Ventilation and Anesthetic Approaches for Rigid Bronchoscopy

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Abstract

Due to growing interest in management of central airway obstruction, rigid bronchoscopy is undergoing a resurgence in popularity among pulmonologists. Performing rigid bronchoscopy requires use of deep sedation or general anesthesia to achieve adequate patient comfort, whereas maintaining oxygenation and ventilation via an uncuffed and often open rigid bronchoscope requires use of ventilation strategies that may be unfamiliar to most pulmonologists. Available approaches include apneic oxygenation, spontaneous assisted ventilation, controlled ventilation, manual jet, and high-frequency jet ventilation. Anesthetic technique is partially dictated by the selected ventilation strategy but most often relies on a total intravenous anesthetic approach using ultra–short-acting sedatives and hypnotics for a rapid offset of action in this patient population with underlying respiratory compromise. Gas anesthetic may be used with the rigid bronchoscope, minimizing leaks with fenestrated caps placed over the ports, although persistent circuit leaks can make this approach challenging. Jet ventilation, the most commonly used ventilatory approach, may be delivered manually using a Sanders valve or via an automated ventilator at supraphysiologic respiratory rates, allowing for an open rigid bronchoscope to facilitate ease of moving tools in and out of the airway. Despite a patient population that often suffers from significant respiratory compromise, major complications with rigid bronchoscopy are uncommon and are similar among modern ventilation approaches. Choice of ventilation technique should be determined by local expertise and equipment availability. Appropriate patient selection and recognition of limitations associated with a given ventilation strategy are critical to avoid procedural-related complications.

Keywords: rigid bronchoscopy; jet ventilator; high-frequency jet ventilator; ventilation technique

Preoperative Assessment

Rigid bronchoscopy, first performed in 1897 by German otolaryngologist Gustav Killian to remove an aspirated pork bone (1, 2), was the only technique available to visualize the airways until the development of the flexible bronchoscope by Shigeto Ikeda in 1967 revolutionized the field of bronchoscopy. Due to the need for general anesthesia with rigid bronchoscopy and lack of standardization in ventilation techniques, flexible bronchoscopy largely replaced rigid bronchoscopy over the ensuing years, given the ability to perform the procedure using moderate sedation in an office-based setting. In fact, even as recently as 2005, only 18% of pulmonary and critical care training programs in the United States offered rigid bronchoscopy instruction to their trainees (3).

However, given the growing interest in management of benign and malignant central airway obstruction by interventional pulmonary groups in the United States, the use of the rigid bronchoscope is undergoing resurgence in popularity. As pulmonologists add rigid bronchoscopy into their spectrum of procedures offered, there can be a steep learning curve for the institution in how to perform this procedure safely and effectively. One aspect of rigid bronchoscopy that is often unfamiliar to pulmonologists and anesthesiologists both is how to optimally ventilate a patient during the procedure. It is the objective of this review to discuss the various approaches to ventilation during rigid bronchoscopy, with focus on jet ventilation. Additionally, because the choice of ventilation affects the anesthetic technique, we review the various approaches available to facilitate the procedures.

Preoperative Assessment

Rigid bronchoscopy is almost exclusively performed under deep sedation or general anesthesia and requires a standard preoperative assessment. Particular attention should be paid to the oral cavity, jaw, and neck mobility. Basic
laboratory tests such as complete blood count, basic metabolic panel, chest imaging, and electrocardiogram should be done before the procedure. Additional testing may be necessary, depending on the patient’s medical history, at the discretion of the anesthesiologist or proceduralist (4).

Patients requiring high levels of supplemental O2 and those with baseline hypercarbia and hemodynamic instability are at increased risk for intra- and post-procedural complications, and risk/benefits of the procedure should be weighed carefully. Additional patient factors that may complicate rigid bronchoscopy include an unstable cervical spine or diminished range of motion of the cervical spine caused by spondylosis (as rigid bronchoscopy requires hyperextension of the neck and, therefore, these conditions can complicate rigid bronchoscopy); maxillofacial trauma or oral disease preventing opening of the jaw to admit the bronchoscope; and laryngeal disease, such as stenosis or obstructing neoplasms, that may prevent translaryngeal passage of the scope without inducing further trauma (5).

