposure Monitoring and Control

This study found evidence of workers' exposure to H_2S and HGVs. Occupational exposure to HGVs, H_2S, low-oxygen environments, and other hazards persist in OGE. It is imperative that OGE companies monitor and control recognized hazards throughout the exploration and production lifecycles. Hazard elimination, substitution, engineering controls, administrative processes, training, and innovative strategies to raise awareness all play important roles in reducing the likelihood of occupational fatality, especially when workers are in remote locations or alone.[33]

Lone Work

This study identified workers who were alone at the times of their death. In its guidance for managing occupational exposure to heat and hot environments the NIOSH recommends the following: "Implementing a buddy system in which workers are responsible for observing fellow workers for early signs and symptoms of heat intolerance, such as weakness, unsteady gait, irritability, disorientation, changes in skin color, or general malaise."[34] While recommended for a different health outcome, a buddy system may be worth considering for the prevention of fatal cardiac events.

In the survey mentioned previously,[6] 97% of the surveyed OGE workers acknowledged having a safety program or policies, and 25% reported a "lone worker program" through their employer. Lone worker programs may include various approaches to reduce risks of working alone. Programs may provide explicit guidelines when workers are required to work in pairs or crews, have prespecified communications protocols (e.g., periodic check-ins), and reduce delays in reaching definitive medical care. Lone worker technologies that workers carry on their persons can be integrated into lone worker programs to enhance communication and hazard awareness among workers, supervisors, and health and safety professionals. Available technologies include a wide range of functionalities, including GPS monitoring, satellite communication, gas monitoring (e.g., O_2), alerts when a worker is motionless, fall detection, and automated check-ins.

Remote Work

Offshore oil and gas operations provide medical evacuation support to workers in distress via helicopter or boat. Efforts to improve access to EMS for onshore OGE sites are needed. Engaging local communities and local EMS is a critical first step. Oil and gas extraction companies may consider providing EMS agencies with detailed location of the oil and gas worksite, information about potential hazards EMS professionals may face, along with other pertinent information. When there are multiple jurisdictions between the worksite and the nearest medical facility, OGE companies may need to engage multiple EMS providers and/or local governments to develop an appropriate response plan. Evaluating and engaging the local medical services would aid in the response time of medical services. Emergency communication systems such as lone worker technology or blue light emergency phones at the worksites could also enhance communication with EMS.

When possible, it would be beneficial to provide an AED at a worksite or in a work truck. The use of bystander AED application has been shown to significantly improve both survivability and functionality after cardiac arrest.[18] Oil and gas extraction companies considering this abatement will need to develop AED maintenance plans accounting for remote sites as well as the fact that AEDs may require climate-controlled environments (e.g., truck cabs may not suffice). Workers would also require training on basic emergency response and AED use. Knowledge in these areas could allow a worker to prepare and respond to a cardiac event on-site. Importantly, AEDs require a bystander to be present and, therefore, are not likely to increase cardiac event survival among lone workers. Given OGE workers' observed willingness to provide life-saving measures in the field, equipping them with AEDs, AED training, and other training in first aid and CPR would give workers tools and skills to increase cardiac survival in remote work areas.

CONCLUSIONS

This study highlights underappreciated hazards that OGE workers face. When an OGE worker experiences a workplace medical incident from a work-related or a personal health event, they may have the additional obstacles of being alone or isolated from definitive medical care.

Because of the unique nature of the OGE environment, it is prudent to address the risk of cardiac death from all causes on the worksite. Workplace policies and programs that increase access to evidence-based cardiovascular health interventions are needed for OGE workers who work alone or in remote areas. Oil and gas extraction employers are responsible for monitoring and controlling workers' exposure to chemicals—including HGVs and H_2S—that have caused worker deaths during tank gauging, fluid transfer, and disposal. Occupational

health providers should be aware that OGE workers lack guidance for medical evaluations. Examples exist for offshore workers in other countries and for US workers in other industries. Oil and gas extraction–specific medical guidelines could help ensure OGE workers are appropriately assessed and educated. Efforts should be made to increase the availability of AEDs in remote locations where oil and gas development occurs, including education and training on proper AED use and maintenance. Because of the risk of fatality in emergent situations such as sudden cardiac deaths, OGE companies should reduce the frequency of lone work as much as possible. Bystanders are necessary to use AEDs and take other life-saving measures. When workers are required to be alone, their health and safety should be supported with dedicated administrative procedures and technology.

