To routinely preoxygenate or not?

A recommendation that preoxygenation should be mandatory, and a routine 'minimum standard' of care for all patients undergoing anaesthesia (Bell, 2004), has created much debate. Traditionally, preoxygenation has been used:

1. As part of rapid sequence induction
2. In patients with a pre-existing condition that limits oxygen transport
3. In those in whom a difficult airway is foreseen.

However, it is not always possible to predict those in whom achieving a secure airway will be difficult, and this provides much of the argument for the universal use of preoxygenation.

Benefits

The principle of preoxygenation is to provide the patient with the maximal amount of time they can tolerate apnoea in case of a 'cannot intubate, cannot ventilate' situation. Preoxygenation requires ventilation with a fractional inspired oxygen tension (FiO_2) of 1.0, in order to de-nitrogenate the functional residual capacity, which typically occupies 2.5 litres of the total lung capacity. Several verified strategies for de-nitrogenation exist, including 3–5 minutes of normal tidal-volume breathing, 30 seconds of hyperventilation or merely five vital capacity breaths.

In healthy patients the end-points of preoxygenation and denitrogenation are defined, respectively, as an end-tidal fractional oxygen concentration ($F_{ET}O_2$) of 0.90 ($F_{ET}O_2$ is an accurate measure of the alveolar gas concentration and is used as a surrogate marker of the degree of denitrogenation) and an end-tidal fractional nitrogen of 0.05 (Berry and Myles, 1994). This is commensurate with approximately 95% of the functional residual capacity being replaced with oxygen, the remaining 5% consisting of 'obligatory' alveolar carbon dioxide. Thus, in theory, a reservoir of 2.375 litres of oxygen is created, and with a resting total body oxygen consumption of 250 ml per minute, the supply should last about 9.5 minutes. In practice, preoxygenation to an $F_{ET}O_2$ of 0.90 provides about 5 'safe' minutes of apnoea time, before desaturation of arterial haemoglobin to less than 92% (as measured by pulse oximetry) (Bhatia et al, 1997).

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Challenges

Inability to achieve preoxygenation is the result of either:

1. Insufficient time for nitrogen washout (an exponential function), or, more commonly
2. Failure to create the tight seal between mask and airway that is required to achieve an FiO_2 of 1.0.

A study of 200 elective surgical patients revealed that preoxygenation was not possible in 11.5% of patients as a result of failure to create a tight seal (Machlin et al, 1993). This has been found to be independent of the anaesthetist's experience (Berry and Myles, 1994). Lack of a tight seal cannot be compensated for by increasing the ventilatory time. Even when a tight seal is established, preoxygenation may not be achieved if the inspiratory flow rate exceeds oxygen flow with consequent nitrogen rebreathing – this is especially true of the four deep breaths in 30 seconds method.

New methods to aid preoxygenation are under development: for example, the NasOral system (Nimmagadda et al, 2000) comprises an oxygen reservoir bag connected to a nasal mask (for inspiration) and a mouthpiece (for expiration). Both nasal mask and mouthpiece are tight-fitting and have a one-way valve ensuring unidirectional flow of gas and minimizing air entrainment, thus achieving a $F_{ET}O_2$ of 0.9.

Risks

Preoxygenation is not without risk. Breathing supraphysiological concentrations of oxygen results in atelectasis, the degree of which is proportional to the FiO_2: breathing an FiO_2 of 1.0 for 5.5 minutes results in 5.6% atelectasis of the total lung area as measured by computed tomography (Edmark et al, 2003). By comparison, breathing an FiO_2 of 0.8 for the same length of time results in significantly less atelectasis (0.6% total lung area, $P<0.01$); however, this is at the expense of the time taken for arterial saturation of oxygen (SaO_2) to fall to below 90% (7 minutes with FiO_2 of 1.0 but only 5 minutes for FiO_2 of 0.8.) The morbidity and mortality associated with the intrapulmonary shunting that occurs from preoxygenation-related atelectasis is unknown, but theoretically this challenges the belief that pre-oxygenation with an FiO_2 of 1.0 is safest or 'best'.

Conclusions

Although intuitively, the routine use of preoxygenation seems justified, on further investigation, numerous challenges exist, including lack of standardized procedure and difficulties in maintaining a tight seal; there is also the potential risk associated with atelectasis. These issues may be worthy of consideration by the individual anaesthetist, before accepting the recommendation that pre-oxygenation form a mandatory part of patient care. **BJHM**

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