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Review

Pre-oxygenation: Implications in emergency airway management

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ABSTRACT

Transient oxygen desaturation during emergency department intubation is an event with potentially devastating consequences. Pre-oxygenation is an important means of increasing a patient's oxygen reserve and duration of safe apnea prior to intubation. In the emergent setting, important modifications to pre-oxygenation techniques need to be considered to best manage critically ill patients. In this review, we discuss recent updates in pre-oxygenation techniques and evaluate the evidence supporting both commonly used and newly emerging techniques for pre-oxygenation, assessing nature and level of illness, the best delivery method of oxygen, using delayed sequence intubation in patients who cannot tolerate non-invasive pre-oxygenation and using apneic oxygenation via nasal cannula and non-rebreather mask during intubation.

Contents

1. Introduction

Definitive airway management using endotracheal intubation is an essential skill for the emergency physician. Since the 1970′s, rapid sequence intubation (RSI) has been the primary method used for emergency department (ED) intubations and in one recent study was the initial intubation strategy in 85% of cases [1,2]. Despite decades of advancement in equipment, protocol and techniques, desaturation, during ED RSI, remains a frequent occurrence. A recent retrospective study of 166 patients undergoing intubation found that roughly one third of participants experienced peripheral oxygen saturation (SpO_2) below 90% and maintained this desaturation for a median time of 80 s [3]. In another study, Ramachandran et al. randomized thirty obese patients to two groups, a control group without apneic oxygenation and test group with apneic oxygenation, and demonstrated mean time to desaturation (SpO2 < 95%) was 3.49 (1.33) min versus 5.29 (1.02) min, respectively [4].

Desaturation and resulting hypoxemia is associated with serious complications including dysrhythmias, hemodynamic decompensation, hypoxic brain injury and cardiac arrest. Cellular tolerance to hypoxemia varies with the brain being the most vulnerable organ to hypoxemic conditions, as it accounts for nearly 20% of oxygen consumption. Irreversible damage occurs to brain cells after just 4 to 6 min of hypoxemia, with the brainstem, hippocampus, and cerebral cortex being the most sensitive areas to hypoxemic insult [5,6]. Cardiac myocytes can fully recover after exposure to a hypoxemic event <20 min, but may experience the phenomenon of stunning after only a few minutes of hypoxemia. The effects of hypoxemia do not end when oxygen delivery improves, as reperfusion may also induce cell death, mainly due to reactive oxygen species [5]. Additionally, hypoxemia precipitates an inflammatory response characterized by neutrophilic infiltration, which causes further cellular injury [6]. Given the frequency with which desaturation occurs in the ED and the significant complications of resulting hypoxemia, renewed

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scrutiny of methods to reduce and prevent desaturation during ED RSI are warranted [7].

One commonly employed method to prevent desaturation is pre-oxygenation, or the delivery of high flow, high fraction of inspired oxygen (FiO_2) prior to intubation. A well described modality, high flow, high FiO_2 is used to extend the duration of safe apnea and to prevent desaturation during the apneic phase of intubation [7]. The goal of pre-oxygenation is to achieve the highest SpO_2 possible and to denitrogenate the residual capacity of the lungs and bloodstream [8]. The hemoglobin dissociation curve dictates that SpO_2 falls at a faster rate with progressively decreasing SpO_2, with a sharp inflection point occurring around 93% [9,10]. Thus, achieving and maintaining an oxygen saturation >93% for the duration of intubation is of paramount importance.

While the overarching benefit of pre-oxygenation is well established, the optimal methodology to accomplish this end goal is less clear. Several variables contribute to successful pre-oxygenation including: the duration of therapy, patient position, the oxygen delivery system, as well as special considerations for patients unable to tolerate traditional measures. Recommendations offered for clinical practice are based on review of current pre-oxygenation literature review (Fig. 1).

2. Most common pre-oxygenation method: unsupported ventilation

The source of oxygen, oxygen flow rate and the use of passive versus positive pressure support are important variables to consider when selecting an optimal pre-oxygenation paradigm. Oxygen sources without pressure support, also referred to as unsupported ventilation and the most commonly employed methods of pre-oxygenation in the ED setting, include facemask with reservoir, true non-rebreather, bag-valve-mask and adjunctive nasal cannula [11]. A face mask with reservoir is currently the most frequently used oxygen source for pre-oxygenation in the ED [8]. Set at 15 L/min, a facemask with reservoir delivers a FiO_2 of 60 to 70% [12]. A true non-rebreather (NRB) mask with one-way valves on all ports can deliver near 90% FiO_2 at flow rates >30 L/min but is rarely available in the ED [8]. Alternatively, a bag-valve-mask (BVM) connected to a reservoir without manual insufflation has been utilized for pre-oxygenation [11,13-15]. Additionally, a traditional low flow nasal cannula may be used to supplement the above modalities.

