Preoxygenation and Prevention of Desaturation During Emergency Airway Management

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Review Article

Emergency Airway Management

- Primary lung pathology
- High metabolic demands
- Anemia
- Insufficient respiratory drive
- Inability to protect airway against aspiration

Hypoxemic Hypoxia

Desaturation (Oxygen Sat below 70%)

- Dysrhythmia
- Hemodynamic decompensation
- Hypoxic brain injury
- Death

Challenge

- Secure a tracheal tube rapidly without critical hypoxia or aspiration

Risk of Desaturation

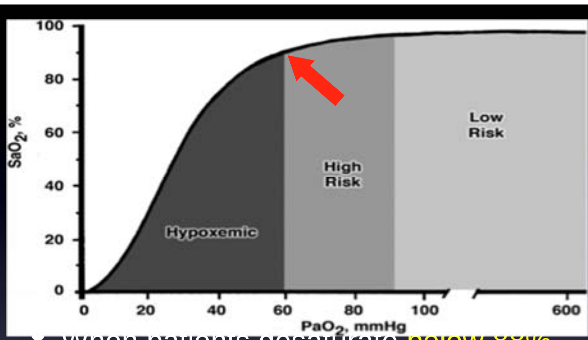
- ***O2 Sat above 90%*** before intubation: low risk with adequate preoxygenation (Ex, 100% sat on room air, without pulmonary pathology, normal Hb level)
- ***O2 Sat below 90%*** before intubation: immediate risk of critical tissue hypoxia during intubation (Ex, septic patient with multilobar pneumonia)

This review tells us:

- How to minimize risk of hypoxemia during emergency tracheal intubation
- Specific techniques based on peri-procedural risk

Rationale behind Preoxygenation

- Enlarges safety buffer range during periods of hypoventilation and apnea
- Extends duration of safe apnea (Def: the time until a patient reaches a saturation level of 88% to 90%) to allow placement of definitive airway



- When patients desaturate below 88%, their status is on the steep portion of the oxygen hemoglobin dissociation curve, and can decrease to critical levels of O2 sat (< 70%) within moments

Standard Anesthesia Induction

- Elective operative patients (stable pt's)
- Administer sedative
- Provide manual ventilation
- Administer muscle relaxant
- Continue manual ventilation until placement of definitive airway
- Preoxygenation is not mandatory

Rapid Sequence Induction

- Pt's with high aspiration risk (critically ill)
- Simultaneous administration of the sedative and paralytic with no ventilation, while waiting for the paralytic to take effect, unless needed to prevent hypoxemia.
- In ED, all patients requiring airway management are assumed to be at risk of aspiration.
- Default technique: rapid sequence tracheal intubation

3 Goals of Preoxygenation

- Bring patient's saturation as close to 100% as possible
- Denitrogenate the residual capacity of the lungs (maximizing oxygen storage in the lungs)
- Denitrogenate and maximally oxygenate the bloodstream

Best Source of FiO2

- True nonrebreather mask: 90-100% FiO2
- Self-inflating bag-valve-mask: ambient FiO2
- Standardly nonrebreather mask, available in ED, set at flow rates of 15 L/min: 60-70% FiO2
- Standardly nonrebreather mask set at 30-60 L/min: > 90% FiO2

Appropriate Duration of Preoxygenation

- Ideally, pt's should continue to receive preoxygenation until greater than 90% end-tidal oxygen level.
- 3 minutes' worth tidal-volume breathing with high FiO2 source (> 90%)
- Cooperative patients: take 8 vital-capacity breaths (maximally inhale and exhale)

Can Increasing Mean Airway Pressure Augment Preoxygenation?

- If pt's do not achieve 93-95% saturation level after 3 minutes of tidal-volume breathing with a high FiO2 source, it is likely that they are exhibiting shunt physiology.
- Shunt physiology: perfused, but not ventilated (pulmonary edema, pneumonia)
- Shunt physiology can be partially overcome by augmenting mean airway pressure

Table 1. Evidence for increased mean airway pressure as a preoxygenation technique.

