Difficult or Impossible Ventilation after Sufentanil-induced Anesthesia Is Caused Primarily by Vocal Cord Closure

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Introduction: Opioid-induced rigidity often makes bag-mask ventilation difficult or impossible during induction of anesthesia. Difficult ventilation may result from chest wall rigidity, upper airway closure, or both. This study further defines the contribution of vocal cord closure to this phenomenon.

Methods: With institutional review board approval, 30 patients undergoing elective cardiac surgery participated in the study. Morphine (0.1 mg/kg) and scopolamine (6 μg/kg) given intramuscularly provided sedation along with intravenous midazolam as needed. Lidocaine 10% spray provided topical anesthesia of the oropharynx. A fiberoptic bronchoscope positioned in the airway photographed the glottis before induction of anesthesia. A second photograph was obtained after induction with 3 μg/kg sufentanil administered during a period of 2 min. A mechanical ventilator provided 10 ml/kg breaths at 10/min via mask and oral airway with jaw thrust. A sidestream spirometer captured objective pulmonary compliance data. Subjective airway compliance was scored. Pancuronium (0.1 mg/kg) provided muscle relaxation. One minute after the muscle relaxant was given, a third photograph was taken and compliance measurements and scores were repeated. Photographs were scored in a random, blinded manner by one investigator. Wilcoxon signed rank tests compared groups, with Bonferroni correction. Differences were considered significant at P < 0.05.

Results: Twenty-eight of 30 patients exhibited decreased pulmonary compliance and closed vocal cords after opioid induction. Two patients with neither objective nor subjective changes in pulmonary compliance had open vocal cords after opioid administration. Both subjective and objective compliances increased from severely compromised values after narcotic-induced anesthesia to normal values (P = 0.000002) after patients received a relaxant. Photo scores document open cords before induction, progressing to closed cords after the opioid (P = 0.00002), and opening again after a relaxant was administered (P = 0.00005).

Conclusion: Closure of vocal cords is the major cause of difficult ventilation after opioid-induced anesthesia. (Key words: Opioids; sufentanil. Muscular rigidity. Chest wall rigidity.)

OPIOID-BASED anesthetic techniques are the most commonly used anesthetic regimens for patients undergoing cardiac surgery. These techniques provide unparalleled hemodynamic stability, blunting of the neuroendocrine responses to surgical stimulation, and postoperative analgesia.1 Opioid-based induction techniques are often complicated by muscular rigidity and difficult ventilation.2 This phenomenon was first described by Hamilton and Cullen in 1953.3 The sequelae of difficult ventilation are clinically important and can include hyperventilation, hypoxemia, pulmonary hypertension, respiratory acidosis, and increased intracranial pressure.4-6 The incidence of this complication varies depending on the opioid and dose used and the rate at which it is administered. The reported incidence of difficult ventilation after a moderate dose of sufentanil ranges from 84–100%.7,8

The recent release of an ultra-short-acting esterase-metabolized opioid may increase the incidence of difficult ventilation in the general operating room population.9 This heightens the need for a clear understanding of the cause of this phenomenon.

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tion is commonly ascribed to rigidity of the abdominal and thoracic musculature. There has been some evidence in the literature that a glottic or supraglottic mechanism may be responsible. This study further elucidates the contribution of the glottis and supraglottic structures to this clinical problem.

Materials and Methods

Thirty patients provided informed consent to enter this institutional review board-approved study. Patients underwent elective coronary revascularization, valve repair or replacement, or both. Patients were excluded if they were older than 90 yr, had undergone previous thoracic surgery, had significant pulmonary disease, were morbidly obese (as defined by a body weight >100 kg), or had a history or physical examination suggesting either an airway abnormality or difficulty with intubation.

Morphine sulfate (0.1 mg/kg) and scopolamine (0.006 mg/kg) given intramuscularly provided preoperative sedation and control of airway secretions. All patients received intravenous, arterial, and pulmonary arterial catheters placed with local anesthesia. Midazolam (1-2 mg) given intravenously provided additional sedation as needed. The oral and pharyngeal mucosa were topically anesthetized with 5% lidocaine ointment and 10% lidocaine spray (Astra Pharmaceuticals, Westborough, MA).