**Approaches to Ventilation**

Several ventilation strategies are commonly used during rigid bronchoscopy to provide adequate oxygenation and ventilation while maintaining appropriate sedation to minimize cough and movement and ensure patient comfort. Generalized challenges to performing safe anesthesia in this patient population with complex comorbidities and often marginal pulmonary status include: limited availability and lack of familiarity with specialized equipment, the need for additional training to apply uncommonly used techniques, and the need for rapid onset and offset of the effects of anesthetic agents. These challenges occur with each ventilation strategy; however, specific features of each may require modification of anesthetic approaches depending on which strategy is selected. The methods of ventilation that are available include:

1. Apneic oxygenation.
2. Spontaneous assisted ventilation
3. Controlled ventilation (closed system)
4. Manual jet ventilation
5. High-frequency jet ventilation (HFJV)

**Apneic Oxygenation**

Some designs of rigid bronchoscopes feature a port on the direct conduit orifice, allowing intermittent airway instrumentation during apnea followed by instrument removal, sealing the port, and positive pressure ventilation either manually or with a standard “anesthesia” ventilator delivering fresh gas via an anesthesia circuit connected to the side port. Packing the oropharynx with gauze minimizes the leak around the uncuffed rigid scope passing through the larynx but requires careful attention to removal of the gauze with Magill forceps at the end of the procedure.

Due to issues with incomplete sealing with oropharyngeal packing and the inconvenience of intermittent airway access, this approach to ventilation is mainly of historical interest. It was the primary approach use by Chevalier Jackson for removal of foreign bodies and biopsy of bronchial lesions. The technique relied on preoxygenation of the patient with 100% FIO2, with a brief period of time used to perform an intervention, followed by removal of the instruments from the bronchoscope and capping the proximal end, enabling the anesthetist to ventilate the patient. Once the patient had been ventilated and oxygenated, additional interventions were performed with repetition of this cycle until the case was completed (5).

The respiratory effects of this approach were examined by Frumin and colleagues (6), who studied apneic oxygenation in humans. Apneic oxygenation was performed in eight human subjects for periods between 15 and 55 minutes. Five out of eight patients developed respiratory acidosis (Pco2 range, 130–250; pH range, 6.7–6.9); as the duration of procedure increased, the incidence of acidosis increased. There was no mortality; two patients developed transient arrhythmia. Given the limitations of this approach, apneic oxygenation has largely been abandoned by most centers except for very brief procedures in selected patients.

**Spontaneous Assisted Ventilation**

Spontaneous assisted ventilation is a total intravenous anesthetic technique whereby the level of sedation is closely titrated throughout the procedure to maintain spontaneous ventilation by the patient. Supplemental oxygen is supplied through the rigid bronchoscope, and ventilation is maintained by the anesthetist via bag ventilation attached to the rigid bronchoscope during periods of deeper sedation and apnea.

Perrin and colleagues (7) described their experience with 124 rigid bronchoscopies in which ventilation was performed using the spontaneous assisted technique. After 3 minutes of preoxygenation by mask, anesthesia was induced by intravenous administration of propofol, phenoperidine, and diazepam or midazolam. After intubation with the rigid bronchoscope, patients were ventilated manually using high-flow oxygen (FIO2, 0.6–1.0) through a bag attached via flexible tubing to the ventilation port of the bronchoscope. Anesthesia was maintained by repeated injections of intravenous anesthetics, and ventilation was assisted manually in case of prolonged apnea or oxyhemoglobin desaturation. Notable complications occurred in 22 procedures and included severe perioperative or postoperative hypoxemia, bronchospasm, and laryngospasm (7). The authors concluded that the technique was effective for rigid bronchoscopic procedure and may have a lower rate of post-procedural reintubation due to the avoidance of neuromuscular blocking agents during the bronchoscopies (7).

Natalini and colleagues (8) compared the efficacy of remifentanil versus fentanyl in 90 patients undergoing rigid bronchoscopy with spontaneous assisted ventilation. All the patients received propofol supplemented by either fentanyl or remifentanil. The authors concluded that both the drugs were safe and provided good operating conditions. Patients who received remifentanil had faster recovery from anesthesia postoperatively.

