Evaluation of Oxygen Delivery Efficiency Using a Prototype Intelligent Oxygen Flowmeter

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Introduction: Supplemental oxygen (O_2) is routinely delivered during procedural sedation and patient controlled analgesia. Traditionally, O_2 is delivered continuously via nasal cannula regardless of breath phase. An alternative method for delivering supplemental O_2 is to deliver the O_2 on demand. Demand delivery gives a pulse of O_2 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 O_2 during sedation and monitored anesthesia care.

We have developed a prototype intelligent O_2 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 O_2 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 O_2 is increased. By increasing O_2 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 O_2 necessary to provide equivalent end-tidal O_2 (ETO_2) 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 CO_2 gas analyzer (CapnoMAC, Datex, Helsinki Finland). Volunteers were asked to lie down in a hospital bed. They were then given O_2 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, O_2 flow was turned off and the expired gas was sampled for three breaths. ETO_2 was then measured using a gas analyzer and the ETO_2 prior to turning off the oxygen was estimated using a backward linear extrapolation of the three expired ETO_2 values.

Results: ETO_2 values were significantly higher ($P < 0.05$) during demand delivery than during continuous flow (See figure). Higher ETO_2 values indicate that higher concentration of the O_2 in the alveoli (F_AO_2) was achieved using demand delivery. Higher SpO_2 values were also observed during demand delivery, indicating that higher PaO_2 values were achieved. For O_2 flows of 1-4 L/min, 100% of the O_2 was delivered during demand delivery. For higher flows during demand delivery, the system was not able to deliver the set O_2 flow because inspiration was either too shallow or too short as indicated by the measured nasal pressure. On average, 95% of O_2 was delivered during 6 L/min set flow and 76% of O_2 was delivered during 10 L/min set flow. Even though demand delivery gave less O_2 when the flow rate was 6 and 10 L/min, the ETO_2 concentrations and SpO_2 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 O_2 values were needed to obtain equivalent ETO_2 concentrations when using demand O_2 delivery.

Discussion: Higher ETO_2 concentrations and SpO_2 values can be achieved using demand O_2 delivery. These findings are consistent with prior evaluation of demand O_2 delivery systems used for long-term O_2 therapy. Even though the prototype system delivers O_2 intermittently, ETO_2 concentrations are higher since all of the oxygen delivered is inhaled. This study has shown that our intelligent O_2 flowmeter can obtain ETO_2 and SpO_2 values equivalent to or higher than continuous flow O_2 delivery while providing the benefits of demand O_2 delivery including O_2 conservation, reduced operating room fire hazard and increased $ETCO_2$ and respiratory rate monitoring accuracy.