QED-100™ Clinical Brief

THE QED-100™ WITH SPONTANEOUSLY BREATHING PATIENTS

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SUMMARY

The QED-100 provides a safer and faster emergence from inhaled anesthetics in spontaneously breathing patients. It can be used during emergence when the patient is breathing through a Laryngeal Mask Airway (LMA), or a face mask.

In spontaneously breathing patients, an activated QED-100 uses rebreathing of CO_2 to raise the patient's $PaCO_2$. This respiratory stimulant increases the patient's spontaneous tidal volume and respiratory rate, which speeds the rate of removal of the inhaled anesthetic from the lungs. The respiratory stimulant also helps the patient breathe through the laryngeal mask or face mask, the airway filter, the QED-100 and the anesthesia circuit, overcoming their combined resistance.

When the QED-100 is used in spontaneously breathing patients, respiratory monitoring is needed to insure that the patient breathes with a tidal volume of at least 500 ml. This provides adequate oxygenation during rebreathing. If the fraction of inspired oxygen drops below 35% or the oxygen saturation drops below 90%, the QED-100 should be deactivated.

QED-100 offers clinical value with spontaneously breathing patients.

INTRODUCTION

The QED-100 was formally tested for emergence from inhaled anesthetics under controlled ventilation. The use of the QED-100 to enhance emergence from inhaled anesthetics during spontaneous ventilation is a topic which is being addressed subsequent to questions arising from new users of the QED-100. Although use of the QED-100 with spontaneous ventilation has been accomplished with a limited number of cases. The QED-100s expected performance characteristics will be detailed in this brief.

Cerebral blood flow increases with increased $PaCO_2$

PHYSIOLOGY

Of course, oxygenation of the patient is paramount! Oxygenation requires adequate ventilation with an adequate amount of oxygen. Given that, it is important to realize that the QED-100 imparts partial re-breathing of the patient's previous breath to achieve emergence from inhaled anesthesia. Since the previous breath is lacking a certain percentage of oxygen and has an increased percentage of CO_2, a mixing of new gas is required to maintain an adequate percentage of oxygen within the QED-100 device. The volume of dead space in use during full expansion of the QED-100's rebreathing loop is ~750 mL. As such, it is imperative that the user understand that a certain patient tidal volume (500 mL) is advocated in order to maintain adequate mixing of exhaled (used) gas and new gas. However, it should also be noted that there are instances of tidal volumes less than 500 mL that have been reported without oxygen desaturation occurring.

With partial rebreathing the end tidal carbon dioxide level will become inspired carbon dioxide and thereby increase the fraction of inspired CO_2 ($FiCO_2$) and thus $PaCO_2$. The effect of increasing $PaCO_2$ not only increases cerebral blood flow velocity (Figure 1), but also increases the drive to breathe (Figure 2). This is especially important during spontaneous ventilation while under the influence of inhaled anesthetics and opioids due to their respiratory depressing effects.

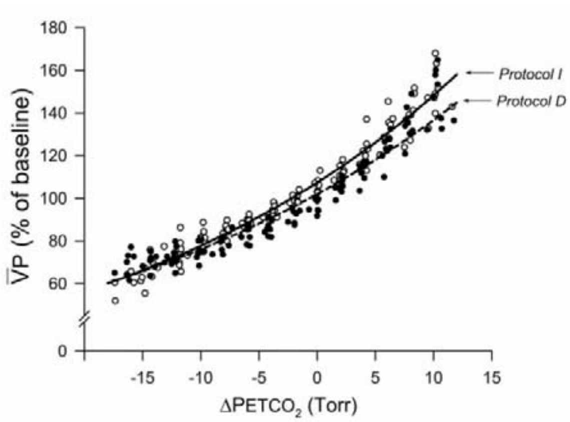

Figure 1. Cerebral Blood Flow Velocity vs. $EtCO_2$[1]

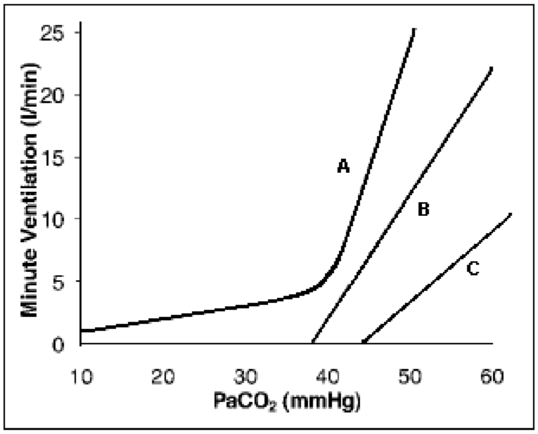

Figure 2. $PaCO_2$ and Drive to Breathe[2]

