Dual Oximetry in Assessment of Cardiopulmonary Function

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"Assessment" of oxygenation may entail measurement and calculation of a variety of physiologic variables. However, the oxygen tension of arterial blood (PaO₂) is by far the most common measurement utilized in the determination of "adequacy" of oxygenation. Because of ease of measurement, PaO₂ often is used as a guide to oxygen therapy, ventilator adjustment, and other therapeutic interventions. Some clinicians have suggested a mathematical manipulation of PaO₂, alone or in combination with other variables, in order to improve diagnostic accuracy and assessment of pulmonary function. The perceived advantage of using the alveolar arterial O₂ tension difference (AAD), the arterial/alveolar oxygen tension ratio (AAI), the PaO₂/FiO₂ ratio (PFI), etc., rather than the PaO₂ alone, often is far greater than the actual advantage. It is apparent that the ease and efficiency of measurements and calculations has played a greater role in determination of monitoring practices than have accuracy and efficacy. Because of advances in monitoring technology during the last decade, a reassessment of monitoring techniques is indicated.

Ultimately, a primary purpose of the cardiorespiratory system is to deliver an adequate volume of oxygen to the periphery to meet metabolic demand. In the past, measurement techniques for determination of oxygen delivery (O₂ del) and oxygen consumption (VO₂) have been cumbersome, time consuming, of questionable accuracy, and difficult to apply in routine clinical situations. Thus, it is not surprising that clinicians have developed only a vague and superficial understanding of oxygen utilization (O₂ util) and its assessment. The flow-directed pulmonary artery catheter has caused significant advances in monitoring of pulmonary and cardiovascular function. However, until recently, even this technology has allowed only intermittent monitoring of some aspects of cardiopulmonary function.

Although the technology for continuous measurement of oxyhemoglobin saturation has been available for more than a decade, only recently has widespread interest been generated. Appropriate use of oximetry requires an understanding of the dynamics of oxygen transport and how alteration in cardiopulmonary function may effect arterial and venous oxyhemoglobin saturation. Recent advances in oximetry, both economic and technical, warrant a reconsideration of the appropriateness of current monitoring practices and assessment of newer, and perhaps more accurate, techniques.

For more than two decades, PaO₂ measurement has formed the basis for pulmonary function monitoring, especially in critically ill patients. For a similar period of time, clinicians have debated whether arterial blood oxyhemoglobin
saturation (SaO₂) or PaO₂ should be monitored. Both measurements have advantages and disadvantages in the accurate assessment of pulmonary function. Similarly, given certain clinical circumstances, oxyhemoglobin saturation will allow more accurate monitoring of pulmonary function than will oxygen tension measurement and given a different set of circumstances, the reverse will hold true. Arterial hypoxemia may result when some areas of the lung have decreased ventilation (Vₐ) with relatively higher levels of concentration (Q). In addition, as the inspired oxygen concentration (FIO₂) is decreased, the hypoxemia producing effect of such low Vₐ/Q areas will be enhanced. Only when an individual breathes pure oxygen will such areas be masked and subsequent arterial hypoxemia attributed only to direct, right-to-left intrapulmonary shunting of blood (Qₛₚ/Qₜ). In order to assess the relative importance of areas with low Vₐ/Q, a two-compartment model composed of normal lung and lung with no ventilation, but persistant perfusion, was proposed. In order to calculate physiologic right-to-left intrapulmonary shunting of blood using this two-compartment model (FIO₂ < 1.0), the clinician must have access to mixed venous blood from the pulmonary artery. Until recently, such access was relatively uncommon. This led clinicians to assume a fixed value for mixed venous blood oxygen content and arterial-venous blood oxygen content difference. By so doing, any variation in arterial blood oxygen content, saturation, or oxygen tension, would be attributed to alteration in pulmonary function. Thus, PaO₂-based calculations of AAD, AAI, PFI, etc., were proposed to assess the efficiency of pulmonary gas exchange. Unfortunately, one may not assume a fixed value for the arterial-mixed venous blood oxygen content difference, and any variable based on such an assumption is likely to be grossly inaccurate, especially in critically ill patients (Fig. 1). In fact, any alteration in cardiac output, oxygen consumption, or hemoglobin con-

Fig. 1. Mathematical relationship between Qₛₚ/Qₜ and PFI, plotted with C(a-̇v)O₂ levels ranging from 2.0 to 8.0 ml/dl. Average normal values were set for Hgb (15.0 g/L), PaCO₂ (40 mmHg), and RQ (0.8). FIO₂ was assumed to be 0.5