Study	Patients	Intervention	Comparator	Outcome
Delay et al[25]	RCT of 28 obese, operative patients	Noninvasive ventilation	Spontaneous ventilation at zero pressure	The patients in the noninvasive positive-pressure ventilation group achieved faster and more complete denitrogenation than the standard group, as measured by an exhaled oxygen level >90%.
Futier et al[26]	RCT of 66 obese, operative patients	Two treatment groups: noninvasive ventilation or noninvasive ventilation with post-tracheal intubation recruitment maneuver	Spontaneous ventilation at zero pressure	At the end of preoxygenation, PaO_2 was higher in the NPPV and NPPV+RM groups compared with the spont vent group and remained higher after TI and the onset of mechanical ventilation
Cressey et al[27]	RCT of 20 morbidly obese women undergoing bariatric surgery	CPAP preoxygenation	Spontaneous ventilation at zero pressure	Showed a 40-s increase in time to desaturation through the use of noninvasive positive pressure. Nonsignificant primary outcome.
Gander et al[28]	RCT of 30 morbidly obese operative patients	CPAP preoxygenation	Spontaneous ventilation at zero pressure	The time until reaching a saturation of 90% after apnea was extended by a minute in the CPAP group
Herriger et al[29]	RCT of 40 ASA I–II operative patients	CPAP preoxygenation	Spontaneous ventilation at zero pressure	Application of positive airway pressure during induction of anesthesia in adults prolongs the nonhypoxic apnea duration by >2 min
Antonelli et al[30]	RCT of 26 hypoxemic ICU patients requiring bronchoscopy	Noninvasive ventilation	Spontaneous ventilation at zero pressure	The PaO_2/FiO_2 ratio improved in the noninvasive positive-pressure ventilation group and worsened in the high-FiO_2-alone group

RCT, Randomized controlled trial; *NPPV*, noninvasive positive-pressure ventilation; *RM*, recruitment maneuver; *CPAP*, continuous positive airway pressure; *ASA*, Ameri-

Baillard et al. (Hypoxemic Critically-ill Pt's in ICU)

- Noninvasive positive-pressure ventilation group had a 98% mean O2 sat
- Standard group: 93%
- 6/26 were unable to improve O2 sat with high FiO2 until they receive NPPV

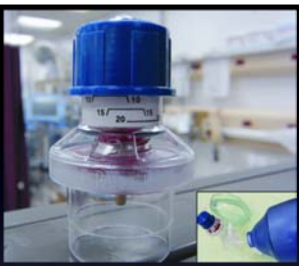
- No negative cardiovascular effects or appreciable gastric distention was observed in noninvasive positive pressure preoxygenation studies.
- Gastric distention and resulting aspiration is unlikely at pressures below 25 cm H2O.
- If tracheal intubation is attempted with saturation below 90%, these patients can critically desaturate in seconds

During Tracheal Intubation

- Standard group's levels decreased to saturations of 81% compared with 93% in NPPV group
- 12 of the control group and 2 of the NPPV group had saturation levels below 80%

Positive Airway Pressure

- Standalone disposable continuous positive airway pressure (CPAP) masks, leave it on until the moment of intubation
- Positive end-expiratory pressure (PEEP) valve on a standard bag mask
- PEEP prevents absorption atelectasis caused by breathing high FiO2 gas level



- A disposable PEEP valve, inexpensive, strain gauge capable from 5-20 cm H2O
- If combined with a nasal cannula set to 15 L/min, it will provide CPAP even without ventilations.

Positioning

- Supine positioning is not ideal to achieve optimal preoxygenation.
- Head-up 20-25 degrees
- Reverse Trendlenburg position (head of stretcher 30 degrees higher than the foot)

When Laying Flat

- More difficult to take full breaths
- More of the posterior lung becomes prone to atelectatic collapse
- Reduces the reservoir of O2 contained within the lungs
- Reduces safe apnea time

Studies

- Lane et al, RCT: 20-degree head-up vs. supine position = 386 : 283 sec (sat drop from 100% to 95% after 3 mins of preoxygenation)
- Ramkumar et al: 20-degree head-up group takes 452 sec vs. 364 sec left supine group to desaturate
- Altermatt et al (BMI > 35, intubated, SpO2 drop from 100-90%): Sitting vs. supine = 214 sec : 162 sec of safe apnea time.

How Long Will It Take to Desaturate after Preoxygenation

- O2 consumption during apnea is approximately 250 ml/min
- In healthy pt's, the duration of safe apnea on room air is about 1 minute compares with approximately 8 minutes when breathing at a high FiO2 level.