It is likely that pre-oxygenation with BVM and NRB are similarly efficacious and the decision to use one over the other should be based on availability, convenience and contextual feasibility. Groombridge et al. found that BVM with and without positive end-expiratory pressure (PEEP) outperformed NRB, using the fraction oxygen in expired air (FeO_2) as a primary endpoint, after a three-minute pre-oxygenation period [16]. BVM with and without PEEP was associated with an amount of oxygen extracted from the air by the lungs FeO_2 of roughly 80% in contrast to an FeO_2 of just over 50% with the NRB group [16]. In contrast, Robinson & Ercole reported that NRB and BVM performed comparably with regards to denitrogenation and that NRB was better tolerated [15]. Using "flush rate" oxygen (~48 L/min), achieved by fully opening a standard oxygen flow meter, Driver et al. found NRB to be non-inferior to BVM without manual insufflation [17]. Further research with standardized methodology is required to elucidate conflicting data between NRB and BVM.

Some have advocated for the adjunctive use of traditional nasal cannulas in addition to the above methods during pre-oxygenation. Some proponents suggest the strategy of using nasal cannula during the apneic phase of intubation increases the quantity of oxygen delivered to the respiratory system and advocate its benefits during laryngoscopy following removal of the facemask. While nasal cannula with NRB has been shown to be superior to NRB alone for pre-oxygenation, the addition of a nasal cannula to a BVM detracted from the performance of the BVM alone [16]. In a helicopter based emergency medical service (EMS), Riyapan et al. found that apneic oxygenation with nasal cannula at 15 L/min was not superior to traditional RSI protocol without apneic oxygenation using an Sp02 < 90 as an endpoint [18]. Conversely, in a larger study also conducted by a helicopter EMS system, Wimalasena et al. reported a decreased incidence of desaturation in patients receiving apneic oxygenation via nasal cannula [19].

3. Duration of pre-oxygenation

The optimal duration of pre-oxygenation is based on the time needed to achieve denitrogenation of expiratory reserve and residual lung volumes. In individuals with intact respiratory drive, three minutes of tidal volume breathing (TVB) with a tightly sealed FiO2 source is sufficient to achieve this goal [8]. In time-limited scenarios with cooperative patients, the time to achieve adequate pre-oxygenation can be decreased by instructing the patient to perform eight vital capacity breathes (VCB) over the course of sixty seconds [20,21]. In a randomized controlled trial of elective preoperative patients randomized to 3 min of TVB at oxygen flow rate of 5 L/min and patients taking 8 VCB at oxygen flow rate at 10 L/min, it was found that 8 VCB provided a greater margin of safety as average (PaO_2) was higher as compared to the TVB method and apnea-induced desaturation time was doubled [22]. Thus, three minutes of TVB or one minute of VCB are in most cases sufficient for adequate preoxygenation, with one minute of VCB likely superior. It should be noted that not all ED patients, either because of acuity or mental status, may be able to perform three minutes of TVB or be alert enough to perform effective VCB. In these cases, understanding the interrelationship between time of pre-oxygenation and type of breathing (TVB or VCB) and their impacts on desaturation time is essential in providing the best margin of safety for intubation.

4. Positioning of the patient during pre-oxygenation

In the preoperative setting, patients have traditionally undergone both pre-oxygenation and intubation in the supine position [23]. Supine positioning is physiologically suboptimal as it decreases functional residual capacity (FRC), thereby decreasing the volume of air remaining in the

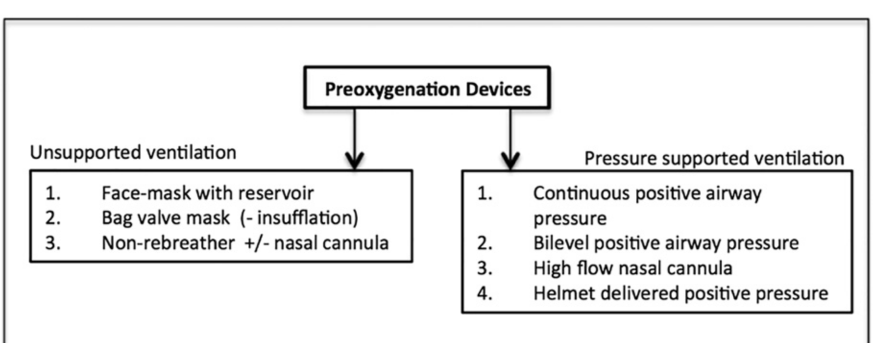

Fig. 1. Oxygen delivery devices used for preoxygenation.