

## Assessing the Dose of Supplemental Oxygen: Let Us Compare Methodologies

Supplemental oxygen is a marvelous “drug,” with several rather unique beneficial physiologic effects. It produces well-documented long-term benefits when administered to hypoxemic patients. A multi-billion-dollar industry has been established to provide supplemental oxygen to those for whom it is indicated. Nevertheless, research into the effectiveness (especially in the long term) of different delivery techniques has been sparse. Therefore the work of Wettstein et al,<sup>1</sup> in this issue of *RESPIRATORY CARE*, is welcome, in that it explores the effectiveness of higher-flow devices than are generally used currently.

There is clearly a dose-response relationship to supplemental oxygen delivery,<sup>2</sup> and we are remarkably casual in clinical practice about how we assign supplemental oxygen dose. In part this is because the predominant mode of oxygen delivery is by nasal cannula. By choosing to deliver oxygen supplementation via only one of the 2 orifices through which we inspire, we guarantee variability in the relationship between the nasal oxygen flow and the dose of oxygen that is delivered. Newer modes of delivery, such as pulse-dose oxygen conservers, make the relationship between the quantity of oxygen supplied and its effects even more difficult to predict.

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These considerations make it important to consider carefully the methods that we use to calculate oxygen dose. Two perspectives are possible. First, we may wish to assess the oxygen concentrations that inspired gas delivers to the gas-exchange area (ie, oxygen concentration in the mixed inspirate). Second, we may wish to assess the effect of a given oxygen-delivery strategy on improving arterial oxygenation (the immediate goal of oxygen supplementation), either as an arterial partial pressure or saturation. Let us consider the 2 perspectives separately.

Assessing the mixed inspired oxygen fraction is deceptively difficult when using a nasal cannula as the delivery device. Three methods are mentioned in the literature.

- Gas can be withdrawn during inspiration from a catheter placed in the oropharynx<sup>3</sup> or the nasal pharynx. The assumption is that this sampling method provides mixed inspired gas, but this assumption is quite hazardous.

Streaming effects occur and good mixing is unlikely. It is probable that the validity of the conclusions of Wettstein et al<sup>1</sup> is seriously compromised by this effect. Consider that, during mouth breathing, supplemental oxygen delivered by nasal cannula is being “pushed” through the nose and into the nasopharynx virtually undiluted by the room air inspirate. The sampling catheter in the nasopharynx will receive an oxygen-enriched gas not representative of the mixed inspirate. This, I believe, explains (and invalidates) the authors’ counterintuitive finding that mouth breathing yields a higher oxygen concentration than nose breathing for a given nasal cannula oxygen flow. (In the interest of full disclosure, I should note that I provided the authors with this insight in my review of their manuscript. As a result, they incorporated this concept into the paper’s discussion but declined to acknowledge that it impacted the validity of their findings.)

- Gas can be sampled at a more distal point, preferably the trachea, where gas mixing is more assured. This can be accomplished with appreciable discomfort in healthy subjects,<sup>4</sup> but is more straightforward if the stable patient with a long-term tracheotomy is studied.<sup>3</sup> Inserting the sampling catheter into the trachea, then sealing the tracheal stoma and allowing the patient to respire through the upper airway should make it possible to obtain a good representation of mixed inspired gas concentration.
- The alveolar gas equation can be used to estimate the mean fraction of inspired oxygen ( $F_{I_{O_2}}$ ) from the mean expired gas concentrations.<sup>3,5</sup> It is necessary to record respired gas concentrations continuously. The simplified alveolar gas equation can be applied:

$$P_{I_{O_2}} = P_{A_{O_2}} + P_{A_{CO_2}}/R$$

where  $P_{I_{O_2}}$  is the inspired oxygen partial pressure,  $P_{A_{O_2}}$  is the alveolar oxygen partial pressure,  $P_{A_{CO_2}}$  is the alveolar carbon dioxide partial pressure, and  $R$  is the respiratory exchange ratio.  $P_{A_{O_2}}$  and  $P_{A_{CO_2}}$  can be estimated from the mean of the expired alveolar plateau once a steady state of oxygen administration is reached. The respiratory quotient may be assumed to be 0.8 or, alternatively, may be mea-

sured in a given subject from steady-state gas-exchange analysis while the subject respire room air. As ventilation-perfusion inhomogeneity will accentuate intra-breath variation in R, this technique is at least theoretically more applicable to subjects with normal lungs than to patients with lung disease. This technique requires that supplemental oxygen delivered through the nasal cannula not be allowed to "contaminate" the exhalate. This is not a problem with pulse-dose techniques that deliver oxygen only during inhalation. For continuous-flow nasal oxygen, however, the subject must exhale through the mouth, and exhaled gas must be sampled selectively from the mouth.

A further major problem in assessing inspired oxygen fraction is that it may vary substantially during the inspiration. This is clearly the case of oxygen-conserving devices that deliver oxygen in a pulse at the beginning of inspiration. It is also the case when inspired flow rate varies through the inspiration but supplemental oxygen flow does not. Variation in the diluting flow will make  $F_{IO_2}$  higher, the lower the inspired flow. The technique utilizing the alveolar gas equation mentioned above would seem to be less sensitive to this problem and is probably the only method to assess a mixed inspired concentration when pulsed-dose conserving devices are used.

The second perspective for assessing oxygen dose is to measure its effects on arterial oxygenation. This methodology can only be employed in patients who are to some degree hypoxemic without oxygen supplementation and depends crucially on the individual patient's degree of lung gas-exchange disorder. Therefore, results are often only interpretable when a substantial number of patients

are studied and the results averaged. Further, this technique is generally only employed in comparing different oxygen supplementation strategies, continuous flow to pulse-dose for example. Manufacturers of pulse-dose oxygen-conserving devices have utilized this methodology to assign "flow settings" that are purported to yield equivalent effects on arterial oxygenation as the same numerical L/min of continuous flow. This equivalence is highly unlikely to apply to all patients (because pulmonary gas-exchange defects differ among patients) and in all conditions (rest, exercise, sleep). It is good clinical practice to titrate oxygen dose *with the device the patient will be using*, at rest, during exercise, and during sleep.

Further studies investigating better methods for adjusting oxygen dose in individual patients should be welcomed.

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