Curve A: Normal, no anesthetic drug effect.
Curve B: Light anesthetic effect
Curve C: Deeper anesthesia

RESPIRATORY DEPRESSANTS

In addition to maintaining oxygenation, the purpose of ventilation is to clear the body of waste products such as CO_2. As stated in the previous paragraph it is known that CO_2 stimulates respiration thereby preventing its build-up. This primarily occurs due to a decrease in respiratory tidal volume.

Respiratory Depressants:

- *Opioids*
- *Paralytics*
- *Respiratory Physics*

Opioids

Opioids such as the fentanyl family, morphine, hydromorphone or meperidine are usually therapeutically necessary during any procedure in which a general anesthetic is required. The benefits of adding opioids to an anesthetic are to help with discomfort after surgery (analgesic effect) but, also to help the anesthetist use less inhaled anesthetics during the surgical case. In addition to its analgesic effect, opioids also have a respiratory depressive effect. This respiratory depressive effect is more profound than that seen with the volatile anesthetics and synergistically adds to the respiratory depression caused by the volatile anesthetics. In addition, its respiratory depressive effect is seen primarily with regard to depression of respiratory rate.

Paralytics

Another spontaneous respiratory deterrent is the use of paralytics. Paralytics are not typically used with LMAs since it is common practice to have patients breathing spontaneously during their use. If, however, a patient is intubated, the use of muscle relaxants for the intubation process and possibly throughout the case may be a more common practice. If that is the case, a patient may start to show signs of spontaneous respiration if the paralytics are given time to “wear-off”. The anesthetist may attempt to allow the patient to breathe on his or her own by turning off the ventilator. It is entirely possible that the patient may breathe spontaneously but with minimal tidal volumes due to residual muscle paralytics augmented by the volatile anesthetic.

Respiratory Physics

A primarily physical reason a patient may not be able to generate a large tidal volume may be due to their inability to overcome breathing resistance. This resistance occurs due to circuit restrictions from the endotracheal tube or the LMA, the humidivac filter, the QED-100 and the anesthesia circuit itself. It must be remembered that with fluid (gas or liquid) flow, resistance is directly proportional to tube length. So, the longer the breathing circuit that is hooked up to the patient, the more resistance they have to breathe through. Decreasing the cross sectional area or radius of the tube can also drastically increase the resistance while breathing.

RESPIRATORY STIMULANTS

Carbon Dioxide

Although it will take more CO_2 in their system in order to stimulate spontaneous breathing, carbon dioxide still works as a stimulant to help patients increase their minute ventilation under anesthesia with volatile anesthetics. The amount of CO_2 needed to achieve increased tidal volumes will depend on how much respiratory depressant such as opioids, volatile anesthetic and/or muscle relaxant are on board. This, of course, will be balanced against the respiratory stimulants such as surgical or pain stimulation, airway stimulation, decreasing amounts of volatile agent and/or opioids.

Discomfort and Pain

It is important to realize that any sort of irritant such as surgical discomfort or airway stimulation can stimulate spontaneous breathing. Conversely, inadequate management of the painful

Respiratory Stimulants:

- *Carbon Dioxide*
- *Discomfort and Pain*
- *Combination Effects*

stimulus whether due to insufficient doses of opioids or anesthetics can also lead to stimulation of spontaneous breathing. One should also be aware of the irritating impact of an endotracheal tube. This irritation is much greater than that of the LMA. The irritation may cause stimulation of breathing or more likely may cause coughing on the endotracheal tube which may be counterproductive to instigating large tidal volumes. This may be more likely in those individuals with already irritated airways such as smokers or asthmatics.

Combination Effects

It is worth noting that upon discontinuing the volatile anesthetic, the respiratory depressing effects will start to abate as the patient rids themselves of the anesthetic. Therefore, the minute ventilation will be augmented by both the declining level of the anesthetic and the increasing levels of CO_2. A ceiling effect for respiration may occur commensurate to the amount of stimulation the patient is experiencing or the amount of opioid on board.

