MEDICAL GAS CONTROL

STUDY REPORT:

The prevalence and impact of home oxygen fires in the U.S.

www.bprmedical.com

The prevalence and impact of home oxygen fires in the U.S.

Abstract

This study used the Google Alerts service to identify online media reports in the U.S. of residential fires involving home oxygen therapy.

Information recorded in the study included: harm, ignition cause, evacuation, whether cylinders exploded, property type, structural damage, displacement of people, and whether a working smoke detector was fitted.

The study found media reports covering 311 separate fires involving home oxygen over a 20-month period resulting in 164 deaths, 71 serious injuries and 119 minor injuries. This amounts to more than one death every 4 days.

Notwithstanding these findings, limitations in the study method suggest that the findings remain an underestimate of the likely death rate, which is estimated at between 100 and 150 deaths per year. This is between 1.5 and 2 times what was previously thought.

The risks associated with home oxygen fires are not limited to the oxygen user. Third parties are also at significant risk with more than 1 in 4 incidents recorded involving evacuation by a third party, including members of the public, neighbours, family, firefighters and the police. 11 third parties are included in the 164 recorded deaths.

Linked to third party risk, the study found that cylinders exploded in 1 in 3 incidents, which raises the potential for harm considerably. Third parties attempting to help evacuate a resident from a burning home will not necessarily know that there are cylinders present. The violence of an exploding cylinder will likely prove fatal to anyone in the building if it occurs.

Furthermore, research suggests that, despite safety valves being fitted to cylinders, a home fire easily creates the conditions for cylinders to explode. Increasing temperature simultaneously increases gas pressure and weakens cylinder strength.

The study confirms a minimum home oxygen fire death rate of 6.7 deaths/100,000 oxygen users, which compares poorly with other countries. In Japan and England, the equivalent rate is 3.3 and 0.34 deaths per 100,000 oxygen users respectively. Put another way, an American home oxygen user is 10 times more likely to die in a home oxygen fire than in Japan, and 20 times more likely than in England.

Comparisons with other countries show that much of the harm seen in the U.S. from home oxygen fires could be prevented through policy change and the introduction of low-cost risk control measures, such as fitting thermal fuses (firebreaks) into oxygen tubing and ensuring there is a working smoke alarm fitted.

It is hoped that this study will provide valuable data to support the changes required to address what remains a persistent and material public health issue in the U.S.

The prevalence and impact of home oxygen fires in the U.S.

Study Method

The study is based upon responses from a Google Alert query using the keywords “oxygen” and “fire” through the period 7th December 2017 to 6th August 2019 inclusive (20 months).

Google Alerts is a content change detection and notification service. The service sends an email to the user when it finds new results—such as web pages, newspaper articles, blogs, or scientific research—that match the user’s search terms.

Each link provided within a daily Google Alerts email was assessed to determine whether it was likely to relate to an oxygen fire. Likely home oxygen fire media reports were visited by following the link provided by Google. If the story was an oxygen fire then the details were added to a database, recording the relevant information. A PDF was taken of the web site screen and attached to the database to provide enduring evidence, in case the link was subsequently moved or removed by the website owner.

There is little data available as to the coverage and effectiveness of the Google Alerts service. It was effective in uncovering the 311 incidents, but it is not known how many media reports it did not find. Many of the incidents had multiple media reports from more than one news agency.

The database provides fields for recording the following: geography (city, state); incident date; link to original news story; ignition source; number of cylinders stored; did cylinders explode?; property (type, degree of damage, neighbouring buildings damaged); assisted evacuation?; injuries (3 subjects recorded separately); working smoke alarm?; number of people displaced; summary of news report.

Some of the fields included drop-down choices with associated criteria to improve consistency of judgement. Further details of the drop-down choices are provided in the relevant section of the Study Results.

The study is ongoing, and data continues to be added to the database, with a view to periodically updating the study report findings.

.

Study Results

General

The study identified 311 separate home oxygen fire incidents across the period.

Incidents were recorded in 45 of the 50 U.S. states. The distribution of incidents and deaths across the U.S. states is provided in Appendix A.

Incidents occur routinely and for the purposes of this study can be considered to be evenly distributed throughout the year. There is some evidence to suggest that incident rate is marginally lower during the summer months of June, July and August, but at this stage there is insufficient data to determine if this is significant; future reports may confirm whether there is a seasonal trend associated with oxygen fires.

Injury and Death

The 311 incident reports resulted in 164 deaths, 71 serious injuries and 119 minor injuries (total 354 injured or killed).

