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Self-fill oxygen technology: benefits for patients, healthcare providers and the environment

"Non-delivery" home oxygen technologies that allow self-filling of ambulatory oxygen cylinders are emerging. They can offer a relatively unlimited supply of ambulatory oxygen in suitably assessed people who require long-term oxygen therapy (LTOT), providing they can use these systems safely and effectively. This allows users to be self-sufficient and facilitates longer periods of time away from home. The evolution and evidence base of this technology is reported with the experience of a national service review in Scotland (UK). Given that domiciliary oxygen services represent a significant cost to healthcare providers globally, these systems offer potential cost savings, are appealing to remote and rural regions due to the avoidance of cylinder delivery and have additional lower environmental impact due to reduced fossil fuel consumption and subsequently reduced carbon emissions. Evidence is emerging that self-fill/non-delivery oxygen systems can meet the ambulatory oxygen needs of many patients using LTOT and can have a positive impact on quality of life, increase time spent away from home and offer significant financial savings to healthcare providers.

Educational aims

- Provide update for oxygen prescribers on options for home oxygen provision.
- Provide update on the evidence base for available self-fill oxygen technologies.
- Provide and update for healthcare commissioners on the potential cost-effective and environmental benefits of increased utilisation of self-fill oxygen systems.

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Healthcare providers should include self-fill oxygen systems as a therapeutic options in those meeting LTOT criteria http://ow.ly/YW2Gv

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Introduction

Two pivotal studies in the 1980s set the scene for the current prescription of long-term oxygen therapy (LTOT); the Nocturnal Oxygen Therapy Trial (NOTT) in 1980 [1] and the report of the Medical Research Working Party in 1981 [2]. These studies established that LTOT, when appropriately prescribed and correctly used, improves the survival of people with chronic hypoxaemia with a diagnosis of chronic obstructive pulmonary disease (COPD) [1, 2]. The NOTT also demonstrated improved quality of life (QoL) with ambulatory

oxygen and a statistically significant improvement in survival compared with stationary oxygen [3].

Recent research has shown that patients on LTOT do not always adhere to their prescribed therapy for a number of reasons. Issues reported as barriers to effective use of these systems include ambulatory oxygen systems being too heavy to carry, a perceived lack of instruction on usage, uncertainty of benefits, worries about ambulatory oxygen systems not lasting long enough and users being self-consciousness when out in public [4].

The 2015 British Thoracic Society (BTS) home oxygen guidelines for adults recommend that ambulatory oxygen assessment should be offered to patients already on LTOT if they are mobile and leave their place of residence on a regular basis [5]. The BTS also recommends that ambulatory oxygen should be offered to patients for use during exercise in a pulmonary rehabilitation programme or during an exercise programme following a formal assessment demonstrating improvement in exercise endurance with the addition of ambulatory oxygen [5].

There is a wealth of evidence that pulmonary rehabilitation reduces dyspnoea, increases exercise capability and improves QoL in people with a diagnosis of COPD [6]. To enable increased exercise and facilitate activities away from home for extended periods of time newer and lighter modalities of ambulatory oxygen systems are emerging.

The biggest trend in the home oxygen arena appears to focus on "non-delivery" oxygen modalities, primarily systems that allow patients to fill cylinders at home, and also the various portable oxygen concentrators that are now available, although not widely accessible to patients through the NHS [7]. The NHS England Carbon Emissions Carbon Footprinting Report was published in 2009 and describes the vision for a sustainable health and care system by reducing carbon emissions, protecting natural resources, preparing communities for extreme weather events and promoting healthy lifestyles and environments [8, 9]. Non-delivery oxygen therapy technology is of particular interest to healthcare providers as it has the ability to reduce the costs of prescribed/purchased oxygen, associated cylinder delivery/collection costs and fuel consumption, as well as reducing the associated impact on the reduction in carbon footprint [10].

