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ORIGINAL RESEARCH

Oxygen reserve index (ORi™) contributes to prediction of hypoxemia and patient safety during tracheal stent insertion using rigid bronchoscopy: a case report

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Abstract
The oxygen reserve index (ORi™) is a new noninvasive and continuous variable, which represents a moderate hyperoxygenation status, with a unitless scale between 0.00 and 1.00. When percutaneous oxygen saturation (SpO_2) exceeds 100%, arterial blood oxygen partial pressure cannot be evaluated without performing arterial blood gas analysis. Because of significant air leakage during rigid bronchoscopy, it is difficult to monitor respiration using capnography, which does not measure end-tidal carbon dioxide ($ETCO_2$) accurately. A 66-year-old man (175 cm, 76.8 kg) with a chief complaint of difficulty in breathing was diagnosed with a thyroid tumor. Computed tomography revealed tracheal stenosis due to direct invasion of the thyroid tumor; therefore, tracheal stenting was planned immediately. After supplying 6 L/min oxygen with a face mask and administering 180 mg of propofol intravenously, the supraglottic airway was intubated. General anesthesia (total intravenous anesthesia) through continuous administration of 6–10 mg/kg/h of propofol and intermittent administration of 50 μg of fentanyl (total 200 μg) preserved spontaneous breathing. During tracheal stent insertion, disconnection between the oxygen supply system and rigid bronchoscopy, and tracheal stent expansion, the ORi tended to decrease before SpO_2 decreased. Thus, measuring ORi could prevent hypoxemia during tracheal stent insertion using rigid bronchoscopy.

Keywords Oxygen reserve index (ORi) · Rigid bronchoscopy · Tracheal stent · Central airway obstruction · Pulse oximetry

1 Introduction

It is difficult to accurately determine the respiratory state while inserting a tracheal stent using rigid bronchoscopy [1]. Continuous monitoring of the oxygenation status is important for patient safety. Because of significant air leakage during rigid bronchoscopy and tracheal stent insertion, it is difficult to judge proper ventilation using capnography, which does not measure end tidal carbon dioxide ($ETCO_2$) accurately.

Pulse oximetry is an essential technique, which noninvasively and continuously monitors the oxygenation status of perioperative patients [2]. However, it is impossible to measure arterial oxygen partial pressure (PaO_2) before and after oxygen saturation reaches 100% without performing blood gas analysis.

The oxygen reserve index (ORi™) (Masimo Corp., Irvine, CA, USA) is a new variable, which represents a moderate hyperoxygenation status, with a unitless scale between 0.00 and 1.00 [3]. ORi is a variable that enables noninvasive and continuous measurement of fluctuations in approximate arterial oxygen partial pressure ranging from 100 to 200 mmHg. In a previous study, ORi facilitated the prevention of excessive oxygenation and prediction of hypoxemia [3].

Herein, we present a case wherein measurement of ORi prevented hypoxemia during tracheal stent insertion using rigid bronchoscopy.

2 Case report

A 66-year-old man (175 cm, 76.8 kg, body mass index 25.1) was visiting his doctor regularly at a local hospital for treatment of hypertension, diabetes, and bronchial asthma. He

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was admitted to the outpatient with a chief complaint of difficulty in breathing. Computed tomography (CT) revealed a thyroid tumor, tracheal invasion, and tracheal stenosis. Therefore, tracheal stenting was planned immediately.

No preanesthetic medication was administered. Electrocardiogram, non-invasive blood pressure measurement, and pulse oximetry were performed for monitoring the patient after entering the operating room. The pulse oximetry sensor (Rainbow® sensor, R1 25L, Revision M, Masimo Corp., Irvine, CA, USA), which is capable of measuring ORi, was attached to the patient's right middle finger. After shielding the sensor, the power of the Root® with Radical-7® (Masimo Corp., Irvine, CA, USA) was turned on, and the value of ORi was confirmed to be zero. Lidocaine 4% was sprayed on the tongue, pharynx, and larynx using a laryngeal spray, and local anesthesia was performed. The SeadLine® EEG Sensor (Masimo Corp., Irvine, CA, USA), which can record an electroencephalogram, was attached to his forehead. The patient's oxygen saturation was 98% in the operating room. In the supine position, preoxygenation was started through administration of oxygen 6 L/min with a face mask.