Of the 164 deaths the study identified, 149 were likely to have been related to oxygen in conjunction with smoking or another ignition source. There were 15 deaths, for which the ignition source was not clear from the media report, although there was evidence of oxygen in the home.

Injuries where the person was not sent to hospital or was sent but discharged that day were recorded as minor injuries.

TABLE 1	Death	Serious	Minor	No Injury
Oxygen user	145	63	51	18
Resident	8	4	26	6
Family Member	9	3	16	7
Firefighter	1	0	16	0
Police	0	0	2	0
Member of public	0	1	6	0
Other	1	0	2	0
Total persons	**164**	**71**	**119**	**31**

Ignition Cause

Determining the cause of ignition often requires an element of judgement to piece together the story. To provide consistency, criteria were set up for each ignition cause drop-down choice (refer Appendix B). Applying judgement and based on one or more of the criteria being met, incidents were categorised by ignition cause.

Most oxygen fires were judged as caused (51%) or probably caused (21%) by smoking in conjunction with oxygen use.

In some cases, the incident report describes the dropping of cigarettes onto the oxygen line as the cause of ignition. In others, the oxygen line is draped across an ashtray. Oxygen users have an interest in not admitting to smoking while on oxygen, for fear of having their oxygen removed. As such the description may well be designed to deflect away from 'smoking while on oxygen'. One example of this is where the oxygen user blamed his pet cat for starting the fire when it bit through his oxygen line, even though he was smoking at the time.

TABLE 2	Death	Injury	No Injury	Total
Caused by smoking	69	63	26	158
Probably caused by smoking	43	18	5	66
Possibly caused by smoking	21	10	2	33
Not clear	13	13	18	44
Other ignition source	5	3	2	10
Total Incidents	**151**	**107**	**53**	**311**

Evacuation and Risks to Third Parties

In addition to the death of oxygen users, the incident reports identify the deaths of a firefighter, a residential care home worker and 9 family members. Reports from 9 incidents were not clear whether the death was that of the oxygen user or another resident. The deaths of 22 pet cats and dogs was also recorded, in some cases their oxygen using owners survived.

Incidents pose a significant risk to third parties who attempt to assist in the evacuation of those caught up in a residential fire.

Of the 164 recorded deaths, 103 deaths did not evacuate at all and were found dead in the building.

Third parties were involved in an evacuation of 69 (29%) of the 238 incidents where evacuation was reported on, including firefighters/police (28), members of the public (24), and family members/ other residents (17). Assisted evacuation was judged to have occurred if the third party had either attempted to or did enter the building to assist with evacuation.

Incidents reported by evacuation method:

TABLE 3	Where the incident outcome was...			
	Death	Injury	No Injury	Total
Not evacuated	103	4	1	108
Not reported	17	42	14	73
Self-evacuated	9	27	25	61
Police/firefighters	12	14	2	28
Member of the public	7	13	4	24
Family member/ other resident	3	7	7	17
Total Incidents	**151***	**107**	**53**	**311**

Cylinder Explosion

One third (102 from 311) of incidents reported at least one cylinder exploded in the fire. This percentage is relatively consistent across all incident outcomes: Death (35%), Injury (31%) and No Injury (30%). Cylinder explosions were reported in 4 (40%) of the 10 incidents where the outcome was either 2 deaths or 3 deaths.

There are several reports of near misses from flying shrapnel from exploding cylinders, including the incident where the volunteer firefighter died as a result of being hit by shrapnel from a cylinder. In this case the fire cause was an oxygen user smoking, the propane cylinder explosion was secondary and resulted in the firefighter's death.

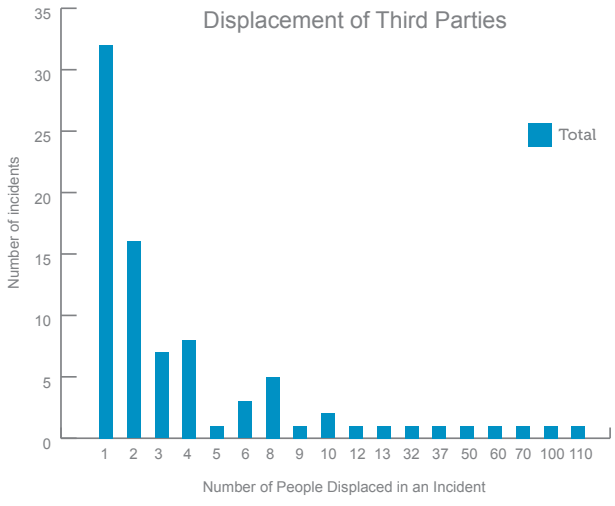
TABLE 4	Cylinder(s) No	Exploded Yes	Total	Cylinder(s) Exploded
Death	99	53	152	35%
1 fatality	93	49	142	35%
2 fatalities	5	3	8	38%
3 fatalities	1	1	2	50%
Injury	84	38	122	31%
No Injury	26	11	37	30%
Total Incidents	**209**	**102**	**311**	**33%**

