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Preoxygenation strategies in emergency airway management

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Maximizing preoxygenation is the cornerstone of safe emergency airway management both in the emergency department (ED) and in prehospital settings. Emergency patients are particularly vulnerable to hypoxemic deterioration during apnea due to factors such as impaired lung function, anemia, and/or increased metabolic demands. Preoxygenation aims to extend the safe-apnea time.[1] However, in clinical practice, this critical step is often underemphasized or inadequately performed.

A recent randomized crossover trial by Roveri et al.[2] evaluated 3 preoxygenation strategies in healthy volunteers: 15 L/min oxygen via non-rebreather mask (NRM), bag-valve-mask (BVM), and BVM with 8 cm H_2O positive end-expiratory pressure (PEEP), each administered for 3 minutes. The addition of PEEP led to significantly higher expired oxygen concentrations (FeO_2) and improved ventilation of dependent lung regions. This finding underscores that, even in healthy individuals, applying PEEP on exhalation improves preoxygenation efficacy.

However, we would like to highlight a practical enhancement that could further optimize preoxygenation using a BVM plus PEEP valve in ED and prehospital settings. Prior operating theater studies showed that CPAP during preoxygenation prolonged safe apnea time.[3–5] In some EDs and prehospital services, nasal cannula oxygen is routinely applied to facilitate apneic oxygenation during emergency induction. An underappreciated advantage of using nasal cannula at ≥10 L/min during BVM plus PEEP preoxygenation is the generation of continuous positive airway pressure (CPAP) across the entire respiratory cycle, i.e., CPAP rather than PEEP. This effect persists regardless of respiratory rate—even during apnea—unlike the intermittent PEEP generated by a BVM with PEEP valve alone.[1]

This combined approach of BVM, PEEP, and supplemental oxygen via nasal cannula offers several theoretical advantages. Continuous, rather than intermittent, positive pressure may enhance denitrogenation in lung-healthy individuals, potentially achieving higher end-tidal oxygen concentrations (EtO_2). Often underappreciated, nasal oxygen flow rates ≥10 L/min may mitigate the impact of mask leaks on preoxygenation efficacy.[6,7] Of note, flow rates below 10 L/min may be deleterious to preoxygenation and should hence be avoided.[7]

Furthermore, apneic oxygenation via nasal cannula during laryngoscopy has been associated with improved peri-intubation oxygen saturation, reduced rates of hypoxemia, and increased first-pass intubation success.[8] In some departments, a practical barrier to implementation of routine use of apneic oxygenation is that nasal cannula are often not applied before preoxygenation begins, requiring placement during apnea, potentially delaying laryngoscopy. This is resolved by routinely applying nasal cannula at ≥10 L/min from the start of preoxygenation alongside BVM with PEEP.[9]

At the same time, the potential hemodynamic effects of PEEP must be considered, particularly that PEEP may reduce venous return in shocked patients.[9] However, applying PEEP—or more accurately, CPAP—during preoxygenation can serve as a useful stress test to identify patients at risk of hemodynamic collapse during induction. Those who are "PEEP sensitive" may benefit from adjusted anesthetic dosing and pre-induction hemodynamic resuscitation including volume restoration, vasoactive support, and/or relief of obstructive shock. Because positive pressure ventilation after intubation will amplify this change, identifying at-risk patients beforehand is clinically valuable.

When using a BVM in a spontaneously breathing patient, clinicians must be aware that a BVM does not necessarily deliver an FiO_2 of 100%. The actual fraction of delivered oxygen (FDO_2) has been shown to vary substantially by BVM manufacturer, with values reported as low as 39.0% (95% confidence interval [CI], 38.7%–39.3%), making some BVMs inadequate for spontaneously breathing patients. BVMs that utilize a duckbill valve without a dedicated disc to block the exhaust port during inspiration perform worse than those equipped with a disc-type patient valve. The addition of an expiratory cap or a PEEP valve to the exhaust port can reduce entrainment of ambient air and thereby improve FiO_2.[10]

Another recent study that should shape emergency clinicians' understanding of preoxygenation is the PREOXI trial, which compared noninvasive ventilation (NIV) to standard oxygen mask preoxygenation in critically ill ED and ICU patients. NIV was delivered with an apnotic ventilation rate ≥10/min.[11] Hypoxemia, defined as SpO_2 <85% between induction and 2 minutes post-intubation, occurred in 9.1% of the NIV group vs. 18.5% in the oxygen mask group (absolute risk reduction 9.4%; 95% CI, −13.2% to −5.6%; $P < 0.001$). Even with the exclusion of patients with apnea, those with hypopnea, or those already receiving positive-pressure ventilation (populations in whom the physiological benefit of NIV would be expected to be greatest), the study demonstrated a statistically significant reduction in hypoxemia. This strategy is also referred to as ventilator-assisted preoxygenation (VAPOX).[12]

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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In the study by Roveri et al., a mean FeO_2 of 52.5% (standard deviation [SD], 6.1%; $P < 0.001$) was achieved after 3 minutes of preoxygenation using an NRM.[2] In contrast, another study in healthy volunteers applied flush-rate oxygen by deliberately turning the flowmeter beyond the 15 L/min mark, achieving actual flow rates of 50–54 L/min. With this method, a mean FeO_2 of 86% (95% CI, 84%–88%) was reached after 3 minutes of preoxygenation.[13] However, this approach may have limited applicability in European and Australian settings, where wall-mounted flowmeters rarely deliver flows above 15 L/min, and exceeding this rate in prehospital environments can rapidly deplete oxygen cylinders. For example, in an Australian study using healthy volunteers, NRM with flush-rate oxygen achieved a median EtO_2 of only 55% (interquartile range, 51%–61%).[14]