In Sick Patients

- Poor cardiac output may delay the readings of actual central arterial circulation by 30 to 60 sec when using finger-probe device.
- The effect of shunting dramatically reduces oxygen storage in the lungs and shortens safe apnea in critically ill pt's.
- Desaturation to 85% may be as short as 23 seconds in critically ill pt's versus 502 seconds in a healthy adult

Apneic Oxygenation

- Aveoli will continue to take up oxygen even without diaphragmatic movements or lung expansion.
- In an apneic patient, approximately 250 ml/min of O2 will move from aveoli to the blood stream.
- Conversely, only 8-20 ml/min of CO2 moves into the aveoli during apnea

Apneic Oxygenation

- The difference in O2 and CO2 movement across the aveolar membrane is due to the significant difference in gas solubility in the blood, as well as the affinity of Hb for O2.
- This causes the net pressure in the aveoli to become slightly subatmospheric, thus generating a mass flow of gas from pharynx to aveoli.

- This phenomenon is called ***apneic oxygenation***
- It permits maintenance of oxygenation without spontaneous or administered ventilations.
- Under uptimal circumstances, a PaO2 can be maintained at greater than 100 mmHg for up to 100 minutes without a single breath.
- 6 min (nasal catheter) vs 3.65 min (control) desaturate to 95% in a RCT of anesthesia patients. Taha et al.

- Apneic oxygenation will allow continued oxygenation but will have no significant effect on CO2.
- To provide apeneic oxygenation during ED tracheal intubations, the nasal cannula is the device of choice.
- The decreased O2 demands of the apneic state will allow nasal cannula to fill the pharynx with a high level of FiO2.
- By increasing the flow rate to 15 L/min, near 100% FiO2 can be obtained.

When and How Should We Provide Manual Ventilations?

- Ventilation provides 2 potential benefits: ventilation and increased oxygenation through aveolar distention and reduction in shunting.

Agressive Ventilation Should Be Executed When

- Profound metabolic acidosis (ex, severe salicylate toxicity), because of cardiovascular collapse with cessation of self-ventilation
- Increased intracranial pressure, in which CO2 increase can lean to cerebral vasodilation
- Risk: regurgitation and aspiration

Second Benefit: Increased Oxygenation

- Crucial, because pt's O2 sat < 90% will not tolerate apnea for 60 seconds
- Ventilation during the onset phase of muscle relaxation can create aveolar distension and lengthen the duration of safe apnea.
- Significant risk in critically ill pt's: positive-pressure ventilation involves decrease venous return and hypotension.

Maneuvers and Positioning

- Patients should be positioned to maximize upper airway patency before and during apneic period, using ear-to-sternal notch positioning
- Nasal airways may be needed
- Jaw thrust to prevent posterior pharyngeal structures to collapse backwards
- Cricoid pressure may negatively affect apneic oxygenation, but no stuides exists to author's knowledge

Choice of Paralytic Agent

- In a study of operative pt's, the time to desaturation to 95% was 242 seconds in succinylcholine group versus 378 seconds in rocuronium group.
- It is hypothesized that the fasciculations induced by succinylcholine may cause increased oxygen use.

Risk Stratification

- Patients requiring emergency airway management can be risk stratified into 3 groups, according to the pulse oximetry after initial application of high-flow oxygen

Table 2. Risk categorization of patients during preoxygenation.*

Risk Category, Based on Pulse Oximetry While Receiving High-Flow Oxygen	Preoxygenation Period (3 Minutes)	Onset of Muscle Relaxation (≈60 Seconds)	Apneic Period During Tracheal Intubation (Variable Duration, Depending on Airway Difficulty; Ideally <30 Seconds)
Low risk, SpO_2 96%–100%	Nonrebreather mask with maximal oxygen flow rate	Nonrebreather mask and nasal oxygen at 15 L/min	Nasal oxygen at 15 L/min
High risk, SpO_2 91%–95%	Nonrebreather mask or CPAP or bag-valve-mask device with PEEP	Nonrebreather mask, CPAP, or bag-valve-mask device with PEEP and nasal oxygen at 15 L/min	Nasal oxygen at 15 L/min
Hypoxemic, SpO_2 90% or less	CPAP or bag-valve-mask device with PEEP	CPAP or bag-valve-mask device with PEEP and nasal oxygen at 15 L/min	Nasal oxygen at 15 L/min

*Risk categories are based on patient's initial response to high-flow oxygen through a tightly fitting nonrebreather mask. Patients who are already hypoxemic exhibit shunt physiology and are prone to rapid desaturation during the peri-intubation. Patients with saturations of 91% to 95% have values close to the precipice of the steep portion of the oxyhemoglobin dissociation curve and should be considered high risk. Patients with saturations greater than or equal to 96% are at low risk for peri-intubation desaturation. Patients in all risk categories should receive preoxygenation in a head-elevated position (or reverse-Trendelenburg if there is a risk of spine injury).