Home oxygen therapy costs millions of pounds every year in the NHS and globally the exact cost is unknown [11]. The demand for the service is growing and with a globally ageing population this will have a major impact on future health policies and programmes [12]. The number of people aged >85 years in the UK has doubled and by 2030 one in five people will be >65 years of age [13].The combination of an ageing population with the increase in prevalence of chronic respiratory disease that is predicted over the next 20–30 years will add to the burden of already overstretched healthcare systems worldwide [14]. A recent study by Turner *et al.* [15] found that hospital admission is more likely in LTOT users, independent of COPD severity.

This review will focus on currently available "self-fill" oxygen delivery systems and will report on the experience of the impact of such systems in a large population of patients in Scotland (UK). For patients and caregivers, the newer oxygen technologies may empower them to spend more time away from the home environment, be more active and support greater independence [10, 16].

Oxygen self-fill technology

The first self-fill delivery system (HomeFill; Invacare Corporation, Elyria, OH, USA) was introduced in the USA in December 1999. The HomeFill system combines an oxygen concentrator with an added reservoir system on top, allowing home refilling of ambulatory cylinders with integral oxygen-conserving headsets. It permits oxygen delivery only during inspiration, thus increasing the oxygen supply time by up to threefold and reducing oxygen wastage (figure 1).

The Devilbiss iFill (Devilbiss Healthcare LLC, Somerset, PA, USA) differs from other self-fill

Figure 1 *HomeFill delivery system (InvaCare Corporation, Elyria, OH, USA).*

Figure 2 *iFill system (Devilbiss Healthcare, LLC, Somerset, PA, USA).*

Figure 3 *UltraFill system (Respiraonics, Murrysviille, PA, USA).*

systems as it operates as an independent fill station (figure 2). It is a stand-alone oxygen filling station and the patient can use and store the device anywhere in the home. It can be used in conjunction with any type of static oxygen concentrator.

The Phillips UltraFill (Respironics, Murrysviille, PA, USA) system combines a stationary oxygen concentrator, filling station and high-capacity 3000 PSI cylinders to meet the needs of a wide range of oxygen patients, including those who are highly active or require continuous flow oxygen (figure 3). It allows oxygen patients the ability to fill cylinders and receive oxygen therapy simultaneously in the home eliminating recurrent oxygen cylinder deliveries.

Self-filling oxygen delivery technology is a relatively new addition to the UK home oxygen service and it combines an oxygen concentrator with an added reservoir/filling system on top (the HomeFill system is used in Scotland) or as an independent unit (Devilbiss iFill). To date, research on some of these systems has demonstrated clinical efficacy and potential benefit for many oxygen-dependent patients. This non-delivery technology means that the home oxygen contractor does not have to make frequent visits to replenish ambulatory oxygen cylinders or refill liquid oxygen systems. The devices are capable of generating enough oxygen to effectively meet the needs of a large number of patients for both their stationary and ambulatory oxygen requirements, allowing the user to be self-sufficient in terms of in-home use, with a relatively unlimited supply of ambulatory oxygen [10, 17–19]. Self-fill systems have an integrated oxygen conserving device attached to the ambulatory oxygen cylinders and, as with any oxygen conserving device, the pulsed dose setting should be titrated for the individual with arterial blood gases or pulse oximetry using the oxygen conserving device of choice while at rest and during activity with the aim of reaching a target oxygen saturation of 90% [20].

What is the evidence for self-fill oxygen systems?

In 2002, Cuvelier *et al.* [21] conducted a randomised controlled cross-over study in 10 people with COPD comparing the HomeFill system with conventional ambulatory oxygen cylinders. They aimed to compare, in clinical conditions, the efficacy of HomeFill in improving oxygenation and exercise capacity of patients during a 6-min walking test. They found the HomeFill ambulatory oxygen system to be as efficient as ambulatory cylinders during short-term exercise and, in addition, proposed that the associated lower financial costs may be worth considering in order to improve ambulatory oxygen therapy and pulmonary rehabilitation programmes [21]. This small study was the first to show the potential of self-fill systems in adding clinical benefit in pulmonary rehabilitation programmes.