High-flow nasal cannula (HFNC) is another preoxygenation strategy. A recent meta-analysis in critically ill patients found that HFNC reduced hypoxemia compared to facemask oxygen (relative risk [RR], 0.51; 95% CI, 0.39–0.65; $P < 0.001$; high certainty), but not compared to NIV (RR, 0.73 [0.55–0.98]; $P = 0.032$; moderate certainty).[15]

In summary, emergency clinicians must be aware of the advantages and limitations of different preoxygenation strategies in order to tailor their approach to both patient physiology and situational factors. Recent evidence especially supports the use of either (1) BVM plus PEEP in combination with nasal cannula oxygen at ≥10 L/min, applied with a tight seal and two-handed technique, or (2) noninvasive ventilation for preoxygenation in emergency airway management. Use of an NRM at 15 L/min alone will often be inadequate; however, efficacy can be improved by using true flush-rate oxygen and/or adding nasal cannula oxygen at ≥10 L/min. Regardless of the technique, early application of nasal cannula oxygen during the resuscitation may assist in facilitating a smoother transition to both preoxygenation and apneic oxygenation.

Conflict of interest statement

The authors declare no conflict of interest.

Author contributions

Ünlü L and Reid C produced the initial draft of the manuscript. Hayes-Bradley C, George J, and Hohenstein C contributed to conceptual discussions and provided critical feedback. Ünlü L revised and finalized the manuscript. All authors reviewed and approved the final version of the manuscript.

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References

[1] Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med*. 2012;59(3): 165–175.e1. doi:10.1016/j.annemergmed.2011.10.002

[2] Roveri G, Camporesi A, Hofer A, et al. Preoxygenation with and without positive end-expiratory pressure in lung-healthy volunteers: a randomized clinical trial. *JAMA Netw Open*. 2025;8(5):e2511569. doi:10.1001/jamanetworkopen.2025.11569

[3] Cressey DM, Berthoud MC, Reilly CS. Effectiveness of continuous positive airway pressure to enhance pre-oxygenation in morbidly obese women. *Anaesthesia*. 2001;56(7):680–684. doi:10.1046/j.1365-2044.2001.01374-3.x

[4] Gander S, Frascarolo P, Suter M, et al. Positive end-expiratory pressure during induction of general anesthesia increases duration of nonhypoxic apnea in morbidly obese patients. *Anesth Analg*. 2005; 100(2):580–584. doi:10.1213/01.ANE.0000143339.40385.1B

[5] Herriger A, Frascarolo P, Spahn DR, et al. The effect of positive airway pressure during pre-oxygenation and induction of anaesthesia upon duration of non-hypoxic apnoea. *Anaesthesia*. 2004;59(3):243–247. doi:10.1111/j.1365-2044.2004.03625.x

[6] Hayes-Bradley C, Lewis A, Burns B, Miller M. Efficacy of nasal cannula oxygen as a preoxygenation adjunct in emergency airway management. *Ann Emerg Med*. 2016;68(2):174–180. doi:10.1016/j.annemergmed.2015.11.012

[7] McQuade D, Miller MR, Hayes-Bradley C. Addition of nasal cannula can either impair or enhance preoxygenation with a bag valve mask: a randomized crossover design study comparing oxygen flow rates. *Anesth Analg*. 2018;126(4):1214–1218. doi:10.1213/ANE.0000000000002341

[8] Oliveira JESL, Cabrera D, Barrionuevo P, et al. Effectiveness of apneic oxygenation during intubation: a systematic review and meta-analysis. *Ann Emerg Med*. 2017;70(4):483–494.e11. doi:10.1016/j.annemergmed.2017.05.001

[9] Greater Sydney Area HEMS. Greater Sydney Area HEMS pre-hospital emergency anaesthesia manual (v 4.0). Sydney HEMS; 2024. Accessed July 17, 2025. https://sydneyhems.com/wp-content/uploads/2024/06/phea-manual-v4.pdf

[10] Grauman S, Johansson J, Drevhammar T. Large variations of oxygen delivery in self-inflating resuscitation bags used for preoxygenation: a mechanical simulation. *Scand J Trauma Resusc Emerg Med*. 2021; 29(1):98. doi:10.1186/s13049-021-00885-3

[11] Gibbs KW, Semler MW, Driver BE, et al. Noninvasive ventilation for preoxygenation during emergency intubation. *N Engl J Med*. 2024; 390(22):2165–2177. doi:10.1056/NEJMoa2313680

[12] Grant S, Khan F, Keijzers G, Shirran M, Marneros L. Ventilator-assisted preoxygenation: protocol for combining non-invasive ventilation and apnoeic oxygenation using a portable ventilator. *Emerg Med Australas*. 2016;28(1):67–72. doi:10.1111/1742-6723.12524

[13] Driver BE, Prekker ME, Kornas RL, Cales EK, Reardon RF. Flush rate oxygen for emergency airway preoxygenation. *Ann Emerg Med*. 2017; 69(1):1–6. doi:10.1016/j.annemergmed.2016.06.018

[14] Hayes-Bradley C, McQuade D, Miller M. Preoxygenation via a non-rebreather mask comparing a standard oxygen flowmeter rate of 15 Lpm to maximally open. *Emerg Med Australas*. 2017;29(3):372. doi: 10.1111/1742-6723.12784

[15] Pitre T, Liu W, Zeraatkar D, et al. Preoxygenation strategies for intubation of patients who are critically ill: a systematic review and network meta-analysis of randomised trials. *Lancet Respir Med*. 2025;13(7):585–596. doi:10.1016/S2213-2600(25)00029-3

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