Displacement of Other Residents

Where the incident report provides information on displacement, or where the dwelling is no longer habitable, then the number of persons displaced in each incident was recorded. The recording of the number of people displaced did not include the oxygen user. Displacement did not include temporary evacuation for the day.

Most incidents (73%) did not displace other residents in the dwelling. Where there was displacement, it tended to be one (10%) or two (5%) other person(s), who typically were family members.

Fires in residential complexes have the potential to displace large numbers of generally elderly people. There were cases were 50, 60, 70, 100 and 110 people were reported to have been displaced because of an oxygen fire incident.



Structural Damage

TABLE 6	Neighbouring property damaged		Total
	No	Yes	
Dwelling destroyed	92	32	124
Multiple rooms	58	8	66
One room	56	5	61
Not reported	32	1	33
Minor local damage	20	0	20
None	7	0	7
Total Incidents	**265**	**46**	**311**

The National Fire Protection Association annual report for 2017[1] estimated a loss of $7.9 billion across 379,000 residential fires, an average of $20,844 per fire. Applying this to the 271 damaged properties would provide an estimated loss of $5.6 million.

Alternatively, and probably more realistically, applying an arbitrary loss figure of say $100,000, $40,000 and $5,000 for the structural damage categories Dwelling Destroyed, Multiple Rooms and One Room respectively would provide a loss estimate of $15.3 million for the 251 properties damaged.

Neighbouring properties were also damaged in 45 (18%) of the 251 incidents where serious damage was reported.

There were many reports of residents having no insurance and having lost both their home and all their belongings. Support from The American Red Cross and the setting up of Just Giving campaigns for families was very common in the reports.

Property Type

Incidents related to oxygen fires in mobile homes was a recurring theme. Of the 311 incidents recorded 64 (21%) related to an oxygen fire in a mobile home. Death was the outcome in 34 of the 64 incidents involving an oxygen fire in a mobile home, resulting in 37 deaths (23% of the total deaths). Mobile homes account for only 7.6% of the housing stock in the U.S.[2], so fires in mobile homes are disproportionately represented.

Some incident reports specifically quote fire investigators, who point out that older style mobile homes do not benefit from more recent federal building regulations that require the use of certain materials to limit the spread of fire.

TABLE 7	Death	Injury	No Injury	Total
House	67	33	21	121
Mobile home/ trailer	34	20	10	64
Apartment (residential complex)	16	21	7	44
Not reported	17	16	6	39
Apartment	13	13	6	32
Other	4	4	3	11
Total Incidents	**151**	**107**	**53**	**311**

Smoke Detectors

Most media reports (273) did not report whether there was or was not a working smoke alarm fitted. Of the 38 incidents where this was explicitly reported on or was otherwise obvious, 53% (20) had a working smoke alarm and 47% (18) did not.

Oxygen tubing is almost always made from PVC, which emits very large amounts of thick black toxic smoke immediately the oxygen tube is ignited. The by-products of combustion of PVC tubing also include potentially lethal levels of hydrogen chloride. A smoke detector will provide the earliest warning and the best opportunity of preserving life.

In the reports, there were many quoted remarks from the lead firefighter stressing the importance of a working smoke alarm.

A recent NFPA study concluded that 57% of deaths in home fires had no working smoke alarm and that you are 54% more likely to survive a fire with a working smoke detector[7].

Further Research and Discussion

Prevalence

There is no reliable reporting system for home oxygen fires, so it is impossible to accurately determine prevalence. The National Fire Protection Association (NFPA) report on Home Structure Fires (2017)[3] estimates an average of 358,500 home structure fires each year based upon figures from 2011 to 2015. It believes that oxygen appliances are involved in less than 1% of these fires, although they account for 3% of the average 2,510 home fire deaths each year.

An earlier NFPA report 'Fires and Burns Involving Home Medical Oxygen'[4] estimated the number of burn victims attending U.S. emergency rooms was 1,190 each year. According to the report, the majority of these were caused by smoking while on oxygen.

