Flexible Bronchoscopy Assisted by Noninvasive Positive Pressure Ventilation

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Noninvasive positive pressure ventilation (NPPV) is defined as any form of ventilatory support applied without endotracheal intubation. An often-used alternative to endotracheal intubation, NPPV reduces the need for invasive mechanical ventilation in patients with hypoxic respiratory failure due to cardiogenic pulmonary edema or immunocompromised state. NPPV is also used to improve postoperative hypoxemia; reduce pulmonary complications after cardiac, upper abdominal, and thoracic surgery; and provide ventilatory assistance for patients with obstructive sleep apnea, obesity hypoventilation syndrome, exacerbations of chronic obstructive pulmonary disease (COPD), and symptomatic expiratory collapse of the central airway.

Critically ill patients with the aforementioned comorbid conditions may require diagnostic or therapeutic flexible bronchoscopy to diagnose or treat causes of airway obstruction, atelectasis, and pneumonia. Standard practice in these instances is to recommend bronchoscopy with high-flow supplemental oxygenation via face mask, or to proceed with sedation and endotracheal intubation in order to ensure airway patency and minimize risks of procedure-related respiratory insufficiency. In many instances, however, bronchoscopy can be safely performed while the patient receives NPPV, sparing patients the discomfort and risks of refractory hypoxemia, intubation, and mechanical ventilation. The limited available published evidence indicates that NPPV-assisted flexible bronchoscopy is used about 3 times per month in tertiary academic centers.

Critical care nurses have an essential role in the preparation and performance of this procedure, as well as in surveillance after the procedure, and, as part of the multidisciplinary health care team, in patient care decisions. The objectives of this article, therefore, are to review the physiological basis for NPPV-assisted flexible bronchoscopy; describe its indications, contraindications, and techniques; and identify ways in which critical care nurses can further influence patient care before, during, and after this airway procedure.
Physiological Basis for NPPV-Assisted Bronchoscopy

Flexible bronchoscopy is often warranted in critically ill patients with atelectasis; pneumonia; airway obstruction by mucus plugs, blood clots, foreign bodies, or tumors; and expiratory central airway collapse characterized by excessive narrowing of the trachea and main bronchi during expiration. In these instances, bronchoscopy restores airway patency, improves ventilation and gas exchange, and might help avoid endotracheal intubation and mechanical ventilation. The risk of this procedure in critically ill patients, however, is not insignificant.

The physiological basis for NPPV-assisted flexible bronchoscopy, therefore, resides in the mechanisms by which bronchoscopy-related adverse events occur. The flexible bronchoscope occupies 10% to 15% of a normal tracheal lumen; resulting hypoventilation may prompt a decrease in PaO₂ by 10 to 20 mm Hg. Procedures may also induce or exacerbate bronchospasm, and, in the presence of hypoxemia, increase the risk of respiratory insufficiency or cardiac arrhythmias. Procedure-related hypoxemia occurs after insertion of the bronroscope through the glottis, which causes partial tracheal obstruction and ventilation-perfusion mismatch. It is also caused by excessive suctioning, which reduces end-expiratory volume and promotes alveolar closure.

In addition, topical anesthetics such as lidocaine or tetracaine, saline washes, and bronchoalveolar lavage fluid administered during the procedure may induce bronchospasm and allergic reactions. Gas exchange is impaired through a process of alveolar filling, especially after bronchoalveolar lavage, for example, when hypoxemia may persist for up to 6 hours. This problem has prompted the American Thoracic Society to recommend avoiding bronchoscopy altogether in patients with hypoxemia that cannot be corrected to at least a PaO₂ of 75 mm Hg or to an oxygen saturation greater than 90%.

Intravenous sedation, usually necessary to ensure patients’ comfort, can further compromise ventilatory status, especially in children and in patients with awake hypercapnia, obstructive sleep apnea, or obesity hypoventilation syndrome, who may have sedation-related increased collapsibility of the central airways. Finally, bronchoscopy can lead to air trapping and respiratory distress in patients with severe COPD because functional residual capacity increases when the scope is inserted nasally. To enhance patient safety and overcome many of these procedure-related risks, endotracheal intubation is often recommended before flexible bronchoscopy is performed.

Indications

NPPV can be used instead of endotracheal intubation as a ventilatory assist technique that helps reduce the risks of bronchoscopy-related adverse events. NPPV improves gas exchange and work of breathing by reducing intrapulmonary shunt and ventilation-perfusion mismatch. These effects are primarily a result of recruitment of collapsed alveoli by positive end-expiratory pressure.

