Evaluation of Oxygen Delivery Efficiency Using a Prototype Intelligent Oxygen Flowmeter

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Introduction: Supplemental oxygen (O₂) is routinely delivered during procedural sedation and patient controlled analgesia. Traditionally, O₂ is delivered continuously via nasal cannula regardless of breath phase. An alternative method for delivering supplemental O₂ is to deliver the O₂ on demand. Demand delivery gives a pulse of O₂ at the beginning of inspiration and stops during expiration. Although demand delivery systems are widespread for home use, these systems are currently not used to deliver supplemental O₂ during sedation and monitored anesthesia care.

We have developed a prototype intelligent O₂ flowmeter that is similar to demand delivery systems but specifically intended for patients receiving sedatives and opioids. The prototype determines respiration rate and inspiratory effort by measuring intranasal pressure through a nasal cannula (NC) port. The amount of O₂ flow given by the system varies according to the respiratory rate so that as the respiratory rate slows, due to opioid and sedative drugs, the delivered volume of O₂ is increased. By increasing O₂ delivery as respiratory rate slows, the system maintains a constant alveolar delivery of inhaled oxygen per time regardless of breath rate.

We conducted a volunteer study to determine the amount of pulsed O₂ necessary to provide equivalent end-tidal O₂ (ETO₂) levels as continuous flow delivery.

Methods: Thirty healthy volunteers (16 Male, 14 Female, average age = 34) were recruited and fitted with a standard nasal cannula and pulse oximeter. The cannula sensing port was connected to the system’s pressure sensor and to an oxygen and CO₂ gas analyzer (CapnoMAC, Datex, Helsinki Finland). Volunteers were asked to lie down in a hospital bed. They were then given O₂ through the NC at 5 flow rates (1, 2, 4, 6, 10 L/min) using both modes of delivery for two minutes at each flow and mode combination. At the end of each two-minute period, O₂ flow was turned off and the expired gas was sampled for three breaths. ETO₂ was then measured using a gas analyzer and the ETO₂ prior to turning off the oxygen was estimated using a backward linear extrapolation of the three expired ETO₂ values.

Results: ETO₂ values were significantly higher (P < 0.05) during demand delivery than during continuous flow (See figure). Higher ETO₂ values indicate that higher concentration of the O₂ in the alveoli (F_AO₂) was achieved using demand delivery. Higher SpO₂ values were also observed during demand delivery, indicating that higher PaO₂ values were achieved. For O₂ flows of 1-4 L/min, 100% of the O₂ was delivered during demand delivery. For higher flows during demand delivery, the system was not able to deliver the set O₂ flow because inspiration was either too shallow or too
short as indicated by the measured nasal pressure. On average, 95% of O₂ was delivered during 6 L/min set flow and 76% of O₂ was delivered during 10 L/min set flow. Even though demand delivery gave less O₂ when the flow rate was 6 and 10 L/min, the ETO₂ concentrations and SpO₂ values were still higher than continuous flow at the set flow rate. For flow rates of 1-4 L/min, less than 40% of constant flow O₂ values were needed to obtain equivalent ETO₂ concentrations when using demand O₂ delivery.

**Discussion:** Higher ETO₂ concentrations and SpO₂ values can be achieved using demand O₂ delivery. These findings are consistent with prior evaluation of demand O₂ delivery systems used for long-term O₂ therapy. Even though the prototype system delivers O₂ intermittently, ETO₂ concentrations are higher since all of the oxygen delivered is inhaled. This study has shown that our intelligent O₂ flowmeter can obtain ETO₂ and SpO₂ values equivalent to or higher than continuous flow O₂ delivery while providing the benefits of demand O₂ delivery including O₂ conservation, reduced operating room fire hazard and increased ETCO₂ and respiratory rate monitoring accuracy.