This study identifies 311 separate reports over 20 months, or an average of 187 reports each year. The media reports identified are very likely to represent actual events and can be considered solid evidence. However, not all media reports will have been found by Google Alerts, not all media reports will contain the search keywords and not all home oxygen fires will be newsworthy. Therefore, it is reasonable to anticipate that the numbers in this study still represent an underestimate of the scale of the problem.

It is also worth noting that the incidents identified in this study were 'newsworthy' and therefore likely to be the larger more destructive fires. Comparing what the news agencies have captured, as recorded as incidents in this study, with the number of burn victims attending hospital (i.e. 1,190) from the NFPA study[4], the number of oxygen fires is clearly many times higher than has been identified by this study, albeit many had an outcome that may have been less damaging. The difference between a localized fire and a major fire however, may be little more than circumstances or luck.

The number of serious injuries is also likely to add to the number of fatalities. Very few of the media reports followed up on hospital admissions, but in their study of smoking-related home oxygen burn injuries, Carlos et al[5] found that 14.5% of patients admitted with burns resulting from a home oxygen fire died in hospital as a result of their injuries. Oxygen patients often suffer from smoke inhalation and burn injuries to the face, torso and inspiratory airways in an oxygen fire. COPD sufferers already have a severe respiratory impairment and may also have other comorbidities. It is likely that some of these oxygen users will have died as a result of injuries sustained in the oxygen fire episode.

Given the evidence from previous NFPA and other studies, it is likely that the number of deaths as a result of home oxygen fires is probably in the range of 100 to 150 each year. This would represent between 4% and 6% of the total fire deaths in the U.S., even though oxygen users only represent 0.5% of the overall population. This means you are between 8 and 12 times more likely to die in a home oxygen fire if you are a home oxygen user in the U.S.

Comparisons with Other Countries

Assuming 100 deaths each year in the U.S. and 1.5 million oxygen users, the U.S. has a rate of 6.7 deaths per 100,000 oxygen patients.

According to a previous study[6], the U.S. appears to have a higher death rate from home oxygen fires than other countries. Figures for Japan and England from the period (2013 to 2017) suggest an average annual death rate of 3.3 and 0.34 deaths per 100,000 oxygen patients respectively.

Given the UK has by some margin the best record for safety it can be considered current best practice for safe oxygen delivery.

While the basic provision of oxygen remains the same across the world, namely an oxygen concentrator for the home and cylinders or portable oxygen concentrator for ambulatory use, there are differences in delivery in each country that impact safety. These differences include: the size of the market; the size and nature of the companies providing oxygen; house construction method (extensive use of wood in the U.S.); the level of cooperation between stakeholders involved in delivering oxygen; risk assessment methodology and rigour; regulation and reporting; and the use of other risk control measures such as smoke detectors and thermal fuses (firebreaks).

Of course, some of these differences may be difficult to address but some measures are relatively easy to adopt.

A working smoke detector is an obvious low-cost risk control measure. Reflecting best practice, ensuring that there is a working smoke detector is a contractual requirement for service providers in the provision of home oxygen in England and Wales. The home oxygen service provider is required to check that there is a working smoke detector alarm as part of a broader risk assessment at each install, service and call-out. Any negative finding is reported immediately to the local Fire and Rescue Service, who will arrange to visit and correct the situation. Interestingly, and as an extension to the contractual requirement, at least one service provider in the UK contracts with their local Fire and Rescue Service to fit smoke detector alarms where one is required. The NFPA estimated[7] that almost three of every five (57%) home deaths in the U.S. resulted from fires with no smoke alarms or no working smoke alarms. The findings of this study are broadly in line with the NFPA findings, albeit the sample size in this study was very low because most media reports did not include this detail.

Similarly, thermal fuses (also referred to as firebreaks) are now widely adopted in home oxygen installations around the world as a simple, low cost risk control measure. A firebreak is a risk control device fitted in the oxygen delivery tube close to the patient that automatically acts to stop the flow of oxygen in the event the oxygen tube is ignited. Firebreaks limit fire escalation and toxic smoke production, thereby buying time for evacuation and reducing risks to the oxygen user and third parties.

The UK mandated the fitting of firebreaks for all home oxygen patients in 2006. Thermal fuses are now used in more than 25 countries around the world. Thermal fuses are a requirement in Europe under medical device legislation and are specifically mandated in Germany. Japan is transitioning to full adoption by February 2021. Since March 2018, the VA in the U.S. has mandated the use of thermal fuses in each home oxygen patient installation. Thermal fuses are an effective, low-cost risk control solution and an integral part of best practice.