In a randomized controlled trial of bronchoscopy with continuous positive airway pressure (CPAP, 7.5 cm H₂O) versus high-flow oxygen in adult patients at high risk for respiratory complications (PaO₂ <125 mm Hg on high-flow mask), researchers evaluated oxygeonization during and after bronchoscopy as well as respiratory complications. Fifteen patients were entered into each arm of the study. Seven patients in the oxygen group needed some form of ventilatory support, including 4 intubations during the 6 hours following the procedure, as opposed to only 1 patient in the CPAP group.

In other studies, NPPV diminished hypercapnia in adult COPD patients with pneumonia undergoing bronchoscopy and overcame hypotonicity of upper airway muscles in adult patients with obstructive sleep apnea. Studies also show that CPAP acts as a pneumatic stent, decreases upper airway collapsibility, and improves tidal volumes and peak inspiratory and expiratory flows in spontaneously breathing infants and children between the ages of 3

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days and 25 months. These changes might otherwise dramatically increase the collapsibility of airway walls when bronchoscopy is performed with the patient under deep sedation.

CPAP also improves spirometry, atelectasis, and exercise tolerance in adult and pediatric patients with expiratory central airway collapse. This syndrome may cause hypercarbic respiratory failure and comprises 2 disorders that may be noted individually or together. These are tracheobronchomalacia (weakness of cartilaginous structures) and excessive dynamic airway collapse, which consists of excessive bulging of the posterior membrane of the trachea and main bronchi resulting in a narrowing of airway caliber by 50% or more during expiration. Dyspnea, refractory cough, inability to raise secretions, and respiratory failure requiring ventilatory support can be prevented by CPAP, which acts as a pneumatic stent that improves lung volumes and airflow.

**Techniques**

Procedures are performed by a bronchoscopist (ie, intensivist, pulmonologist, thoracic surgeon), with the help of at least 1 respiratory therapist or nursing assistant and the patient’s critical care nurse. The presence of a critical care nurse is important because patients often have life-threatening comorbid conditions, require sedation and reassurance, and are at constant risk of compromised respiratory function.

First, a resuscitation mask is secured to the patient’s face with elastic straps (Figure 1). The patient is then connected to the ventilator by using a dual-axis swivel adapter (T-adapter) attached to the mask. This has a tight disposable cap that prevents air leakage. Silicone or jelly lubricant is applied to the bronchoscope, which is advanced into the nares through the swivel adapter. An alternative technique has been described in which the authors modified a total full face mask by inserting a plastic cylinder secured in the mask at a position that allows introduction of the bronchoscope through the mouth.

Bronchoscopy is performed in standard fashion for airway inspection and performance of diagnostic procedures. If necessary, bronchoalveolar lavage is performed after wedging the tip of the bronchoscope into the target bronchial segment and instilling up to 200 mL of physiological saline solution in 30- to 50-mL aliquots. The procedure can be performed with the patient upright or supine. In case it is necessary to evaluate the degree of airway narrowing and the response to positive pressure ventilation in patients with expiratory central airway collapse, bronchoscopy can be done both on and off NPPV (Figure 2). Changes in patients’ positioning, as well as alterations in NPPV settings, are controlled by the bronchoscopy assistant and critical care nurse while the bronchoscopist maintains the scopeatraumatically within the airway.

NPPV parameters depend on clinical indications. In cases of refractory hypoxemia, or hypercarbia from COPD, for example, CPAP is set at 5 cm H₂O and pressure support ventilation is set at 15 to 17 cm H₂O. Various criteria (ie, ratio of PaO₂ to fraction of inspired oxygen [FIO₂], <100 or <300) have been used in studies to decide when to start NPPV-assisted bronchoscopy.

In patients with expiratory central airway collapse, a CPAP of 7 to 10 cm H₂O usually ensures airway patency. CPAP can be incrementally increased by 3 cm H₂O until airway caliber during exhalation is at least...
50% of that noted during inspiration. CPAP can, however, prevent an accurate evaluation of dynamic airway obstruction by preventing airway collapse. Hence, dynamic airway lesions within extra- and intrathoracic airways (ie, laryngomalacia, tracheobronchomalacia) should be additionally studied without CPAP to assess collapsibility.

**Monitoring Requirements**

Monitoring during NPPV-assisted bronchoscopy helps prevent procedure-related morbidity, apply appropriate ventilatory settings, and detect early signs of respiratory or hemodynamic compromise. These may occur not only as a result of performing bronchoscopy in an already frail patient (eg, with extensive pulmonary infiltrates, oxygen saturation <90%, PaO₂ <75 mm Hg, forced expiratory volume in 1 second <1 L) but may also be caused by aspiration, which is more likely to occur during NPPV because of gastric distention. The major risks and complications of this procedure, how to recognize them, and strategies for nursing management are summarized in the Table.

