The pulse oximeter has become a virtually indispensable monitor for measuring a patient’s peripheral capillary oxygen saturation (Spo2) accurately and reliably in a continuous, noninvasive fashion.1 Despite its ubiquitous use as a detector of hypoxemia, pulse oximetry has limited utility to herald an oxygen desaturation event until the partial pressure of oxygen (Pao2) falls below 80 mmHg. Above this threshold, a patient’s Spo2 will typically remain at or near 100%, whereas Pao2 may be accelerating quickly past the inflection point of the oxygen–hemoglobin dissociation curve and proceed to decrease rapidly.2 In this issue of Anesthesiology, Szmuk et al.3 present a pilot study of the oxygen reserve index (oRI), a novel pulse oximeter–based nondimensional index that may provide a clinically important warning of impending desaturation in patients who have increased Pao2 levels. The authors report results from a prospective clinical trial in children that measured oRI after preoxygenation, induction of general anesthesia, successful tracheal intubation, and then disconnection of the anesthesia circuit. Their major finding was that the oRI indicated impending desaturation at a median of 31.5 s (interquartile range, 19 to 34.3 s) before noticeable changes in Spo2 occurred.

The authors performed a prospective cohort study at a single, tertiary pediatric hospital. A total of 25 healthy children aged 3 to 12 yr were studied using a pulse oximeter that was equipped to collect the optical raw data needed to compute ORI. Anesthesia was induced with 8% sevoflurane in 100% O2 supplemented by intravenous propofol and fentanyl. On confirmation of tracheal intubation, the anesthesia circuit was disconnected to eliminate apneaic oxygenation, and the saturation was permitted to fall to 90%. The anesthesia circuit was reconnected immediately, and the patients were ventilated with 100% oxygen. The ORI and Spo2 values were recorded at 1-s intervals at the beginning of apnea, beginning and end of intubation, beginning and end of the ORI alarm (calculated offline using the manufacturer’s proprietary algorithm), and 2 min after reoxygenation. The authors defined the early warning time as from the beginning of the rapid decrease of the ORI values (indicated by the start of the reserve index alarm), until saturation reached 98%. Alarm activation was based on the rate of change in ORI not on a specific ORI value. The ORI was at 0 (its minimum value) when Spo2 was less than 98% and increased rapidly as Spo2 increased to 99% and higher during reoxygenation.

The authors’ study of ORI bears significant promising clinical and translational implications. The traditional process of intubation via direct laryngoscopy and tracheal tube placement in preoxygenated, apneic patients involves some guesswork. Clinicians must constantly estimate a patient’s oxygen reserve and how much time remains to intubate safely before the attempt must be aborted and ventilation must be resumed. Although pulse oximetry can help to prevent anesthesia-related mishaps during this process, the monitor’s lag time makes it a suboptimal detector of impending hypoxemia.4,5 Indeed, despite the widespread availability and use of pulse oximetry and capnography, the most common acute severe complications in pediatric anesthesia are related to airway management and the respiratory system.6 ORI has the potential to answer one of the most crucial questions during intubation: how
much time does the patient have remaining for this intubation attempt before he or she desaturates? As Szmuk et al. have shown, ORI takes a ubiquitous early warning system and makes it an even earlier warning system. In addition, ORI can indicate when patients have been adequately preoxygenated and might have utility as an adjunct monitor of hypoventilation in patients who are on supplemental oxygen and whose $P_{O_2}$ is increased.

The study design was appropriate for a pilot study, and the study subjects and anesthetic protocol reflect typical pediatric anesthesia practice. The monitor used for this study was not equipped to display ORI; thus, investigators were blinded to the ORI values throughout the study period. Measurements were made with adequate granularity (1-s intervals). However, the study had several weaknesses and limitations, many of which the authors mention: the authors did not test the utility of ORI in abnormally high oxygen consumption states; the study population was small in number and consisted entirely of preoxygenated, apneic healthy children; no arterial blood gas sampling was performed to determine the correlation between ORI and $P_{O_2}$; the ORI measurements were obtained from a pulse oximetry sensor on the patient’s toe, which likely increased the $S_{P_{O_2}}$ delay in the setting of acute hypoxemia; and ORI was validated in a study of 11 adult volunteers that was neither peer reviewed nor published. Finally, ORI remains available only for investigational use in the United States.

Pulse oximetry is used worldwide every day despite minimal empirical evidence that the monitor improves outcomes, although some have argued that at this point pursuing such research would be similar to designing a randomized controlled trial to prove that parachutes are safe. Szmuk et al. have provided an exciting pilot study of a promising advancement in pulse oximetry technology. This study is an important first step in understanding the clinical utility and relevance of ORI and how it can improve patient monitoring and safety in the perioperative setting and throughout the hospital. Substantial work remains to determine the accuracy and reliability of ORI and to validate and optimize the ORI alerts in various patient populations—particularly in higher risk patients such as children, parturients, the critically ill, and those with diminished pulmonary reserve. All anesthesiologists should appreciate advanced warning of impending oxygen desaturation. Every second counts during those crucial moments, and novel technology that has the potential to warn clinicians sooner than the current technology is worth a much closer look.

Competing Interests

The authors are not supported by, nor maintain any financial interest in, any commercial activity that may be associated with the topic of this article.

Correspondence

Address correspondence to Dr. Simpao: simpaoa@email.chop.edu

References

2. Davis DP, Hwang JQ, Dunford JV: Rate of decline in oxygen saturation at various pulse oximetry values with prehospital rapid sequence intubation. Prehosp Emerg Care 2008; 12:46–51