Best practice can point the way towards reducing the number of deaths resulting from home oxygen fires. Regulation and mandatory incident reporting along with the culture in the UK of cooperation between stakeholders, a strong risk assessment process and the use of low-cost risk control measures, such as smoke alarms and thermal fuses, results in a markedly safer outcome for home oxygen users and third parties.

Understanding the potential for and risks associated with cylinder explosions

Exploding cylinders are referenced in 33% of the reported incidents. Cylinder explosions therefore represent a very serious risk, both in terms of probability of occurrence (1 in every 3) and severity of harm.

Number of cylinders provided: According to a survey by Jacobs et al[8], of 1,926 patients receiving home oxygen therapy, 80% used a portable system outside the home. Jacobs reported that 33% of these were portable oxygen concentrators. Based on these figures 54% of oxygen users will have an oxygen cylinder. With an estimated 1.5 million oxygen users in the U.S., this suggests that there are in the order of 800,000 oxygen users with cylinders at home.

The number of cylinders provided to each oxygen user varies based upon the home oxygen patient's requirement, their circumstances and geography, and the home oxygen service provider. It is not uncommon for a service provider to deliver up to 10 cylinders in one delivery. There is anecdotal evidence that some oxygen users have stores of up to 20 or 30 cylinders in and around the home. Indeed, one incident reported in this study had a count of 28 cylinders in the building.

Potential for cylinder explosion: In a fire, two factors work in combination to increase the likelihood of an oxygen cylinder explosion.

The first relates to the rapid increase in gas pressure in the cylinder as temperature increases. The pressure inside the cylinder is proportional to absolute temperature. So, a gas cylinder filled to 2,000 psig at 70°F (21°C), would reach a pressure of 3,770 psig at 500°F (260°C).

The second is that the oxygen cylinder weakens considerably as its temperature goes up. An oxygen cylinder made from the widely adopted aluminium 6061-T6 would have lost 60% of its tensile strength at 500°F (260°C)[9].

The high number of cylinder explosions and the relatively short time between the fire starting and the first cylinder exploding, as reported in some of the media articles, points towards two possible mechanisms for raising cylinder temperature.

The first is the heat in the room generated from the fire. A typical house fire can be 100°F at floor level and 600°F at eye level[10]. The thermal energy from a fire in a room will be absorbed rapidly by the highly conductive aluminium cylinder. If the cylinder is in the room in which the fire starts, this rapid temperature rise may happen within minutes, presenting a severe threat.

An alternative hypothesis may be the extreme heat provided by the ignited PVC oxygen tube. PVC is an oil-based polymer that burns readily in 100% oxygen. Once an oxygen tube is ignited by a cigarette or other source it will burn back along the tube towards the source of the oxygen. Where this source of the oxygen is an oxygen cylinder, the ignited tube will reach and may be adjacent to the cylinder.

Tests have shown that an ignited PVC oxygen delivery tube providing a flow of oxygen of just a few litres per minute discharges a white flame with a temperature exceeding 1,400°F. This extreme heat source has the potential to locally weaken an oxygen cylinder if the tubing is contacting the oxygen cylinder wall.

Cylinder pressure relief valves: In order to minimise the risk of gas container explosions, Pressure Relief Devices (PRDs) are required to be fitted to gas cylinders by law. CFR Title 49 § 173.301 paragraph (f) states: *'Pressure relief device systems……a cylinder filled with a gas and offered for transportation must be equipped with one or more pressure relief devices sized and selected as to type, location, and quantity, and tested in accordance with CGA S–1…… and CGA S–7. The pressure relief device must be capable of preventing rupture of the normally filled cylinder when subjected to a fire test conducted in accordance with CGA C–14 ……'*

However, large multinational companies involved in the manufacture or supply of gases and gas cylinders state in their literature that Pressure Relief Devices do not necessarily prevent cylinder explosions when they are involved in a fire. This is corroborated by CGA pamphlet S-7 concerning selection of Pressure Relief Devices for Compressed Gas Mixtures in Cylinders, which states:

'WARNING: PRDs might not prevent rupture of a cylinder under all conditions of fire exposure. When the heat transferred to the cylinder is localized, intensive, and remote to the relief device, or where the fire builds extremely rapidly such as in an explosion and is of very high intensity, the cylinder can weaken sufficiently to rupture before the relief device operates or while it is operating.'

This appears to suggest a regulatory requirement might not be met routinely. Another explanation could be that the test method given in CGA C-14 does not represent an oxygen cylinder in a house fire scenario in all circumstances, because presumably the cylinders and their valves are proven compliant with the test before being made available to the market.