In 2003, Lewarski *et al.* [22] demonstrated similar efficacy of pulsed-dose oxygen delivery *via* the HomeFill system compared to continuous flow ambulatory oxygen again using the 6-min walk test as the comparator. They reported that the practical benefits of a self-filling ambulatory oxygen/combined oxygen concentrator system included the freedom to refill ambulatory oxygen cylinders as needed, in order to fit in with ambulatory oxygen requirements, leading to improved portability. They also proposed that healthcare providers may experience a substantial decrease in the high and recurring operational costs associated

with the provision of ambulatory oxygen cylinder home delivery dependent systems [22].

In 2009 a study by Stickland *et al.* [23] reported no significant difference in a 6-min walk test between four ambulatory oxygen systems (one of which was HomeFill) in oxygen saturation, walk time and walk distance in 39 study participants with stage IV COPD. This study demonstrated that ambulatory oxygen delivered *via* the homeFill system could meet the needs of these patients with severe lung disease during ambulation.

A review paper by Dunne [19] provides an excellent summary of the currently available technologies and reminds prescribing clinicians that, when used correctly by knowledgeable and properly trained patients, non-delivery LTOT systems can provide the user with a level of independence unattainable by other delivery dependent ambulatory oxygen systems. The ambulatory oxygen needs of LTOT users changes as activity increases or decreases according to their daily activities, a flexibility which can be met by non-delivery systems that are capable of providing sufficient concentrated oxygen at a continuous or pulsed-dose flow rate to maintain oxygen saturation during activity [18, 19].

A small survey by Murphie *et al.* [10] was conducted when the self-fill system was first introduced to 25 patients who were already receiving LTOT and ambulatory oxygen *via* portable cylinders. This survey showed a preference for the self-filling ambulatory oxygen systems by users compared to the standard ambulatory oxygen cylinders, with users reporting greater independence. In addition the system offered the potential for significant financial savings compared with alternative ambulatory oxygen provision, particularly if it were to be made more widely available across the UK [10].

A randomised controlled trial by Turnbull *et al.* [24] enrolled 40 patients from a mixed population of patients with exercise hypoxaemia and/or LTOT and aimed to assess patients' activity and preference using the HomeFill ambulatory oxygen system *versus* their usual ambulatory oxygen cylinder device. 29 patients completed follow-up and no statistically significant difference in mean daily activity was found when using the HomeFill system compared to their usual ambulatory oxygen. They concluded that the HomeFill system was equivalent to usual provision of cylinder ambulatory oxygen and was preferred by those who used this non-delivery modality of oxygen provision [24].

More recently, a national survey of patients' views on the HomeFill system was conducted by NHS Scotland following a change to the national home oxygen service contact [16]. 750 HomeFill users were approached with a 62% response rate. Results indicated the system was easy to use, with a reported 50% increase in time spent away from the home in those who went out at least four times per week. Approximately 92% of respondents self-reported an improved QoL with the HomeFill system, and all the respondents rated the quality of the service provided by the home care oxygen provider as good or better [16].

At the American Thoracic Society meeting in 2014 an abstract on the iFill system was presented regarding the use of this system in a small observational study in 10 patients with chronic respiratory insufficiency. The researchers concluded that the iFill system was able to deliver ambulatory oxygen to individuals to meet their flow rates, was safe (maintaining mean oxygen saturation during the 6 min walk test at 94%) and provided user satisfaction in terms of the pulsed-dose delivery [25].

Although all of the above mentioned studies on non-delivery, self-fill oxygen modalities include small numbers of participants, there is growing evidence that these systems can meet the LTOT stationary and ambulatory oxygen needs of patients with COPD and deserve consideration beside other ambulatory oxygen modalities. Despite self-fill systems being available in the UK for >5 years these non-delivery, self-fill oxygen delivery modalities have not yet been adopted more widely within the UK. Given the potential overall cost savings compared to other current delivery modalities of alternative ambulatory oxygen systems commissioners of home oxygen services should be urged to consider inclusion of these options for those clinicians prescribing LTOT.