ENSURING SAFE SPONTANEOUS VENTILATION

Coughing on the endotracheal tube:

- *Tidal volume may suffer*
- *O_2 use increases*
- *CO_2 production increases*

Oxygenation

The primary safe endpoint is that the patient maintains a tidal volume that allows for adequate oxygenation. Again, a safe tidal volume to be used in conjunction with an activated QED-100 advocated by Anecare Laboratories is at least 500 mL. If tidal volumes are less than 500 mL, special attentiveness should be paid to both the fraction of inspired oxygen and oxygen saturation. If the fraction of inspired oxygen drops below 35% or the oxygen saturation drops to less than or equal to 90%, the QED-100 should be deactivated. Without the re-breathing dead space, it may be possible that the patient may decrease his or her minute ventilation as the carbon dioxide is “blown-off”.

Nitrous Oxide Removal

If nitrous oxide is used during the case and not discontinued well before the end of the case, it may be possible for the patient to continue to re-breathe the nitrous oxide and not rapidly emerge from anesthesia, This condition may be apparent if one were to see the fraction of inspired nitrous oxide not appreciably drop on successive breaths. It should be noted that even if the fraction of inspired oxygen and oxygen saturation remains within a safe range, it may be prudent to deactivate the QED-100 after the end tidal volatile agent concentration reaches less than or equal to 1/3 of its MAC value. Again, expect that the minute ventilation may decrease.

Coughing on the Endotracheal Tube

If coughing due to tracheal irritation occurs, aside from being really difficult to watch, the tidal volume may suffer. In addition, since the patient is more stimulated, oxygen consumption and CO_2 production may increase. As stated above, this situation is more apt to occur in patients who are smokers or are asthmatics. It is also more apt to occur in patients who are being control ventilated. Bronchospasm, or closing of the small airways in the lungs, is more apt to occur during these coughing fits. In addition, these patients may be in stage II and are more apt to experience laryngospasm, closing of the vocal cords or airway, if the endotracheal tube is pulled too early. In this situation, it would probably be advisable to deactivate the QED-100 and allow the clinician to proceed as he or she would normally. This type of emergence may occur with or without the QED-100 device.

THE LARYNGEAL MASK AIRWAY

The laryngeal mask airway (LMA) is a device that is used to help facilitate spontaneous respiration while under general anesthesia, Figure 3. While under general anesthesia with volatile or intravenous anesthetics, a patient’s airway anatomy may relax and breathing may be obstructed. The LMA is a less intrusive and therefore less irritating device than the endotracheal tube. The LMA keeps the airway open by providing a direct airway conduit to the trachea but not does not extend into the trachea as does the endotracheal tube.

LMA Usage

The LMA may be chosen over the endotracheal tube because of its relative ease of placement, less irritability of the airway, less resistance for spontaneous breathing and therefore possibly smaller amount of anesthetic needed. Since the LMA may require less anesthetic and is not placed into the trachea, which is therefore less

LMA Use

- *Ease of placement*
- *Less irritation of the airway*
- *Less resistance to spontaneous respiration*

irritating, most anesthetists perceive that by using the LMA, patients may exit anesthesia faster. Since the LMA is considered a less adequate method to secure the airway, it will most likely only be used when the airway is more geographically accessible to the anesthetist, Figure 4. It also does not protect the airway from gastric contents like an endotracheal tube. It is also not considered to be a device of choice for positive pressure ventilation for a prolonged period of time. Therefore, it will only be used in cases in which aspiration of gastric contents is of relatively low risk, shorter cases and overall less complex surgical cases.

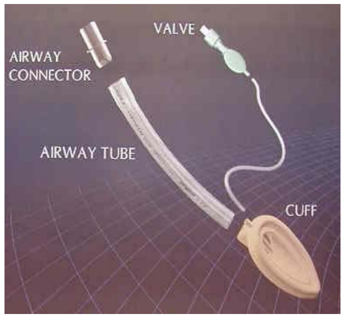

Figure 3. LMA

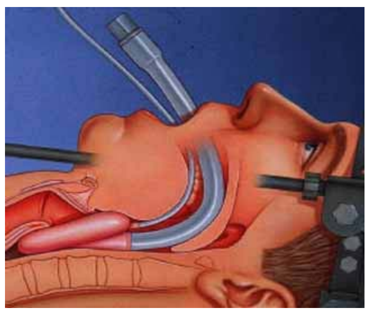
Figure 4. LMA Use

The QED-100 with the LMA

The QED-100 has been used on a limited basis with the LMA. Preliminary usage has only shown positive results. As stated above, during spontaneous ventilation at emergence, the QED-100 may be activated to facilitate emergence from a general anesthetic maintained with a volatile agent. The QED-100 will function adequately to initiate rebreathing of CO_2. This will then steadily allow the patient to increase his or her minute ventilation in response to the rise in CO_2. This increased respiration will allow for elimination of the volatile anesthetic.