Another complication is that the required relieving capacity of the PRD is determined by the cylinder volume. The PRD is normally incorporated into a cylinder post valve and supplied by a manufacturer other than the cylinder manufacturer. It is therefore necessary to take great care in selecting the appropriate valve and PRD combination for the cylinder size and its application.

Outcomes for a cylinder in a fire: Three potential outcomes for an oxygen cylinder involved in a fire could be as follows:

1. The oxygen cylinder resists the fire, the PRD does not open. This only seems likely if the fire is minor and is brought under control relatively quickly.

2. The PRD opens as the cylinder heats up. It would be expected this would dramatically escalate the speed and ferocity of the fire surrounding the cylinder; as alluded to in CGA pamphlet S-7.

3. The Pressure Relief Valves fails to operate quickly enough to prevent rupture. The powerful explosion would be accompanied by instantaneous release of the heated oxygen gas. This might happen if the fusible portion of the PRD was not heated above its melting temperature e.g. where only the base of the cylinder is heated by a fire.

There may be no absolutely safe method of preventing oxygen cylinder explosions in a house fire. Where cylinders are present, reducing the risk of a fire spreading from its source is essential, especially where there is the potential for significant numbers of oxygen cylinders to be stored in the home healthcare environment.

By-products of combustion of PVC oxygen tubing

Oxygen tubing is almost always made from PVC, which emits very large amounts of thick black toxic smoke immediately the oxygen tube is ignited. The by-products of combustion of PVC tubing include potentially lethal levels of hydrogen chloride.

Combustion of PVC (plasticised polyvinyl chloride) oxygen tubing releases elemental chlorine which readily combines with hydrogen released from the plasticiser and PVC to form hydrogen chloride (HCl) gas[11]. HCl presents two significant hazards in fires, by causing incapacitation through sensory irritancy (leading to painful breathing, swelling of the airways, and ultimately death), and by inhibiting the conversion of CO to the less toxic CO_2[12].

Assuming that all the chlorine within the oxygen tubing were converted to HCl (hydrogen chloride) gas, a typical 50-foot length of oxygen tubing, containing 6.8 g of elemental chlorine per meter length, can release ~50 litres of gaseous hydrogen chloride into the environment. HCl gas has a NIOSH IDLH (immediately dangerous to human life) limit of 50 ppm. Assuming the HCl was released in an empty 6 m long x 4 m wide x 2.5 m high room with negligible ventilation, the mean ambient concentration of HCl could be over 800 ppm, with significantly higher local concentrations.

Given their compromised respiratory health, home oxygen patients may be more easily incapacitated than the general population would be should they be exposed to hydrogen chloride gas inhalation during a home oxygen fire.

Key Findings

This study provides a unique and hitherto unavailable perspective on the nature and scale of the problem of home oxygen fires in the U.S.

Key findings from the study:

- The study found media reports covering 311 separate fires involving home oxygen over a 20-month period resulting in 164 deaths, 71 serious injuries and 119 minor injuries.
- Nearly three quarters of oxygen fires (72%) were either caused, or were probably caused, by patients smoking while using oxygen therapy.
- Around 1 in 4 incidents (22%/69 incidents) where evacuation was reported required a third party to assist evacuation from a burning building. Surprisingly, the majority of this assistance came from members of the public, family members or other residents (41 incidents) rather than either firefighters or police (28 incidents). This highlights the significant risk that home oxygen fires pose to third parties.
- Exploding cylinders are referenced in 33% of reported incidents, presenting a high and unpredictable risk to the emergency services and members of the public.
- Further analysis of the frailty of aluminium gas pressure cylinders in a fire shows just how quickly and easily a cylinder might explode despite being fitted with safety valves. Even a limited home fire might create the conditions to increase gas pressure and weaken cylinder strength sufficiently to trigger a cylinder explosion. Alternatively, an ignited PVC oxygen tubing that has burnt back to the cylinder might sufficiently weaken an adjacent section of the cylinder to deliver the same outcome.
- 20% of incidents and 22% of deaths were associated with mobile homes or trailers, even though they represent only 7.6% of the total home stock in the U.S.
- In addition to the obvious human misery associated with every incident, there is practical loss and damage to the family home and belongings. The study revealed that nearly two-thirds of homes were either destroyed (40%/124) or severely damaged (21%/66). The cost of damage over the 311 incidents is in the order of $15 million. Many people have no insurance and relied on the American Red Cross and Just Giving campaigns.
- Losses were not restricted to the oxygen user and their family. In 45 of the incidents neighbouring buildings were damaged and people were evacuated and displaced, often this was elderly people in residential complexes. There were cases where 50, 60, 70, 100 and 110 were forced to relocate for more than one day as a result of an incident.

