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EDITORIAL

Nasal high-flow preoxygenation for endotracheal intubation in the critically ill patient? Con

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In 1959, Weitzner et al. published a cornerstone clinical study addressing the issue of arterial desaturation during apnoea following induction of general anaesthesia [1]. They showed that face-mask ventilation with 100% inhaled oxygen (O_2) before apnoea enabled the maintaining of arterial oxygen saturation up to 4 min in contrast to less than 1 min following ventilation with air. In 2019, preoxygenation is recommended for all patients before induction of anaesthesia and endotracheal intubation, and the end point of maximal preoxygenation is defined as an end tidal oxygen concentration (ETO_2) ≥ 90% [2]. Preoxygenation remains an area of research because hypoxaemia during upper airway management is still a concern in the operating room [2] and much more so in the intensive care unit where severe hypoxaemia and cardiac arrest have been reported to occur in 26% and 2.7%, respectively, during orotracheal intubation of adult critically ill patients [3, 4]. Furthermore, technological progress in anaesthesia machines, intensive care units ventilators, and oxygenation devices could improve the efficacy of preoxygenation and must be evaluated.

In the present issue of *Intensive Care Medicine*, Guitton et al. reports the results of a multicentre randomized controlled trial comparing high-flow nasal oxygen (HFNO) to bag-valve mask oxygenation for preoxygenation in non-severely hypoxemic adult patients requiring orotracheal intubation [5]. They show that preoxygenation with HNFO failed to improve the lowest SpO_2 during intubation as compared to the "worst" method of preoxygenation in these patients (i.e. spontaneous breathing through a bag-valve mask).

Our first comment will recall that, in patients with acute respiratory, haemodynamic, and neurological failure requiring rapid airway control, increased oxygen consumption, decreased functional residual capacity, decreased cardiac output, loss of patient's cooperation, and increased risk of unanticipated difficult airway act synergistically to dramatically increase the time for maximal preoxygenation [6, 7], and the risk of severe hypoxemia during orotracheal intubation [3]. It has been convincingly shown in such patients that preoxygenation should be performed using non-invasive ventilation (NIV) with positive end expiratory pressure (PEEP). In adult patients with acute respiratory failure or hypoxaemia, preoxygenation through NIV with PEEP has been shown to maintain SpO_2 and arterial partial pressure of O_2 better than preoxygenation with a bag-valve mask [8, 9]. In healthy patients, NIV with PEEP significantly reduced the time to obtain a maximal preoxygenation (i.e. ETO_2 ≥ 90%) [10]. Finally, besides its specific pulmonary effects, NIV with PEEP has been shown to ensure an optimal preoxygenation through counteracting inward air leaks resulting from an ineffective face-mask seal [11].

Second, it is now the time in intensive care units to monitor the efficacy of preoxygenation (i.e. ETO_2) and not only the lowest SpO_2 during orotracheal intubation which is a serious adverse event related, at least in part, to inadequate preoxygenation [1]. Monitoring ETO_2 is a standard of care in the operating room [2] because physiologic models and clinical studies have shown that the rate of oxyhaemoglobin desaturation is highly sensitive to the initial fraction of alveolar oxygen [1, 6, 7]. These models have also shown that hypovolaemia, anaemia,

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reduced cardiac output, pulmonary ventilation-perfusion mismatch, hypoventilation and reduced alveolar volume contribute to shorten the onset of hypoxaemia during apnoea [4]. All these variables can contribute to the high rate of severe hypoxaemia and cardiac arrest associated with orotracheal intubation in adult critically ill patients [3, 4].