Finally, the quality of data for OGE fatality surveillance could be improved. Given the high proportion of US deaths from cardiovascular disease and the limited resources for death investigation, it is understandable that fatal cases must be triaged for full autopsy. Administering relevant toxicological panels immediately after an OGE worker death, even when an autopsy is not performed, would be a relatively low-cost option to improve understanding of deaths from exposure to HGVs or H_2S in the OGE industry.

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REFERENCES

1. Murphy S, Kochanek K, Xu J, Arias E. *Mortality in the United States, 2020.* NCHS Data Brief; 2021.
2. CDC. Heart disease facts. https://www.cdc.gov/heartdisease/facts.htm. Accessed June 21, 2022.
3. Curry SJ, Krist AH, Owens DK, et al. Risk assessment for cardiovascular disease with nontraditional risk factors: US Preventive Services Task Force recommendation statement. *JAMA* 2018;320:272–280.
4. American College of Cardiology. ASCVD risk estimator plus [web-based calculator]. Last Updated October 2021. Available at: https://tools.acc.org/ascvd-risk-estimator-plus/. Accessed June 21, 2022.
5. Yeoman K, Sussell A, Retzer K, Poplin G. Health risk factors among miners, oil and gas extraction workers, other manual labor workers, and nonmanual labor workers, BRFSS 2013–2017, 32 states. *Workplace Health Saf* 2020;68:391–401.
6. Hagan-Haynes K, Ramirez-Cardenas A, Wingate KC, et al. On the road again: a cross-sectional survey examining work schedules, commuting time, and driving-related outcomes among U.S. oil and gas extraction workers. *Am J Ind Med* 2022;65:749–761.
7. Torquati L, Mielke GI, Brown WJ, Kolbe-Alexander T. Shift work and the risk of cardiovascular disease. A systematic review and meta-analysis including dose-response relationship. *Scand J Work Environ Health* 2018;44:229–238.
8. Vyas MV, Garg AX, Iansavichus AV, et al. Shift work and vascular events: systematic review and meta-analysis. *BMJ* 2012;345:e4800.
9. Holtermann A, Marott JL, Gyntelberg F, et al. Occupational and leisure time physical activity: risk of all-cause mortality and myocardial infarction in the Copenhagen City heart study. A prospective cohort study. *BMJ Open* 2012; 2:e000556.
10. Harrison RJ, Retzer K, Kosnett MJ, et al. Sudden deaths among oil and gas extraction workers resulting from oxygen deficiency and inhalation of hydrocarbon gases and vapors—United States, January 2010–March 2015. *MMWR Morb Mortal Wkly Rep* 2016;65:6–9.
11. NIOSH. [Website] Fatalities and hospitalizations related to the ignition, inhalation, or suspected inhalation of hazardous gases and vapors while handling fluids at oil and gas sites: 2015–2016. *Special Topic Report* 2018. Available at: https://www.cdc.gov/niosh/topics/fog/SpecialTopic2018.html. Accessed April 12, 2023.
12. Retzer K, Schmick E, Ramirez-Cardenas A, King B, Snawder J. Gases and vapors continue to pose hazards on oil and gas well sites During gauging, fluid transfer, and disposal. NIOSH Science Blog blog August 24, 2018, 2018. Available at: https://blogs.cdc.gov/niosh-science-blog/2018/08/24/oil-and-gas-vapors/. Accessed April 12, 2023.
13. NIOSH. Forward-looking infrared (FLIR) footage of transfer or petroleum condensate to the tank of a truck. Available at: https://www.facebook.com/niosh/videos/310521326422321/. Video posted to Facebook. Accessed September 6, 2022.
14. NIOSH. Fatalities in the oil & gas Extraction Industry. Last Reviewed June 24, 2021. Available at: https://www.cdc.gov/niosh/topics/fog/default.html. Accessed June 21, 2022.
15. NIOSH-OSHA Hazard Alert: Health and Safety Risks for Workers Involved in Manual Tank Gauging and Sampling at Oil and Gas Extraction Sites (2016). DHHS (NIOSH) Publication Number 2016-108. Available at: https://www.cdc.gov/niosh/docs/2016-108/default.html. Accessed April 12, 2023.