The NHS Scotland experience: national home oxygen project

Prior to 2013 community pharmacies supplied both large cylinders and ambulatory oxygen cylinders to patients in Scotland, with the home oxygen contractor providing the LTOT (oxygen concentrator) component of the service. The formal route to prescription of supplemental oxygen was *via* secondary care respiratory teams but oxygen cylinders could be prescribed by primary care general practitioners, without the patient necessarily achieving the required physiological criteria for LTOT as per the BTS guidelines [5], and potentially without a robust clinical diagnosis. Oxygen cylinders were then provided *via* community pharmacies, with a wide variation in the quality of services provided. If the numbers of large oxygen cylinders used were greater than a certain level it was deemed appropriate for a static oxygen concentrator to be arranged on financial grounds. Unfortunately, and perhaps inevitably, some patients received therapy they did not require and others received systems which were not necessarily appropriate.

With the development and introduction of new technology to the UK home oxygen service, further options arose and the HomeFill system appeared in Scotland in 2011, offering the potential for patients to refill ambulatory oxygen

cylinders at home and giving a potentially unlimited supply, again with possible financial benefits [10]. NHS Dumfries and Galloway (Dumfries, UK) had the opportunity to be the first health board to trial these non-delivery home oxygen systems and took the opportunity to counsel feedback from the users. The responses were universally positive, albeit from small numbers, with reports of increasing freedom and confidence due to reduced concerns about duration of supply. With this non-delivery system patients avoided the need to travel to community pharmacies to collect oxygen cylinders and, encouragingly a simple calculation suggested significant financial benefits over the previous cylinder system [10].

In 2013 there was a national review of the home oxygen service resulting in the consolidation of all home oxygen delivery systems under a single contractor. The transition to this new service was delivered over the course of 2013. With widespread support from respiratory clinicians, and the home care contractor facilitated by NHS Health Facilities Scotland, there was the opportunity to pursue a national home oxygen service which would offer a robust basis for the future, aiming to be cost-effective and patient focused. Clinicians were heavily involved in the discussions and the aim was for a contracted national service provider to cover all modalities and thereby remove the previous complexity. A single point of access to the service was envisaged through specialist respiratory clinical teams, ensuring that: 1) patients were optimally assessed; 2) their underlying disease was addressed; and 3) their oxygen prescription and delivery system matched their physiological needs.

The transition to the national home oxygen service has offered significant benefits from both clinical and patient perspectives. There is now equity of access through a single point of contact, thus all patients should have an accurate diagnosis following appropriate clinical assessment and the appropriate modality of supplemental oxygen subsequently prescribed. The transition also offered the opportunity for a further review of the benefits of the change, and of HomeFill in particular. Following the initial phase of the changeover there was the opportunity to conduct a postal survey of 750 individuals who had been provided with HomeFill systems, as reported previously. A quick calculation suggested financial savings in excess of 70% compared with delivered ambulatory oxygen cylinders and prompted a more comprehensive economic analysis [16] through the York Health Economics Consortium (University of York, York, UK). York Health Consortium conducted a comprehensive economic analysis of the differences between the previous home oxygen service in NHS Scotland and the HomeFill system. They looked at the nationally available date on prescribing costs of cylinder oxygen and developed a costing model that incorporated cylinder costs, oxygen conserver devices where used, and consumables such as tubing and oxygen nasal/mask delivery equipment. They compared the important delivery costs with the costs of HomeFill including the rental fee of equipment as well as electricity use / costs and reimbursement.

Table 1 *Difference between cylinder delivery and HomeFill costs per patient per month*

Oxygen usage	Flow rate L·min^{-1}					
	1	2	3	4	5	6
0.5 h per day	N/A	N/A	N/A	–€189	–€221	N/A
0.75 h per day	N/A	N/A	N/A	–€249	–€296	N/A
1.5 h per day	N/A	N/A	–€344	–€440	–€536	N/A
2.5 h per day	N/A	–€380	–€541	–€702	–€863	N/A
4 h per day	N/A	–€580	–€841	–€1104	–€1364	N/A

N/A: not applicable.