The critical care nurse should continuously observe the patient and the monitors and should be ready to reposition the patient or suction the patient’s mouth in case of aspiration of gastric contents. Reassurance should be provided continuously to the patient undergoing this procedure because the patient’s cooperation is essential, even when a sedative is being administered. Moderate (conscious) sedation is usually used during bronchoscopy because of patients’ anxiety, pain, oropharyngeal or nasopharyngeal irritation, cough, dyspnea, and chest discomfort.

Although sedation is generally safe during bronchoscopy, all sedative regimens produce some cardiopulmonary depressant effects, which may be exacerbated in critically ill patients. Practice patterns vary regarding the type and use of sedation during bronchoscopy. Both the method and the level of sedation delivered vary (eg, titration vs fixed doses). The choice of sedative agent and dose generally depends on age, underlying medical comorbid conditions, and concomitant medications of the patient and also the preference of the bronchoscopist.

Careful monitoring of all patients and adherence to guidelines is important to ensure a safe outcome. Electrocardiography and pulse oximetry are continuously monitored. If the oxygen saturation decreases to less than 80% for more than 1 minute, or in case of poor clinical tolerance, the nurse should increase the FIO₂ to keep oxygen saturation above 90%.

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**Figure 2** Patient with respiratory distress due to expiratory central airway collapse from Mounier-Kuhn syndrome. Flexible bronchoscopy during noninvasive positive pressure ventilation is performed with the patient upright (A) and supine (B), revealing severity (see monitor in photo) and extent of airway collapse and allowing removal of secretions. The highlighted cross-sectional area in panels A and B shows the significant change in the airway caliber associated with the change from upright to supine position.
Psychomotor agitation, tachycardia, and tachypnea suggest that the patient is experiencing discomfort or hypercarbia is developing, which may cause lethargy and even coma if not corrected. Seizures may occur as a result of excessive topical anesthetic and of course one should watch for allergic reactions (rash, swelling, acute onset of airway petechiae). Tidal volume and minute ventilation should be monitored continuously, and if parameters decrease from baseline levels, then the setup CPAP may have to be increased. If no improvement occurs or the patient’s condition deteriorates (systolic blood pressure <80 mm Hg, encephalopathy or coma, refractory hypoxemia despite FiO₂ of 1.0), then endotracheal intubation becomes compulsory. A resuscitation cart must therefore be readily available, and the critical 

| Table: Recognition and nursing management of the risks and complications associated with use of noninvasive positive pressure ventilation during flexible bronchoscopy |
|---------------------------------|---------------------------------|---------------------------------|
| **Risks and complications**    | **Recognition**                 | **Management**                  |
| Aspiration                      | Presence of gastric content in the mouth | Prompt suctioning of the mouth |
|                                 | Bronchoscopic visualization of penetration of the gastric content in the larynx and the trachea | Placement of patient in left lateral decubitus position |
|                                 | Preparedness for endotracheal intubation if patient is unable to protect airway | |
| Arrhythmias                     | Electrocardiography             | Drug therapy for specific rhythm |
| Hypoxemia                       | Monitor pulse oximetry          | Adjustment of fraction of inspired oxygen (FiO₂) to keep oxygen saturation >90% |
|                                 | Monitor for cyanosis, arrhythmias, altered mental status | Preparedness for endotracheal intubation if patient has hypoxemia despite FiO₂ of 1.0 |
|                                 | Monitor for oxygen desaturation (usually in severe hypercarbia) | Chin lift and jaw thrust and use of nasopharyngeal tubes when caused by upper airway obstruction (e.g., obstructive sleep apnea) |
| Hypercarbia                     | Monitor tidal volume and minute ventilation | Increasing continuous positive airway pressure to maintain baseline minute ventilation |
|                                 | Monitor patient for psychomotor agitation, tachycardia, and tachypnea (early findings of hypercarbia) | Preparedness for endotracheal intubation in case patient's condition deteriorates (systolic blood pressure <80 mm Hg, encephalopathy or coma, hypoxemia despite FiO₂ of 1.0) |
|                                 | Monitor patient for impaired cognition, lethargy, and unresponsiveness (late findings of untreated hypercarbia) | Chin lift and jaw thrust and use of nasopharyngeal tubes when caused by upper airway obstruction (e.g., obstructive sleep apnea) |
|                                 | Monitor for oxygen desaturation (usually in severe hypercarbia) | |
| Bronchospasm                    | Monitor for wheezing             | Prompt administration of nebulized bronchodilators (albuterol 2.5 mg with or without ipratropium 0.5 mg); may be repeated every 20 min to response |
|                                 | Monitor for signs and symptoms of hypercarbia and hypoxemia | |
| Laryngospasm                    | Monitor for stridor              | Prompt administration of nebulized racemic epinephrine (2.25%): 1-3 inhalations |
|                                 | Monitor for signs and symptoms of hypercarbia and hypoxemia | Provision of high flow oxygen |
|                                 | | Chin lift and jaw thrust maneuver |
| Seizures                        | Monitor mental status (coma may represent subclinical status epilepticus) | Placement of patient in left lateral decubitus position |
|                                 | Do not exceed 400 mg lidocaine for local analgesia | Preparedness for endotracheal intubation if patient is unable to protect airway |
|                                 | Careful monitoring of elderly patients with liver and cardiac dysfunction | Drug therapy for status epilepticus |
| Oversedation                    | Monitor for altered mental status and signs and symptoms of hypoxemia and hypercarbia | Flumazenil 0.2-0.5 mg intravenously to maximum 3 mg to reverse benzodiazepine-induced oversedation |
|                                 | | Naloxone 0.1-0.2 mg intravenously every 2-3 minutes as needed to reverse opiate-induced oversedation; 0.4-2.0 mg intravenously may be used for respiratory depression |
|                                 | | Preparedness for endotracheal intubation if patient is unable to protect airway |
care nurse should have easy access to endotracheal tubes, lubricants, and bite blocks to facilitate bronchoscopically or laryngoscopically assisted oral intubation.