The patient was administered propofol 180 mg intravenously, before a supraglottic airway device, i-gel®, (INTERSURGICAL Ltd., Wokingham, Berkshire, UK), size 4, was inserted into the patient's oral cavity. Airway management was confirmed through capnography, which detected $ETCO_2$, revealing the carbon dioxide concentration in expiration; also, the patient's spontaneous respiration was continuously determined. Continuous propofol infusion was adjusted for intravenous administration at 6–10 mg/kg/h while maintaining the value of patient state index (PSi™) between 25 and 50. The PSi corresponds to values of 40–60 of the bispectral index (BIS) [4]. When the PSi was > 50, propofol 30 mg was additionally and intermittently administered. Fentanyl 50 µg was administered before performing rigid bronchoscopy. In addition, arterial blood pressure was monitored continuously. A flexible bronchoscope was inserted via the i-gel, and the trachea, tracheal bifurcation, and the stenotic site were observed. Two tumors occluding the airway were detected on the left side wall of the trachea about 3 cm peripherally from the vocal cord. The tumor on the mouth side was covered with a normal trachea epithelium, but the lesion was exposed on the surface of the tumor on the caudal side.

After removing the flexible bronchoscope, oxygen was administered via the i-gel until the value of ORi reached a plateau. The value of ORi did not exceed 0.51 during the operation, although sufficient oxygen was administered. A rigid bronchoscope was inserted after removing the i-gel. Dumon TD 18 (Novatech SA, La Ciotat Cedex, France), which is a type of tracheal stent, was inserted under rigid bronchoscopy. The tracheal stent was straight, and the sizes of the stent were as follows: outside diameter, 18 mm; thickness, 1.5 mm. Spontaneous assisted ventilation [1], namely, preserving spontaneous breathing using an anesthesiologist-assisted manual ventilation technique, was performed during rigid bronchoscopy and oxygen administered through the side port. Oxygen and air flow, arterial oxygen partial pressure, and respiration rate detected with $ETCO_2$ are shown in Fig. 1. Figure 1 also shows the changes and the values of ORi and SpO_2 during the operation. At the time of tracheal stent insertion, ORi was zero and the pulse oximetry reading was maintained at 99% (tracheal stent in Fig. 1). The tracheal stent migrated to the distal side of the trachea and its position was corrected with a pair of endoscopic forceps. Subsequently, the ORi declined (disconnection in Fig. 1), and its cause was investigated immediately; however, the pulse oximetry reading did not drop to less than 99%. It was found that the decline in ORi was due to accidental disconnection between the oxygen supply tube and rigid bronchoscope. Because these were reconnected immediately after the problem was identified, the patient did not fall into a hypoxemic state. Owing to the insufficient tracheal stent expansion, the lumen of the tracheal stent was dilated using an esophageal dilatation balloon (CRE™ balloon dilator; Boston Scientific, Boston, MA, USA). Two nylon threads were sutured between the patient's neck and the tracheal stent. We confirmed hemostasis and ended the operation. We performed arterial blood gas analysis three times during the operation. The timings were as follows: first, after inserting the supraglottic airway (SGA); second, before inserting the rigid bronchoscope; third, after re-connecting the oxygen supply tube with the rigid bronchoscope (Fig. 1). Chest X-ray imaging revealed the appropriate position of the tracheal stent that we had inserted.

The operation time was 25 min, and the anesthesia time was 132 min. The volume of infusion was 800 mL of 1% glucose-added acetate Ringer's solution, the urine volume was 70 mL, and the balance was + 730 mL.