Conclusions

1. **Prevalence:** The absence of any national reporting system that specifically records and reports on home fires involving oxygen makes understanding the scale of the home oxygen fire problem in the U.S. very difficult.

   The previous landmark report by the NFPA[4] suggests that home oxygen fires lead to around 70 fatalities each year, while describing this as a 'likely underestimate'.

   This study records an annual average fatality rate of 100. Again though, this study is likely to be an underestimate, because a) not all home oxygen fires may be reported in the media, b) the Google Alert search may not find the media report, c) the media report may not use both the search terms 'fire' and 'oxygen', and d) there has been no follow-up on those recorded as having a serious injury, some of which statistically are likely to subsequently die of the burn and smoke inhalation injuries they incurred.

   Given the above, it is likely that the death rate in the U.S. from home oxygen fires is probably between 100 and 150 people each year, which is 1.5 to 2 times what was previously thought.

   The rate of deaths found by the study represents at least 4% of all home fire deaths in the U.S., while home oxygen users only represent 0.5% of the U.S. population overall. Therefore, home oxygen users in the U.S. are 8 times more likely to die in a home oxygen fire than other U.S. citizens. Furthermore, this can be multiplied by 3 (i.e. 24 times) if that oxygen user lives in a mobile home.

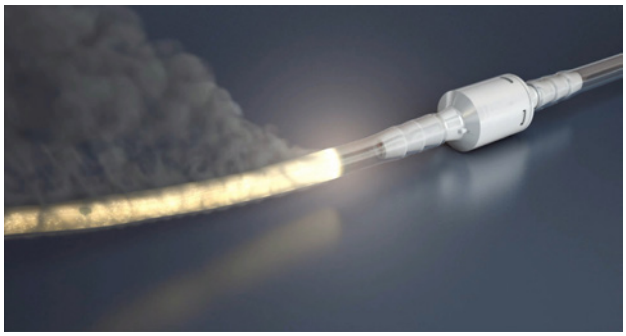
2. **Risks to third parties:** The study highlights that the risk in a home oxygen fire is not simply to the oxygen user. Third parties assisted in more than 1 in 4 evacuations, including members of the public, neighbours, family, firefighters and the police. 11 third parties are included in the 164 recorded deaths.

   A cylinder exploded in 1 in 3 incidents recorded in the study, which presents an obvious additional and somewhat unpredictable risk to oxygen users and third parties.

   Research suggests that, despite safety valves being fitted to cylinders, a home fire easily creates the conditions for cylinders to explode. Temperature simultaneously increases gas pressure and weakens cylinder strength.

   Third parties attempting to help evacuate a resident from a burning home will not necessarily know that there are cylinders present. The violence of an exploding cylinder will likely prove fatal to anyone in the building if it occurs.

   The fitting of thermal fuses (firebreaks) into oxygen circuits seems an obvious precaution to limit the rate at which fires escalate and buy essential time for evacuation.



Thermal fuses (also known as firebreaks) stop the flow of oxygen in the event of a fire in the tube

3. **Comparisons with other countries:** The study confirms a minimum home oxygen fire death rate of 6.7 deaths/100,000 oxygen users, which compares poorly with other countries. In Japan and England, the equivalent rate is 3.3 and 0.34 deaths per 100,000 oxygen users respectively. Put another way, an American home oxygen user is 10 times more likely to die in a home oxygen fire than in Japan, and 20 times more likely than in England.

   The UK has the best record for safety and therefore can be considered current best practice. Regulation and mandatory incident reporting, along with a culture in the UK of cooperation between stakeholders, a strong risk assessment process and the use of low-cost risk control measures, such as smoke alarms and thermal fuses (firebreaks), results in a markedly safer outcome for home oxygen users and third parties.

   Some of these measures are structural and may be challenging to implement, but others are relatively straightforward and low-cost, such as fitting thermal fuses (firebreaks) to oxygen circuits and ensuring there is a working smoke alarm fitted.

4. **Public health:** This study provides for the first-time important evidence about the nature of home oxygen fires and an update on the scale of the problem in the U.S.

   - The study found media reports covering 311 separate fires involving home oxygen over a 20-month period resulting in 164 deaths, 71 serious injuries and 119 minor injuries.
   - Based on evidence from other countries, much of this harm can be prevented through policy change and the introduction of low-cost risk control measures.
   - It is hoped that this study will provide valuable data to support the changes required to address what remains a persistent and material public health issue in the U.S.