After bronchoscopy is completed, positive pressure ventilation is maintained for at least 30 minutes, after which it can be discontinued if the oxygen saturation is greater than 92% and no evidence of respiratory insufficiency is apparent. Monitoring continues until the effects of intravenous sedation subside and the gag reflex has returned. The nursing staff monitoring the patient during this period must be aware that respiratory distress from hypoxemia or bronchospasm can occur after the scope is removed from the airway. Subtle changes in a patient’s condition or vital signs may signal impending respiratory failure, bronchospasm, hemodynamic instability, or impaired gas exchange. Timely administration of supplemental oxygen, bronchodilators, and other medications might suffice, but if clinically indicated, patients may need to be promptly intubated.

Contraindications

Although NPPV-assisted bronchoscopy is usually safe in the critical care setting, contraindications include hemodynamic instability (systolic blood pressure < 80 mm Hg), recent (<1 week) myocardial infarction, excessive psychomotor agitation, respiratory failure caused by neurological disease, status asthmaticus, and the presence of facial deformities or recent oral, esophageal, or gastric surgery that prohibit use of a face mask and increase the risk of gastric insufflation or aspiration. If bronchoscopy is necessary during cardiopulmonary resuscitation, respiratory arrest, severe hemodynamic instability, or acute and chronic encephalopathy, NPPV should not be used, and endotracheal intubation is warranted to ensure airway access. Intubation in these situations also maximizes chances for adequate oxygenation and ventilation.

During NPPV, an inability to maintain oxygen saturation above 85% despite the use of a high FIO₂ is also considered an indication for endotracheal intubation. The presence of copious secretions that cannot be cleared or that are associated with acidosis or changes in mental status should also prompt endotracheal intubation because mechanical ventilation via an indwelling endotracheal tube offers the benefit of a secure airway, facilitates carbon dioxide clearance, improves gas exchange, unloads respiratory muscles, and reduces the risk for massive aspiration during bronchoscopy. It also allows repeated insertions of the bronchoscope in order to remove obstructing mucus plugs or blood clots.

Conclusion

NPPV assistance is a satisfactory alternative to endotracheal intubation in many patients with severe refractory hypoxemia, severe COPD, postoperative respiratory failure, or severe obstructive sleep apnea and obesity hypoventilation syndrome who require flexible bronchoscopy for diagnostic or therapeutic purposes. NPPV-assisted bronchoscopy also facilitates the assessment of dynamic central airway processes such as malacia or excessive dynamic airway collapse.

Knowledge of this procedure and its consequences expands the scope of practice of critical care nurses and allows them to function more effectively within a multidisciplinary health care team. Indeed, careful monitoring during the procedure is essential to prevent and detect procedure-related adverse events or deterioration of the patient’s condition due to underlying disease processes and comorbid conditions.

The evidence to support the use of NPPV-assisted bronchoscopy is, however, based on only a few studies with a small number of patients. Future research should clarify whether this procedure has a favorable effect on intubation needs and procedure-related morbidity.


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