A split fiberoptic Berman style airway was placed, followed by an appropriately sized Patil-Syracuse mask (Anesthesia Associates, San Marcos, CA). Patients breathed 100% oxygen through the mask connected to a semiclosed circle breathing system attached to a standard anesthesia machine. An adult-sized fiberoptic bronchoscope (Pentax model FB19H) was placed through the port in the Patil-Syracuse mask and the airway and positioned just above the opening of the glottis. A color video camera system (Dyonics digital camera system; Smith & Nephew, Andover, MA) attached to the fiberscope provided both real-time video images and color photographs as needed. With the patient breathing quietly, the first photograph was taken at end expiration.

Anesthesia was induced with 3 μg/kg sufentanil administered as a 2-minute infusion. Phenylephrine or ephedrine were given intravenously as needed to maintain normal hemodynamics. At the conclusion of the sufentanil infusion, a photograph was taken of the glottis, after which the fiber scope was removed and the mask port closed off with the attached cap. The anesthesia machine ventilator provided 10 ml/kg tidal volume breaths at a rate of 10 per min through the mask and airway during a maximal jaw thrust maneuver. A capnograph side stream spirometer (Datex Capnograph Ultima; Helsinki, Finland) placed in the breathing circuit just proximal to the mask provided measurements of dynamic pulmonary compliance (Exhaled volume/plateau pressure – positive end-expiratory pressure). Data from five sequential breaths were recorded. The median value was used for analysis. Bag mask ventilation was then attempted and subjectively scored as follows: 0, cannot empty gas from the breathing bag; 1, able to ventilate with greater than normal effort; 2, able to ventilate with usual effort; 3, near-effortless ventilation.

After the data were recorded as just described, 0.1 mg/kg pancuronium given as a bolus provided muscle relaxation. One minute after muscle relaxants were given, subjective and objective compliances were measured again. Then the fiberscope was placed in the airway to obtain a third photograph. The patients were intubated either with the aid of fiberscope or by direct laryngoscopy at the discretion of the attending anesthesiologist.

The photographs obtained for all patients were coded by a research assistant, randomized, and then scored by one of the authors (J.C.H.) not present for any of the inductions. The photographs were scored as 1 = vocal cords opened, 2 = vocal cords partially closed, or 3 = vocal cords closed.

The Wilcoxon signed rank test compared subjective and objective compliance data. Freidman's nonparametric analysis of variance was used for picture score data. A significant effect of time was analyzed further by pairwise Bonferroni-corrected Wilcoxon signed rank tests. The study design allowed the patients to act as their own controls.

Results

Thirty patients completed the study protocol. Twenty-eight of the thirty patients exhibited severely compromised subjective and objective measures of pulmonary compliance after the induction of anesthesia with sufentanil. All 28 of these patients had closed vocal cords at the time of postoperative photography. Pooled data for all
Table 1. Objective/Subjective Compliance Data and Picture Scores

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>After Opioid</th>
<th>After Relaxant</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective compliance (ml/cm H\textsubscript{2}O)</td>
<td>NA</td>
<td>7 (1–55)</td>
<td>54 (27–95)</td>
<td>0.000002</td>
</tr>
<tr>
<td>Subjective compliance (score)</td>
<td>NA</td>
<td>0 (0–2)</td>
<td>3 (1–3)</td>
<td>0.00002</td>
</tr>
<tr>
<td>Picture (score)</td>
<td>1 (1–2)</td>
<td>3 (1–3)*</td>
<td>1 (1–2)†</td>
<td>0.00002*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00005†</td>
</tr>
</tbody>
</table>

Objective compliance (ml/cm H\textsubscript{2}O)
- Patient 10: NA
- Patient 28: NA

Subjective compliance (score)
- Patient 10: NA
- Patient 28: NA

Picture (score)
- Patient 10: 1
- Patient 28: 1

Data are median (range).
NA = not applicable.
* Baseline versus after opioid.
† After opioid versus after relaxant.

Patients showed compromised subjective compliance (median score, 0.0 ml/cm H\textsubscript{2}O; range, 0–2 ml/cm H\textsubscript{2}O) and objective compliance (median score, 7.0 ml/cm H\textsubscript{2}O; range, 1–55 ml/cm H\textsubscript{2}O) after induction. Both subjective (median score, 3 ml/cm H\textsubscript{2}O; range, 1–3 ml/cm H\textsubscript{2}O) and objective compliance (median, 54 ml/cm H\textsubscript{2}O; range, 27–95 ml/cm H\textsubscript{2}O) improved after the muscle relaxant was given (P < 0.00002 for each; table 1).

