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NEW PERSPECTIVES IN PULMONOLOGY

Long-term oxygen therapy (LTOT) revisited: In defense of non-delivery LTOT technology☆

Oxigenoterapia de longa duração (OLD) revista: Em defesa da tecnologia OLD sem fornecimento domiciliário

The term ''*non-delivery LTOT*'' is used to describe installations of newer home oxygen therapy systems where oxygen concentrator technology is used to provide both stationary and ambulatory oxygen.[1] The use of non-delivery LTOT equipment obviates the need for oxygen supply companies to make repeat (and costly) home deliveries to replenish depleted gaseous or liquid oxygen contents, the majority of which is most often used during ambulation away from the stationary system.

The evidence base for LTOT supports the use of both stationary and ambulatory oxygen systems to maintain adequate oxygenation at all times and under all conditions of use.[1,2] Non-delivery LTOT systems therefore offer hypoxemic COPD patients requiring continuous, uninterrupted supplemental oxygenation, and meaningful, real-time options. With a properly functioning non-delivery system, LTOT users now have the option of spontaneously going where they want to go, when they want to go, and how they want to go, as opposed to constantly waiting (and hoping) that a much needed re-supply delivery will take place as scheduled.

There are three options presently available to provide non-delivery LTOT.[1] One method is to use a standard stationary oxygen concentrator, in tandem with a pressure booster, to re-fill small portable cylinders. A second option is the use of a portable oxygen concentrator (POC). The third option, still under development, is a standard oxygen concentrator, used in tandem with a cryogenic liquefier, to re-fill a small canister with liquid oxygen. All three options employ the use of concentrated oxygen (≈93%) as opposed to medical grade oxygen (99.9%).

All of the aforementioned non-delivery systems incorporate the pulse dose delivery of oxygen. With pulse dose delivery, a preset volume (or bolus) of oxygen is administered at some point during the inspiratory phase of a patient's breathing cycle. In this regard, pulse dose delivery devices provide an intermittent flow (IF) of oxygen as opposed to the more ubiquitous continuous flow (CF) delivery. Oxygen administered with an IF device is quantified in milliliters (mL) per breath while the standard for CF is liters per minute (L/min).

In theory, the ability to adjust the size of a delivered pulse volume of oxygen, as well as the speed at which the selected pulse dose volume will be delivered, should facilitate optimum oxygenation. This is especially desirable during the periods of even moderate ambulation when systemic oxygen demand increases.[3] It should be noted that pulse volume dosing was originally developed to conserve gaseous or liquid contents of smaller portable units.[4] While this original oxygen conservation application is still valid when used with home re-filled gaseous or liquid cylinders, when integrated into a POC, the IF function is to prolong battery life. This raises important questions about the accuracy of oxygen dosing when a POC is used as a non-delivery LTOT system, although evidence suggests that similar issues surround the use of traditional oxygen conserving devices.[5–7]

There are two classes of POCs – those that can only operate in the pulse dose/IF mode (single-mode POCs), and those capable of operating in both the pulse dose/IF mode *and* CF mode (dual-mode POCs). On average, single-mode POCs weigh $\leq$ 4.5 kg, whereas dual-mode POCs weigh slightly more, ≈7.7 kg. The trade-off with the lighter weight single-mode POCs is a reduction in the amount of concentrated oxygen that can be produced. Where single-mode POCs produce approximately 700–900 mL of concentrated oxygen per minute, dual-mode POCs are capable of producing up to 3000 mL per minute. The larger oxygen production capability of dual-mode POCs provides prescribers and home care clinicians more options while individually titrating chronic hypoxemic patients to a target arterial oxygen saturation.[1]

All POCs (single and dual mode) share the common feature of operating from flexible power sources, i.e. standard

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household electrical outlet, the external power outlet in motor vehicles and aircraft, or a rechargeable battery. When home oxygen patients first learn about POCs, especially patients using a CF delivery device, they are quickly enamored with the lightweight feature of most single-mode POCs. The most attractive feature is the potential ability to use a 3–4 kg, easily carried device that is literally self-contained, allowing the device to be used for both stationary and ambulatory purposes. However, many soon discover that the reduced oxygen production per minute (the trade-off for the device's lighter weight) is insufficient to prevent desaturation at all times and under all conditions, especially during extended ambulation. A recent report also showed the inability of a pulse dose/IF POC to be used in conjunction with noninvasive ventilation to provide supplemental oxygen.[8]