3 Comment

In the present case, safe anesthetic management and avoidance of hypoxemia were achieved through ORi monitoring during tracheal stent insertion. Anesthetic management for the tracheal stenting procedure in our hospital usually involves general anesthesia, which preserves spontaneous breathing without muscle relaxant administration. Surgeons prefer this anesthetic technique because it prevents sputum and saliva from accidentally entering the lungs. Alternatively, rigid bronchoscope insertion requires deep level sedation and immobilization because it is highly irritating to the patients. Opioids, which are powerful analgesics, often cause respiratory depression. It is difficult to administer an appropriate amount of opioid while preserving

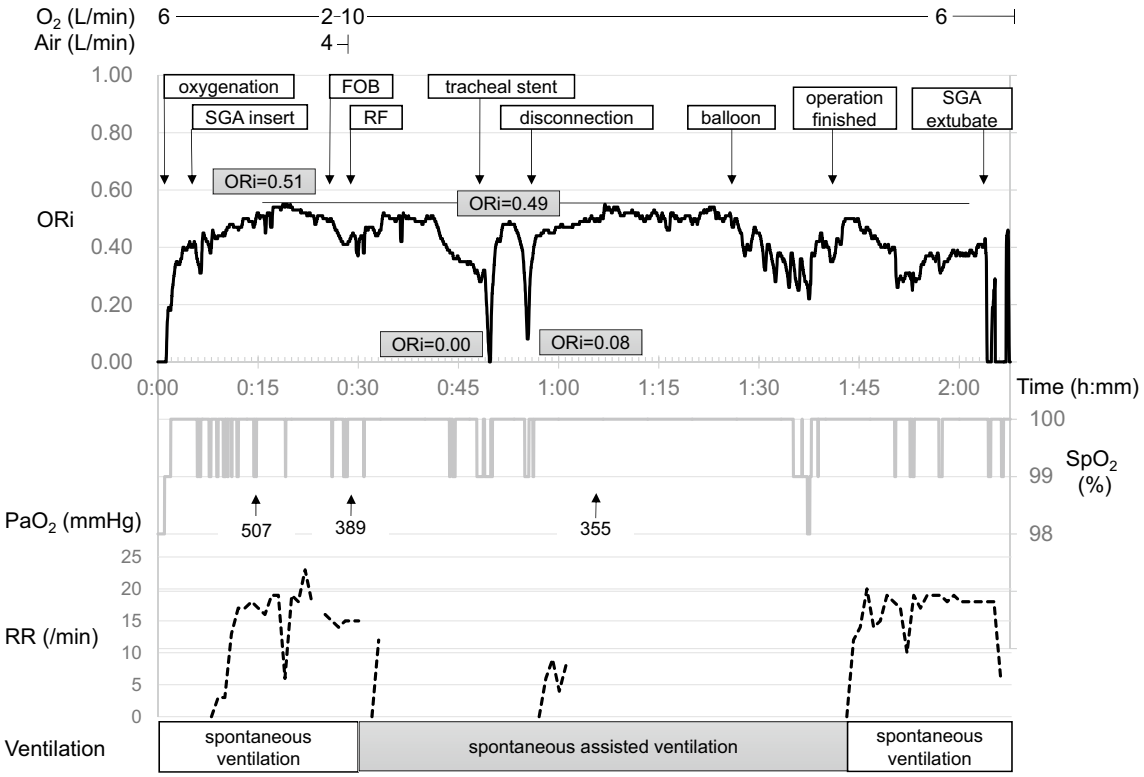

Fig. 1 The oxygen reserve index (ORi) and percutaneous oxygen saturation (SpO_2) values are indicated at each point. Oxygenation = the time at which oxygen 6 L/min was administered with a face mask, SGA insertion = the time at which the supraglottic airway (SGA) device was inserted, FOB = the time at which the fiber optic bronchoscope was inserted via the SGA, RF = the time at which the rigid bronchoscope was inserted, tracheal stent = the time at which the tracheal stent was inserted and expanded, disconnection = the time at which the rigid bronchoscope and oxygen supply tube were found disconnected, balloon = the time at which the esophageal balloon expanded the tracheal stent, end of operation = the time at which the tracheal stent procedure was completed and the SGA device was reinserted, SGA extubate = the time at which the SGA device was extubated, PaO_2 = arterial oxygen partial pressure, RR = respiratory rate measured with capnography

spontaneous respiration. Some reports have described that it could be safely managed even if a muscle relaxant is used [5]. Whether muscle relaxants can also be used remains controversial [1, 6].