16. Ridl S, Retzer K, Hill R; NIOSH. Oil and gas extraction worker fatalities 2014; NIOSH fatalities in oil and gas extraction (FOG) database. Published: 2017. Available at: https://stacks.cdc.gov/view/cdc/47830. Accessed April 12, 2023.
17. Office of Management and Budget. North American industry classification system manual, United States, 2022 (2022). Available at: https://www.census.gov/naics/. Accessed April 12, 2023.
18. Pollack RA, Brown SP, Rea T, et al. Impact of bystander automated external defibrillator use on survival and functional outcomes in shockable observed public cardiac arrests. *Circulation* 2018;137:2104–2113.
19. Toosi M, Torpey E. Older workers: labor force trends and career options [U.S. Bureau of Labor Statistics website]. Published: 2017. Available at: https://www.bls.gov/careeroutlook/2017/article/older-workers.htm. Accessed June 24, 2022.
20. Bagnall RD, Weintraub RG, Ingles J, et al. A prospective study of sudden cardiac death among children and young adults. *N Engl J Med* 2016;374: 2441–2452.
21. Ramirez-Cardenas A, Wingate KC, Pompei R, King B, Scott KA, Hagan-Haynes K, Chosewood LC. Fatalities involving substance use among U.S. oil and gas extraction workers identified through an industry specific surveillance system (2014–2019). *J Occup Environ Med*. 2023 Mar 30. doi: 10.1097/JOM.0000000000002856. Epub ahead of print. PMID: 36998177.
22. Pulgaron ER, Delamater AM. Obesity and type 2 diabetes in children: epidemiology and treatment. *Curr Diab Rep* 2014;14:508.
23. Faturos A, Bodor G, Proe L, Lathrop S. Occupational mortality in the New Mexico oil and gas industry. *J Forensic Sci* 2021;66:2283–2288.
24. OSHA Region VIII. OSHA compliance officer pocket card: investigating non-traumatic fatalities in the oil and gas industry. 2016.
25. OSHA. Reporting fatalities, hospitalizations, amputations, and losses of an eye as a result of work-related incidents to OSHA. 29 CFR § 1904.39(b)(5). Available at: https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1904/subpart-E/section-1904.39. Updated October 7, 2022. Accessed October 12, 2022.
26. Hartenbaum NP. *The DOT Medical Examination: An Unofficial Guide to Commercial Drivers' Medical Certification*. 7th ed. Beverly Farms, MA: OEM Press; 2020.
27. Serra C, Rodriguez MC, Delclos GL, Plana M, Gómez López LI, Benavides FG. Criteria and methods used for the assessment of fitness for work: a systematic review. *Occup Environ Med* 2007;64:304–312.
28. National Fire Protection Association (NFPA) Standard 1582: Standard on Comprehensive Occupational Medical Program for Fire Departments. (2022). Quincy, MA. url: https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1582. Accessed April 12, 2023.
29. Scott KA. [Virtual Meeting] NIOSH National Occupational Research Agenda Oil and Gas Extraction Sector Council Meeting - Health Workgroup. Dec. 13, 2021.
30. NIOSH. 29-Year-Old Firefighter Suffers Cardiac Arrest After Two 24-hour Shifts - Wisconsin (2019). *Death in the line of duty...* NIOSH Fire Fighter Fatality Investigation and Prevention Program Report #F2019-06. Available at: https://www.cdc.gov/niosh/fire/pdfs/face201906.pdf. Accessed April 12, 2023.
31. 47-Year-Old Firefighter Suffers Cardiac Arrest at Gym After Shift—Massachusetts (2019). A report From the NIOSH fire fighter fatality investigation and prevention program. Report #F2018-01.
32. Boal WL, Li J, Sussell A. Health insurance coverage by occupation among adults aged 18–64 years—17 states, 2013–2014. *MMWR Morb Mortal Wkly Rep* 2018;67:593–598.
33. NIOSH. Hierarchy of controls. Available at: https://www.cdc.gov/niosh/topics/hierarchy/default.html. Accessed December 14, 2022.
34. NIOSH. NIOSH criteria for a recommended standard: occupational exposure to heat and hot environments. By Jacklitsch B, Williams WJ, Musolin K, Coca A, Kim J-H, Turner N. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 2016-106. 2016.