The QED-100, LMA and Oxygenation

It must be emphasized again that tidal volumes of 500 mL are recommended in order to maintain adequate oxygenation while using the QED-100 at its maximum dead space of 750 mL. If tidal volumes are less than 500 mL, as stated above, the anesthetist must pay careful attention to the FiO_2 and oxygen saturation. Again, remember that the patient will most likely increase his or her tidal volume and or respiratory rate in response to the increasing CO_2.

The QED-100, LMA and Expectations

The QED-100 will help facilitate emergence of patients from volatile anesthetics while using the LMA. It is important to realize that emergence will be dependent on the amount of minute ventilation a patient is taking. This may or may not be a lot depending on factors for spontaneous ventilation as stated above. It is also important to remember that the LMA is not as stimulating as the endotracheal tube. Therefore, the emergence with an LMA most likely will be smoother than that with an endotracheal tube, but possibly not quite as rapid.

CASE STUDY #1

53 year old, 75 kg, Caucasian male with history of hypertension scheduled for ORIF of left tibial plateau fracture.

The patient received premedication with midazolam 2 mgs.

Induction

The patient was taken to the operating room. Monitors were placed. Preoxygenation occurred.

The patient was induced for a general anesthetic with:

1. Fentanyl 50 mcgs
2. Lidocaine 80 mgs
3. Propofol 200 mgs

After loss of consciousness, a LMA #5 was placed without difficulty.

Maintenance

The patient was maintained with 2.0% sevoflurane.

Surgery commenced. 600 mcgs of fentanyl were titrated throughout the case. There were no difficulties and the surgery ended 3 hours later. Right before emergence, the patient was breathing at tidal volumes equal to 600 mL at 9 times per minute. His end tidal carbon dioxide was 51 mmHg.

Emergence Case 1:

- *3.5 minutes*

Emergence Case 2:

- *6.0 minutes*

Emergence

The QED-100 was activated. The patient immediately began to re-breathe carbon dioxide. The inspired anesthetic agent went to zero within 5-6 breaths. The patient progressively began to increase both his tidal volume and respiratory rate to prevent his end tidal carbon dioxide from going above 51 mmHg. His tidal volume went to 1100 mL at 18 breaths per minute.

The patient was awake and had the LMA removed after 3.5 minutes. His minute ventilation right before removal of the LMA was approximately 20 liters per minute.

CASE STUDY #2

42 year old 65 kg Hispanic female, otherwise healthy scheduled for ORIF of right distal radial fracture.

The patient received premedication with midazolam 2 mgs.

Induction

The patient was taken to the operating room. Monitors were placed. Preoxygenation occurred.

The patient was induced for a general anesthetic with:
1. Fentanyl 50 mcgs
2. Lidocaine 60 mgs
3. Propofol 170 mgs

After loss of consciousness, a LMA #4 was placed without difficulty.

Maintenance

The patient was maintained with 2.0% sevoflurane.

Surgery commenced. 500 mcgs of fentanyl were titrated throughout the case. There were no difficulties and the surgery ended 2 hours later. Right before emergence, the patient was breathing at tidal volumes equal to 450-500 mL at 6 times per minute. Her end tidal carbon dioxide was 47 mmHg.

Emergence

The QED-100 was activated. The patient immediately began to re-breathe carbon dioxide. The inspired anesthetic agent went to zero within 5-6 breaths. The patient progressively began to increase both her tidal volume and respiratory rate. The tidal volume achieved 600 mL and rate 12 breaths per minute. The end tidal CO_2 rose to 60 mmHg. The patient was awake and had the LMA removed after 6.0 minutes. Her minute ventilation right before removal of the LMA was approximately 8 liters per minute.

End Notes

1. Ide K., Eliaszіw M, Poulin MJ: J APPL Physiology, 95:129-137, 2003
2. Gross JB, When you breathe IN you inspire, when you DON'T breathe, you...expire: new insights regarding opioid-induced ventilatory depression; Anesthesiology 2—3, Oct; 99 (4): 767-70

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