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Making use of the Oxygen Reserve Index (ORi™): a new parameter of oxygenation reserve potential

Keisuke Yoshida*, Tsuyoshi Isosu and Masahiro Murakawa

Department of Anesthesiology, Fukushima Medical University School of Medicine, Fukushima, Japan

Abstract

The Oxygen Reserve Index (ORi™) is a new parameter for monitoring oxygen reserve noninvasively. ORi indicates real-time oxygenation reserve status in the mild hyperoxia range (partial pressure of oxygen [PaO_2] of about 100 to 200 mmHg) and can be measured non-invasively by applying an exclusive sensor to a finger. ORi is a nondimensional index with a range of 0.00 to 1.00 that changes according to the oxygenation reserve status of the patient. In this mini-review, we provide an overview of reports on ORi and discuss how to make use of this index in clinical practice.

Introduction

Monitoring of oxygen status is essential in respiratory care. The arterial oxygen saturation (SpO_2) monitor was first developed in the 1970s [1] and SpO_2 has now become a required indicator to estimate the oxygen saturation of arterial blood noninvasively. However, SpO_2 has some weak points. When partial pressure of oxygen (PaO_2) increases beyond 100 mmHg, SpO_2 remains maximal (close to 100%); therefore, SpO_2 is not suitable for determining the degree of hyperoxemia. In addition, at about the time SpO_2 falls, the decline of PaO_2 passes the inflection point of the oxygen-hemoglobin dissociation curve and accelerates quickly, and thereafter, SpO_2 decreases rapidly with the decline of PaO_2 [2]. Therefore, even if measures are taken soon after SpO_2 drops, there is a risk of hypoxemia.

The Oxygen Reserve Index (ORi™) (Masimo Corp., Irvine, CA, USA) is a new parameter that indicates real-time oxygenation reserve status in the mild hyperoxia range (PaO_2 of about 100 to 200 mmHg). ORi can be measured noninvasively by applying a sensor that is similar in form to a pulse oximeter sensor. This sensor uses multiwave length pulse co-oximetry and is shielded to avoid light exposure. ORi is a nondimensional index that changes according to the oxygenation reserve status from 0.00 (no reserve) to 1.00 (much reserve) [3]. ORi has unique characteristics that differ from SpO_2 but has only just been introduced and there are few reports on ORi at present.

ORi as an alarm for deterioration in oxygenation

ORi has the potential to be used as an alarm for deterioration in oxygenation in general anesthesia. During induction of anesthesia in 25 children, Szmuk et al. found that ORi rapidly decreased 31.5 s (interquartile range, 19-34.3 s) before SpO_2 decreased to 98% [4], using the ORi alarm according to the manufacturer's proprietary algorithm. It was concluded that knowing even roughly how much time remains before the rapid desaturation phase begins is likely to guide proper decisions.

We investigated the utility of ORi for Rapid Sequence Induction (RSI) of general anesthesia in 20 adult patients. RSI is a technique designed to secure the airway from aspiration of gastric contents in the induction of general anesthesia. However, during RSI, patients experience apnea without ventilation; hence, RSI has a risk for occurrence of hypoxemic events. ORi began to decline 32.5 s (interquartile range 18.8-51.3 s) before SpO_2 began to decline in 77% of patients [5]. We also found that ORi varies greatly among individuals; therefore, it is important to monitor based on ORi trends, rather than specific values, in RSI.

These two reports suggest that monitoring of ORi with SpO_2 predicts hypoxemia-related complications after tens of seconds in clinical settings beyond general anesthesia. In patients requiring mechanical ventilation, the disruption of oxygenation during suction through an endotracheal tube is the same situation as described above. The risk of a sudden change in oxygenation status is also high due to a sudden change of respiration or circulation dynamics, blockage of the intubation tube, and loss of respiratory circuits. Therefore, ORi monitoring may enable earlier recognition of hypoxemia in acute status patients.

ORi as an indicator of hyperoxia

In intensive care, there are many reports on adverse effects related to hyperoxemia [6-8], including association of hyperoxemia with increased mortality in patients with stroke, traumatic brain injury, and those resuscitated from cardiac arrest [9]. Hyperoxic acute lung injury is also related to hyperoxemia, and Kallet et al. showed that hyperoxia produces high levels of reactive oxygen species that overwhelm natural antioxidant defences and destroy cellular structures [10]. Despite these adverse effects of hyperoxemia, this condition often develops in clinical settings [11]. Graaff et al. found that hyperoxia is frequently seen, but in

Correspondence to: Keisuke Yoshida, Department of Anesthesiology, Fukushima Medical University School of Medicine, Fukushima, Japan, Tel: +81-24-547-1342, Fax: +81-24-548-0828, E-mail: kei-y7of@fmu.ac.jp

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most cases does not lead to adjustment of ventilator settings if fraction of inspiratory oxygen (F_IO_2) <0.41 [12]. Moreover, it was suggested that one of the causes of non-adjustment of ventilator settings is that medical staff prefer some level of hyperoxia because monitoring of PaO_2 is relatively infrequent. Therefore, monitoring using ORi may improve this situation.

Regarding the relationship between ORi and PaO_2, Applegate et al. compared 485 sets of ORi and PaO_2 values from 106 patients and found a positive correlation when PaO_2 was ≤240 mmHg (r^2 = 0.536), but not when PaO_2 was >240 mmHg (r^2 = 0.0016) [13]. It was also found that ORi >0.24 can identify PaO_2 ≥100 mmHg when SpO_2 is >98%, and that ORi >0.55 appears to be a threshold for PaO_2 >150 mmHg. Therefore, this study suggests that measurement of ORi will allow an estimation of PaO_2 in the mildly hyperoxic or greater range. The study used intraoperative ORi data, but if the results are also applicable in intensive care, clinicians may be able to adjust ventilation settings without frequent PaO_2 analysis. If ORi can detect ineffectual hyperoxia, use of high F_IO_2 will be decreased and hyperoxia-related complications may be reduced.

Prospects for future use of ORi

There are several areas that need to be explored to establish future use of ORi. First, ORi varies among individuals, and there is some variation in the relationship between ORi and PaO_2. Patient factors such as age, physique, and body temperature may affect ORi, but the details are unclear, and ORi may also be affected by other factors. In daily use of ORi during general anesthesia, we found that the index fluctuates with changes of posture and pneumoperitoneum. Isosu et al. found that ORi rapidly decreased after intravenous injection of indigo carmine in all of 20 patients who underwent elective gynecologic surgery [14]. A better understanding of the factors that influence ORi will make it possible to estimate PaO_2 range from ORi more accurately.

A second question refers to utilization of ORi in intensive care settings. ORi is useful in the mild hyperoxic range (PaO_2 100-200 mmHg), and therefore, the index might be suitable for critically ill patients under mechanical ventilation. However, at present, there are no data for ORi in intensive care, and further clinical studies are needed. By understanding the features of ORi and SpO_2 and using these two monitoring parameters together, it may be possible to adjust a ventilator noninvasively without sampling arterial blood.

In this review, we have outlined published reports on ORi and discussed the usefulness of this index. Further studies are required to make use of the unique characteristics of ORi.

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