Editorials

Demand Valves for Oxygen Therapy: Your Mileage May Vary

A decade ago oxygen therapy with a demand valve was novel.[1] Today I rarely see ambulatory patients using a reservoir cannula or transtracheal catheter (the other novel oxygen-conserving device). I also see far fewer patients using conventional (continuous-flow) oxygen valves. Most patients use demand valves with a nasal cannula, because the equipment is inconspicuous, noninvasive, smaller, lighter, and makes the oxygen last longer than conventional (continuous-flow) oxygen. Convenience has won.

Until recently, respiratory therapists (RTs) had only a handful of demand oxygen valves to consider.[1] Today they are faced with more than two dozen![2] With so many choices it is tempting to assume that one demand valve is as good as the next. The article by Bliss et al in this issue of RESPIRATORY CARE suggests that would be a mistake and is a reminder that there are important differences in demand-valve performance.[3]

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Using their bench model,[4] Bliss et al measured the amount of oxygen delivered through a nasal cannula by 18 commercially available demand valves, at settings that the manufacturers imply are equivalent to continuous flow. For comparison they tested the output of a conventional (continuous-flow) valve. Their findings are striking: less than a third of the demand-valve measurements were truly equivalent (within 10% of the oxygen delivered by the continuous-flow valve) when tested at clinically pertinent respiratory rates. More often than not, "equivalent setting" seemed to be a misnomer. Fortunately, half the demand-valve measurements *exceeded* the equivalent continuous-flow measurement, but it is disturbing that 10% of the demand-valve measurements *fell short* (ie, were less than 70% of the continuous-flow measurement).

The results for maximum demand-valve output (approximately 6 L/min) are also striking. Some demand valves provided an oxygen concentration of 40%, but output dropped by nearly a third when respiratory rate was doubled to 30 breaths/min. That some demand valves provided fairly high oxygen concentrations seems reassuring at first. However, the average resting respiratory rate of patients with stable chronic obstructive pulmonary disease is 20 breaths/min[5] so that 40% oxygen concentration probably represents "best case" performance.

A brief review of the operating principles behind demand valves may be helpful before considering the volume-referenced setting system proposed by Bliss et al. There are 4 basic types of demand valves:

1. Demand-type demand valves deliver oxygen only during inspiration and thus eliminate wasteful oxygen delivery during exhalation.
2. Pulse-type demand valves provide a bolus (pulse) of oxygen in early inspiration, which may help the oxygen enter better-ventilated lung regions. By eliminating oxygen delivery during exhalation and to dead space (from where it would be soon exhaled), pulse-type demand valves have the potential to conserve more oxygen than demand-type valves.
3. Hybrid valves combine the characteristics of pulse and demand types to provide an early inspiratory bolus followed by inspiratory flow.
4. "Smart" valves can be programmed to do interesting things. Some can deliver a relatively large oxygen bolus with each breath or during every second, third, or fourth breath. In theory, that oxygen bolus may penetrate to better ventilated lung regions and "spare" oxygen may be stored in dead space for rebreathing. Other "smart" valves can adapt to clinical responses, such as respiratory rate, and, when unable to adapt, default to continuous flow.

For simplicity, Bliss et al assumed only 2 types of demand valves, pulse and demand, and compared the concentration of oxygen provided with the volume of oxygen delivered per inhalation. The data spread was wide at higher oxygen concentrations (see Figure 3 in the Bliss et al article). Examining the lines-of-best-fit suggested that pulse-type valves provided higher concentrations of oxygen (see Figure 4 in the Bliss et al article). However, by restricting oxygen volume provided to the early part of inspiration (and accounting for the pulse principle) and reanalyzing their data, the data spread narrowed (see Figure 5 in the Bliss et al article). Bliss et al propose that their simple adjustment might permit better comparison of performance. Because the relationship is more linear, a volume-referenced setting system may eventually be used to predict performance. Time will tell if a simple volume-referenced approach will be sufficient.

Life is rarely simple. Manufacturers may eventually have to adopt a more sophisticated (and expensive) performance approach. For example, the performance (as accuracy and reproducibility) of diagnostic spirometers can be rigorously evaluated by 24 computer-generated standard waveforms.[6]

Readers should remember that the Bliss et al study was a bench study and resist the temptation to use the data to select one brand or type of demand valve over another. The study evaluated a single, basic, and important aspect of performance: oxygen output. But other aspects of performance, such as economy, were not evaluated.

Armed with the knowledge that demand valve outputs differ markedly, RTs should carefully assess the needs of each patient before selecting a specific demand valve. Needs may include simplicity of operation (no switches to turn on, no batteries to change or charge), economy, lightness, and the ability to deliver higher-than-usual oxygen flow. Remember that demand valves were designed for patients with chronic obstructive pulmonary disease and that patients with advanced interstitial lung disease may literally outrun their oxygen supply; that is, hypoxemia may occur despite providing oxygen at high flow and volume.

It may also be advisable for the RT to verify that the chosen demand valve achieves adequate oxygen saturation during both rest and activity.[7] Given the limitations of pulse oximetry,[8] some clinicians empirically aim for relatively high saturations (eg, 95% not 90%) during exercise.

Finally, long-term reliability is an important consideration that, to my knowledge, has not been reported.[9] Until then RTs should ask their patients to discuss problems with their demand valves.

Some readers may find my automobile metaphor (fuel economy rating) simplistic and obvious. One should remember that the world has had more than a century of experience with automobiles. I ask that you tolerate the metaphor once more. Astute readers will note (in Figure 2 in the Bliss et al article) that the concentration of oxygen delivered by the continuous-flow valve dropped when respiratory rate increased and recognize the phenomenon of air entrainment; that is, room air (21% oxygen) dilutes the supplemental therapeutic (100%) oxygen. Depending on circumstances, RTs may raise oxygen flow or change delivery from cannula to a high-flow/high-concentration delivery system. We often train patients to increase their oxygen flow during exercise or when dyspneic. In other words, human intervention may be required even when using a "smart" valve. In 1929 the manufacturer of a super-luxury automobile bragged about an innovation more important than the V12 engine (itself a remarkable innovation): an automatic spark advance. Why? Buyers would no longer require an experienced chauffer to adjust timing to keep the engine running smoothly under varying conditions of speed, acceleration, and altitude. Within a decade average citizens could buy automobiles with automatic spark advance.

I hope the next generation of demand valves will be "really smart" and automatically respond to clinical factors such as respiratory rate and adequacy of oxygenation while also providing economy, ease of use, and high reliability. How the engineers will accomplish this (with multiple mini-sensors? with processors programmed to accommodate a wide range of clinical circumstances?) is their responsibility. Until then RTs continue to play an important role in evaluating and applying demand oxygen valves.[10]

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