ORi values showed a declining trend approximately 30 s before oxygen saturation dropped [7]. The time preceding the pulse oximetry reading drop is beneficial for anesthesiologists, providing them time to safely investigate problems in the anesthetic machine and oxygen supply system. In the present case, we noted the declining trend of ORi that preceded the discontinuation of oxygen supply before oxygen saturation dropped; thus, we were able to prevent hypoxemia. The Guideline of the American Society of Anesthesiologists' Monitored Anesthetic Care states that endoscopic examination of a patient in a deep sedative state should be performed under the supervision of anesthesiologists [8]. In addition, in a case presented by Applegate et al., the patient's PaO_2 was over 100 mmHg at a rate of 100% when the ORi was over 0.24 [9]. Vos et al. reported that the relative change in ORi is important and the absolute value of ORi should not be used to evaluate PaO_2 [10]. To date, the value indicated by pulse oximetry as 100% was the highest level of noninvasive monitoring. ORi serves as an indicator that can prevent hypoxemia; also, surgeons could expect to quickly resume the operation if problems arise. It is conceivable that continuing oxygen administration until the ORi values reach a plateau after the pulse oximetry reading reaches 100% contributes to patient safety.

In conclusion, assessing downward trends of ORi values could prevent hypoxemia during tracheal stent insertion using rigid bronchoscopy.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Written informed consent was obtained from the patient.

References

1. Pathak V, Welsby I, Mahmood K, Wahidi M, MacIntyre N, Shofer S. Ventilation and anesthetic approaches for rigid bronchoscopy. Ann Am Thorac Soc. 2014;11:628–34. https://doi.org/10.1513/AnnalsATS.201309-302FR.
2. Aoyagi T. Pulse oximetry: its invention, theory, and future. J Anesth. 2003;17:259–66. https://doi.org/10.1007/s00540-003-0192-6.
3. Scheeren TWL, Belda FJ, Perel A. The oxygen reserve index (ORI): a new tool to monitor oxygen therapy. J Clin Monit Comput. 2018;32:379–89. https://doi.org/10.1007/s10877-017-0049-4.
4. Soehle M, Kuech M, Grube M, Wirz S, Kreuer S, Hoeft A, Bruhn J, Ellerkmann RK. Patient state index vs bispectral index as measures of the electroencephalographic effects of propofol. Br J Anaesth. 2010;105:172–8. https://doi.org/10.1093/bja/aeq155.
5. Conacher ID. Anaesthesia and tracheobronchial stenting for central airway obstruction in adults. Br J Anaesth. 2003;90:367–74.
6. Perrin G, Colt HG, Martin C, Mak M-A, Dumon J-F, Gouin F. Safety of interventional rigid bronchoscopy using intravenous anesthesia and spontaneous assisted ventilation. Chest 1992;102:1526–30. https://doi.org/10.1378/chest.102.5.1526.
7. Szmuk P, Steiner JW, Olomu PN, Ploski RP, Sessler DI, Ezri T. Oxygen reserve index: A novel noninvasive measure of oxygen reserve—a pilot study. Anesthesiology 2016;124:779–84. https://doi.org/10.1097/ALN.0000000000001009.
8. American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. Practice guidelines for sedation and analgesia by non-anesthesiologists. Anesthesiology 2002;96:1004–17.
9. Applegate RL 2nd, Dorotta IL, Wells B, Juma D, Applegate PM. The relationship between oxygen reserve index and arterial partial pressure of oxygen during surgery. Anesth Analg. 2016;123:626–33. https://doi.org/10.1213/ane.0000000000001262.
10. Vos JJ, Willems CH, van Amsterdam K, van den Berg JP, Spanjersberg R, Struys MMRF, Scheeren TWL. (2018) Oxygen reserve index: validation of a new variable. Anesth Analg. https://doi.org/10.1213/ane.0000000000003706 (**Epub ahead of print**).