As anticipated from the initial review and simple calculations, there is significant financial benefit due to the use of HomeFill. Table 1indicates the potential monthly savings per patient based upon ambulatory oxygen cylinder use. Calculations indicate a cost for three cylinders of approximately €100 per week, or €5200 per year, compared with a cost for HomeFill of just €1100 per year, *i.e.* a saving of approximately €4000 for each patient.

The economic analysis was conservative in that it assumed equivalence of outcomes for both modalities and did not take into consideration any potential clinical benefits in the modelling. Even with this conservative estimate, the provision of the HomeFill system to ~1000 patients saves about €2 million per year in Scotland. The health economics team indicate that for a more realistic figure one can anticipate that many patients are using a flow rate of ~2 L per min and are perhaps using the ambulatory oxygen HomeFill cylinders for an average of a couple of hours per day, giving an estimated saving of about €4–6 million per annum.

Potential for reduction in carbon emissions with the self-fill system

The current NHS Scotland home care oxygen contractor was asked to provide a calculation of home

Self-evaluation questions

1. What are the potential benefits for self-fill oxygen technologies in the following areas?
   a) For users
   b) For healthcare providers
   c) For the environment

Suggested answers

1. a) Increased time spent away from the home, relatively unlimited supply of ambulatory oxygen.
   b) Reduced costs compared to prescription of ambulatory oxygen cylinders and liquid oxygen.
   c) Reduced carbon emissions related to reduced delivery costs for these non-delivery dependent self-sufficient systems.

oxygen provision distances travelled with the delivery and maintenance of the HomeFill ambulatory oxygen systems compared to ambulatory oxygen cylinder use. They were able to provide an average vehicle speed of 40 miles·h^{-1} with an average distance of 13.3 miles travelled per home delivery visit.

Based on the assumption that individuals using the ambulatory oxygen cylinder system would require one visit per week to replenish their ambulatory oxygen cylinders, this would amount to 52 visits per year. The HomeFill ambulatory oxygen system would only require four visits per year to service the equipment, giving a reduction of 48 home visits and 638.4 miles per patient in HomeFill users. At the time of writing this review there are now 1213 HomeFill users in Scotland and the estimated reduction in travel with this system compared to the ambulatory oxygen cylinder delivery model is 774379 miles. The estimated carbon emission reduction for the HomeFill system for this number of users is 261.29 tonnes of equivalent carbon dioxide. If self-fill home oxygen systems are widely adopted and prescribed in suitably assessed individuals then there are clear financial and environmental efficiency savings for healthcare systems globally.

Conclusion

The national reform of oxygen services in Scotland has resulted in a single, consistent care pathway with the involvement of experienced clinicians improving the diagnostic/management component and delivery of a consistent national service through the use of a single service provider. The feedback from patients indicates that this has proved a positive step and certainly the new technologies have offered benefits with regard to ambulatory services, with improved QoL accompanied by significant financial savings.

There is a growing body of evidence that self-fill oxygen technology meets the ambulatory oxygen requirements of a large number of people who require LTOT and can have a positive impact on QoL, with increased time spent away from home, and offers significant financial savings to healthcare providers. For remote and rural regions, nationally and globally the appeal of non-delivery LTOT and ambulatory oxygen combined systems increases with the additional environmental impact from reduced fossil fuel consumption and carbon emissions. When patients are being assessed for LTOT we recommend that self-fill technologies should be one of the choices offered to individuals who wish to leave their home on a regular basis, with the proviso that appropriate clinical assessment has demonstrated its utility to meet ambulatory oxygen requirements. Self-fill oxygen delivery systems have been available in the UK for >5 years and whilst one could argue for a larger randomised controlled trial, the authors would propose that with the available evidence, particularly the financial impact, it should be more widely utilised.

Conflict of interest

Disclosures can be found alongside the online version of this article at breathe.ersjournals.com

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