At the root of the problem is the widely held misperception that a numerical setting on a pulse dose/IF device is equivalent to the corresponding continuous flow – e.g. a numerical setting of 1, 2 or 3 is equal to 1, 2 or 3 L/min. This is not the case and often results in unintended sub-optimal dosing. It is intuitive that the exact dose of any medication prescribed for long-term control of a chronic medical condition (e.g. hypertension, hyperlipidemia, hyperglycemia) be known. This truism applies equally when oxygen is used as a controller medication for chronic hypoxemia. Failure to know the dose of any delivered medication is not conducive to attainment of optimum clinical outcomes or sustained symptom control. With respect to sub-optimal LTOT dosing, the inability to correct underlying severe chronic hypoxemia often leads to a worsening of the deadly adverse sequelae of COPD.[9]

Regardless of which type of POC is used, when operating in the pulse dose/IF mode, the amount of the oxygen pulse volume (in mL) must be known for each numerical setting. It is also essential to know the delivered oxygen purity at a particular setting, as well as the effect an increase in the breathing rate would have on the delivered oxygen purity. For example, some single-mode POC models, when set on the device's maximum setting, may well deliver oxygen purity $\geq$ 90% at a breathing rate of 12 breaths/min, only to have the oxygen purity decrease into the mid 80% range when the breathing rate increases to 20 breaths/min or higher. In this all-too common example, the patient's requirements exceed the performance capability of the selected POC. A decrease in oxygen purity typically results in periods of unintended arterial desaturation, and may lead to the incorrect perception that the disease state is deteriorating, when in fact, it is the LTOT equipment that is failing the patient.[10]

Regrettably, not all manufacturers promoting POCs for non-delivery purposes provide detailed information regarding the pulse dose volume (expressed in mL) of a particular delivery device at a specific setting. Equally frustrating is the absence of information on the impact of increased breathing rates on concentrated oxygen purity at each setting. Further, there is no consistency in the number of numerical settings a particular device may have. Some models have three settings (i.e. 1, 2, and 3) whereas others have five settings, and some even six or more. Adding further confusion is the fact that, in most cases, the selected setting does not display the delivered pulse volume. Thus, one model POC will deliver a pulse volume of 27 mL at the highest setting of 3, whereas a competing model will deliver a pulse volume of 192 mL at the highest setting of 9. The former example is characteristic of single-mode POCs whereas the latter is characteristic of the more robust dual-mode POCs. In the absence of uniform data on performance specifications, especially with single-mode POCs, the only way to ensure adequate oxygenation is to conduct an individualized titration study and equip the patient with a personal pulse oximeter.[11]

While appealing in concept, because of the aforementioned deficiencies, it must be understood that non-delivery technology is not for every LTOT user. While there may be those who cannot be adequately saturated with one model of single-mode POC, another brand single-mode POC with higher oxygen production capabilities might work. At the same time, there may those patients in whom no single-mode POC will work, but who can attain satisfactory oxygenation with a dual-mode POC. It is therefore incumbent for both prescribers of LTOT and home care clinicians to understand the capabilities and limitations of non-delivery LTOT systems. It is this writer's experience that this is the exception rather than the rule. Accordingly, it is highly recommended that patients having any type of pulse dose/IF device prescribed for any use need a titration study to determine the device's ability to maintain adequate oxygenation under all conditions of intended use.[2,12,13]

In summary, when used correctly by knowledgeable prescribers, home care clinicians and properly trained patients, non-delivery LTOT systems can provide a welcome alternative to being tethered to a large, stationary LTOT device, this in spite of the aforementioned performance limitations. Technological advances are sure to result in higher oxygen production capability of POCs even as unit weight decreases. Also on the horizon is the presumable integration of closed-loop, oximetry-driven oxygen delivery technology where oxygen dosing is automatically adjusted to maintain a target arterial saturation.[13-15] As non-delivery LTOT technology does continues to evolve, one hopes that the appropriate regulatory agencies will establish uniform standards in terms of equipment labeling, dosing representations and performance capabilities to redress the issues and concerns described herein.

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