High-flow nasal O_2 allows for delivering up to 60 l min^{-1} of heated and humidified gas with 21–100% inspired O_2 fraction. Over the past decade, HFNO has been shown to improve oxygenation, dyspnoea, and comfort in acute hypoxaemic respiratory failure as compared to conventional oxygen therapy [12]. However, the effectiveness of HFNO depends on the following mandatory conditions: the patient must breathe with his mouth hermetically closed, the patient's peak inspiratory flow must remain lower than 60 l min^{-1}, and the size of the nasal cannula must be adapted to the patient's nostril size to limit inward air pollution. If these conditions are fulfilled, HFNO decreases resistance of the upper airway, decreases work of breathing, induces a moderate positive expiratory nasopharyngeal pressure, and reduces oxygen dilution with room air [12]. Unfortunately, a patient with acute respiratory or haemodynamic failure breathes with his mouth largely open in order to decrease inspiratory flow resistance. Furthermore, to cope with the mismatch between O_2 demand and supply, respiratory pattern changes and the peak nasal and oral inspiratory flow can be as high as 110 and 280 l min^{-1}, respectively [13]. In such cases, inward air dilution is unavoidable during HFNO resulting in a significant decrease in the inspired concentration of O_2 which precludes maximal preoxygenation [10]. We recently showed in healthy volunteers that HFNO resulted in a lower and highly variable ETO_2 than preoxygenation through a face mask [14]. After 3 and 6 min of preoxygenation through HFNO, only 4% and 46% of volunteers had an $ETO_2 \geq 90\%$, respectively.

Together, these data clearly show that HFNO is not a reliable method of preoxygenation. First, it is impossible to closely monitor the ETO_2 which is the most useful index of maximal preoxygenation. Second, data show that the ETO_2 obtained following preoxygenation with HFNO is lower than 90% and highly variable. We must never forget that the rate of oxyhaemoglobin desaturation is highly sensitive to the initial alveolar fraction of oxygen. Third, the mandatory conditions required to ensure the effectiveness of HFNO (mouth closed, peak inspiratory flow < 60 l min^{-1}) may not be fulfilled in critically ill patients with acute respiratory, haemodynamic, and neurologic failure.

Nevertheless, the advantage of HFNO is in providing an efficient apnoeic oxygenation [12]. We suggest that it should be used as an adjunct to preoxygenation through NIV, as recently reported by Jaber et al. [15]. This study suggests that a combination of preoxygenation through NIV with apnoeic oxygenation through HFNO resulted in a significantly higher minimal SpO_2 during intubation than preoxygenation with NIV alone.

In conclusion, the higher the measured ETO_2, the longer will be the apnoea without desaturation. We

Table 1 Modifiable safety factors to prevent respiratory complications during orotracheal intubation in intensive care unit

Modifiable factors	Effect
Optimizing patient's environment	Call for help, presence of at least one skilled practitioner Difficult intubation protocol adopted by the medical and paramedical staff Difficult intubation specific devices ready to use
Positioning the patient	30° head-up inclination
Specific monitoring during the procedure	Continuous inspired and expired concentration of oxygen (preoxygenation) Continuous inspired and expired concentration of carbon dioxide (tube placement)
Maximising inspired oxygen concentration	Inspired concentration of oxygen is 100% High level of fresh gas flow (≥ 15 l min^{-1}) Select the best face mask according to the patient's face Avoid leaks around the face mask Counteract air pollution using a positive end expiratory pressure
Method for preoxygenation	Non-invasive ventilation with positive end expiratory pressure if possible
Duration of preoxygenation	Until end tidal oxygen ≥ 90% If end tidal oxygen < 90% ,anticipate a high probability of rapid desaturation
During intubation	Apnoeic oxygenation through high-flow nasal oxygen Optimise laryngeal view by external laryngeal manipulation Maintenance of oxygenation is the priority
Tracheal intubation confirmation	Visual confirmation of the tube between vocal cords Check the presence of capnography (gold standard)
Reporting the procedure	Report the procedure and the events observed in the patient's medical record

have summarized some modifiable factors (Table 1) to improve the safety of orotracheal intubation in the ICU.

"A good beginning, makes a good ending".

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Compliance with ethical standards

Conflicts of interest

The authors declare that they have no conflict of interest.

Ethical approval

An approval by an ethics committee was not applicable.

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