References

1. Fire Loss in the U.S. in 2017; NFPA Everts.Ben; October 2018
2. U.S. Census 2000. Chapter 14 Housing. U.S. Census Bureau.
3. Home Structure Fires; NFPA Ahrens.Marty; December 2018
4. Fires and Burns Involving Home Medical Oxygen; NFPA Ahrens,Marty; August 2008
5. Smoking-Related Home Oxygen Burn Injuries: Continued Cause for Alarm; Carlos et al; November 2015.
6. An international comparison of fatalities from home oxygen fires: 2013-2017; BPR Medical Ltd; 2019
7. Smoke Alarms in U.S. Home Fires. NFPA. January 2019.
8. Patient Perceptions of the Adequacy of Supplemental Oxygen Therapy; Jacobs et al; 2017
9. Table 4.2 of the Aluminum Design Manual 2010 (The Aluminum Association Inc.)
10. Ready, official website of the dept of homeland security, https://www.ready.gov/home-fires
11. Richard E. Lyon and Marc L. Janssens, Report DOT/FAA/AR-05/14 on Polymer Flammability, May 2005, Federal Aviation Administration, U.S. Department of Transportation
12. T Richard Hull, Anna A Stec And Keith T Paul, Hydrogen Chloride in Fires, Fire Safety Science -Proceedings of The Ninth International Symposium, pp. 665-676, International Association for Fire Safety Science

Appendix A

Row Labels	Incidents	Fatalities
Alabama	8	3
Arizona	3	1
Arkansas	3	3
California	16	7
Colorado	4	1
Connecticut	4	1
Delaware	3	-
Florida	15	8
Georgia	5	2
Hawaii	1	-
Idaho	2	1
Illinois	12	8
Indiana	11	9
Iowa	2	1
Kansas	3	2
Kentucky	6	2
Louisiana	4	3
Maine	5	2
Maryland	10	5
Massachusetts	7	2
Michigan	9	5
Minnesota	3	2
Missouri	8	3

Row Labels	Incidents	Fatalities
Montana	4	1
Nevada	2	1
New Hampshire	2	3
New Jersey	2	2
New Mexico	8	3
New York	19	12
North Carolina	8	8
Ohio	24	13
Oklahoma	5	2
Oregon	5	1
Pennsylvania	19	12
South Carolina	4	4
South Dakota	1	2
Tennessee	14	5
Texas	7	2
Utah	7	3
Vermont	1	-
Virginia	12	6
Washington	7	4
West Virginia	4	3
Wisconsin	10	3
Wyoming	2	3
Grand Total	311	164

Appendix B

Ignition Cause judgement criteria

Drop-down Choice	Criteria
Caused by smoking	• The news report said that the fire was caused by smoking whilst on oxygen • Subject was using oxygen and had burns to body
Probably caused by smoking	• Smoking at the time of incident • Oxygen user known to be a smoker, whilst on oxygen • Oxygen user had previous incidents or near misses • Investigation concludes it was 'accidental' • On oxygen at the time of the incident and only person involved
Possibly caused by smoking	• Only oxygen user involved • Other factors pointing to oxygen fire
Other ignition source	• Other fire source quoted, such as candle or heater
Not clear	• Nothing in the news report to suggest an ignition cause

Further Information

If you would like to know more about oxygen firebreaks or require clarification on any point in this White Paper, then please contact info@bprmedical.com

BPR Medical

BPR Medical is an international leader in the design and manufacturing of medical gas control products. Based in Nottinghamshire, UK, it continues to provide innovative products for acute hospital, emergency and home care applications. The company has won many awards including a Queen's Award for Innovation in 2012 for its Firesafe™ product range and is currently the world's leading supplier of oxygen firebreaks in medical applications. The team specialises in developing successful long-term partnerships with some of the leading medical gas companies and currently exports to 50 different countries. BPR has developed an enviable reputation by delivering on quality at all levels in the business in line with its Zero Defects goal.

Disclaimer

BPR Medical makes no claim as to the legal or regulatory accuracy of the statements in this White Paper and the reader should not rely on anything contained within it when making commercial or other decisions in relation to its operational policies. BPR Medical strongly recommends that independent legal and regulatory advice is obtained before taking any action.

BPR Medical would welcome contact from any organisation that could help to improve on the body of knowledge on home oxygen fires, with the aim of increasing awareness and transparency of this problem.