All patients scored 1 or 2 (cords opened) before the opioid was given. The median score after opioid was 3 (cords closed: range, 1–3; P = 0.00002). After relaxant, median score was 1 (cords opened: range, 1–2; P = 0.00005). The two patients who did not exhibit severely compromised compliance values after anesthetic induction had opened vocal cords at the postoperative photograph (picture scores = 1; table 1).

Many of the patients whose vocal cords closed after the infusion of sufentanil also exhibited an involution of the epiglottis and the aryepiglottic structures (see figure 1). The involution of the glottic structures is similar to the airway changes of laryngospasm.\textsuperscript{17}

Discussion

An increase in chest and abdominal wall muscle tone is most frequently cited as the cause of difficult ventilation after opioid induction of anesthesia.\textsuperscript{10,11} In 1983 Scamman\textsuperscript{12} noticed that patients with tracheostomies placed under local anesthesia before the induction of general anesthesia with 17 μg/kg fentanyl experienced only a small decrement in pulmonary compliance. How-

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Fig. 1. Photographs obtained from patient 1.
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However, an identical induction sequence in patients with natural airways resulted in impossible ventilation. Arandia and Patil, in a letter to the editor, described difficult ventilation in patients after opioid induction. Fiberoptic visualization of the glottis revealed closed vocal cords in some. They also described patients who had opened vocal cords but could not be ventilated. They ascribed this finding to chest wall, abdominal rigidity, or both.

Abrams et al. recently reported that preinduction placement of an oral tracheal tube allows a minimal decrement in ventilatory compliance on opioid induction of anesthesia. The current study goes further in demonstrating closure of the glottis and suprahyoid structures as the proximate cause of difficult ventilation after a sufentanil infusion. Patients in this study displayed a 93% incidence of difficult ventilation after the 3 μg/kg dose of sufentanil, which corresponds with the 84% incidence previously reported using a similar protocol.

This protocol did not allow us to determine what contribution, if any, contraction of the chest and abdominal musculature make to the experience of difficult ventilation after sufentanil induction of anesthesia. Data from the study by Abrams et al. showed a statistically insignificant change in pulmonary compliance after opioid induction in intubated patients. It is likely that in adults, this mechanism makes a minor contribution to the problem of difficult or impossible ventilation after opioid induction of anesthesia. To obtain accurate measurements of ventilatory compliance using an unintubated airway requires an excellent mask seal, proper placement of an oral airway, and use of an aggressive jaw thrust maneuver. We have used this technique in several studies and our data are consistent across the different protocols. We are confident that the changes in compliance demonstrated after opioid induction of anesthesia are not caused by airway obstruction above the level of the glottis.

The exact mechanism of increased muscle tone after the rapid infusion of an opioid is not known. Recent animal work indicates that stimulation of central μ₁ receptors increases efferent motor traffic, resulting in muscle contraction and rigidity. Activation of K₁ and Δ₁ receptors can attenuate this response.

Because muscle contraction requires an intact neuromuscular junction, neuromuscular blockade effectively terminates the clinical signs of opioid-induced rigidity. Priming alone with a nondepolarizing muscle relaxant does not effectively prevent rigidity. A simultaneous infusion of relaxant and opioid allow smooth induction without compromising ventilatory compliance. Jaffe and Ramsey independently noted that the administration of nondepolarizing muscle relaxants resolved the ventilatory embarrassment caused by opioids before the train-of-four measured at the adductor pollicis was affected. Both nondepolarizing and depolarizing muscle relaxants have been shown effectively to relax the laryngeal musculature before they have any effect on peripheral neuromuscular function. Understanding that laryngeal closure is the cause of opioid-induced difficult ventilation explains why the administration of muscle relaxants rapidly allows effective ventilation.

Focusing on activation of the laryngeal musculature as the proximate cause of difficult ventilation after opioid administration suggests that the administration of a small dose of a rapidly acting neuromuscular blocking agent may prevent this clinical problem. Additional investigations will explore this possibility.

References


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