We Should Know

- Preoxygenation extends the duration of safe apnea, recommended for every ED tracheal intubation
- Source: standard reservoir facemasks with the flow rate of oxygen set to maximum
- How long: pt's with an adequate respiratory drive should receive preoxygenation for 3 minutes or take 8 breaths, with maximal inhalation and exhalation.

- CPAP masks, NPPV, or PEEP valves on a bag-valve-mask device should be considered when high FiO2 cannot achieve 93-95% O2 sat
- Positioning: head-elevated whenever possible. Reverse Trendlenburg position for possible spinal injury and immobolized pt's.
- Pt's with high O2 sat on room air are at low risk, and may maintain O2 sat as long as 8 minutes. Critically ill pt's are at high risk, and may desaturate immediately.

- Apneic oxygenation can extend the duration of safe apnea (after sedative and muscle relaxant) with nasal cannula, set at 15 L/min of greater.
- Manual ventilation: 1) low risk(95%), no necessary 2) high risk(91-95%), evaluate risk/benefit 3) hypoxemic patients: low-pressure, low-volume, low-rate ventilations will be required.

- Ear-to-sternal notch positioning, jaw thrust, and nasal airway may be needed to provide upper airway patency.
- In patients at high risk of desaturation, rocuronium may provide a longer duration of safe apnea than succinylcholine.

Sequence of Preoxygenation and Prevention of Desaturation

(Assuming 2 oxygen regulators*)

Preoxygenation Period

- Position the patient in a semi-recumbent position (~20°) or in reverse Trendelenberg. Position the patient's head in the ear-to-sternal-notch position using padding if necessary.
- Place a nasal cannula in the patient's nares. Do not hook the nasal cannula to oxygen regulator.
- Place patient on a non-rebreather mask at the maximal flow allowed by the oxygen regulator (at least 15 lpm, but many allow a much greater uncalibrated flow)
- If patient is not saturating > 90%, remove face mask and switch to non-invasive CPAP by using ventilator, non-invasive ventilation machine, commercial CPAP device, or BVM with PEEP valve attached. Titrate between 5-15 cm H_20 of PEEP to achieve an oxygen saturation > 98%. Consider this step in patients saturating 91-95%.
- Allow patient to breath at tidal volume for 3 minutes or ask the patient to perform 8 maximal exhalations and inhalations
- Attach a BVM to oxygen regulator and set it to maximal flow (at least 15 lpm). If the patient required CPAP for preoxygenation, attach a PEEP valve to the BVM set at the patient's current CPAP level

Apneic Period

- Push sedative and paralytic (preferably rocuronium, if the patient is at risk for rapid desaturation)
- Detach face mask from the oxygen regulator and attach the nasal cannula. Drop the flow rate to 15 lpm.
- Remove the face mask from the patient.
- Perform a jaw thrust to maintain pharyngeal patency.
- If the patient is high risk (required CPAP for preoxygenation), consider leaving on the CPAP during the apneic period or providing 4-6 ventilations with the BVM with a PEEP valve attached. Maintain a two-hand mask seal during the entire apneic period to maintain the CPAP.

Intubation Period

- Leave the nasal cannula on throughout the airway management period to maintain apneic oxygenation.

* If 3 regulators are available, attach reservoir face mask, BVM, and nasal cannula to them. If only one regulator is available, consider using a stand-alone oxygen tank to offer a second source of oxygen.

Conclusion

- Low risk(96-100%): properly positioned and receive preoxygenation, active ventilation and passive apneic oxygenation may not be necessary
- High risk(91-95%) after high FiO2: positioning, preoxygenation and passive oxygenation should be used. Evaluate risk/benefit of using PEEP.

Conclusion

- Initially hypoxemic(90% or less after high FiO2): aggressive efforts should be made, including PEEP during preoxygenation, ventilation during the onset of phase of muscle rexaxnts, and passive oxygenation during tracheal intubation.

Thank you for the attention