**Controlled Ventilation (Closed System)**

An alternative to spontaneous assisted ventilation is controlled ventilation. In this technique, the rigid bronchoscope is used similarly to an endotracheal tube to provide inhaled anesthetic under positive pressure ventilation. This technique requires use of silastic caps on the ports of the rigid scope (Figure 1) as well as packing the mouth with gauze to minimize air leaks from the uncuffed rigid tube (10). This technique can be challenging to perform due to the operating characteristics of common
anesthetic equipment. Most ventilators used in the operating room are a component of a stand-alone, integrated anesthetic delivery system and are, by design, compact and simple. Typical designs are based on a simple “bag squeezer” principle, whereby direct mechanical pressure (e.g., Manley ventilator) or a driving gas (most modern designs) compress bellows to deliver a VT to the patient. One common feature is a relatively low inspiratory flow rate to drive the bellows, which can be as low as the minute ventilation in the case of a Manley ventilator or up to 120 L/min inspiratory flow, for example, for GE Healthcare anesthesia delivery system ventilators (Aisys, Avance CS<sup>2</sup>, Aespire View, and Aestiva).

A second common feature is an even lower flow rate of fresh gas, delivering an air/oxygen or air/nitrous oxide mixture carrying a vaporized inhalational anesthetic agent to fill the bellows. The programmed VT is generated by the driving gas applying pressure to the ventilator bellows, a reservoir of fresh gas and recycled patient-exhaled gas, typically ~1,500 ml. The flow rate of the driving gas (usually oxygen to avoid hypoxia if inadvertently mixed with fresh gas) determines the ability of the ventilator to generate an inspiratory pressure in the setting of a circuit leak. The fresh gas flow recharges the reservoir in readiness for the next breath; maximum fresh gas flows are 20 to 30 L/min, and a circuit leak will limit filling of the reservoir. As a consequence of ventilator design, therefore, it is difficult to compensate for circuit leaks because they prevent the development of a sustained inspiratory pressure and prevent effective “recharging” of the reservoir/bellows with fresh gas, both necessary to deliver adequate VT to the patient.

In addition to the inability to deliver an adequate minute ventilation, a circuit leak means the loss of delivery of the desired oxygen mixture and anesthetic agent to the patient, risking hypoxia and either unplanned awakening and movement, if spontaneously ventilating, or awareness (“paralyzed and awake”), if receiving neuromuscular blocking/paralytic agents.

Nitrous oxide and inhalational anesthetic agents are considered pollutants. They are scavenged from a sealed circuit and removed from the operating room environment via a vacuum system to avoid excessive occupational exposure to the operating room staff. With a circuit leak, pollution of the operating room environment with inhalational anesthetic agents must also be considered.

**Overcoming the Circuit Leak**

**Self-Inflating Bag**

Ironically, a simple, self-inflating bag (e.g., Ambu) is far more effective than a typical “anesthesia” ventilator at compensating for a circuit leak. The elasticity of the bag rapidly recharges the reservoir/bag for the next breath; coordination of manual bag pressure and observation of chest rise is a means of flow compensation for a circuit leak. Limitations include operator judgment and fatigue, lack of control of FiO<sub>2</sub> with high flow rates of “diluting” room air occurring during rapid elastic filling of the bag, and inability to deliver inhalational anesthetic agents.

Despite these challenges, controlled ventilation is the method of choice in some centers. A related method of closed ventilation involves placing a small endotracheal tube through the larynx to ventilate the patient and then passing a rigid bronchoscope alongside the endotracheal tube. This approach is similarly limited as described above (5).

**Jet Ventilation**

Jet ventilation uses a high-pressure gas source that is applied to an open airway in short bursts via a small-bore catheter. Two modes of jet ventilation are currently available. The technique as originally described by Sanders (11) in 1967, uses a hand-operated valve (manual jet ventilation) connected to 100% oxygen and a pressure-limiting device to deliver gas to the patient at 50 psi or less with a respiratory rate usually in the range of 10 to 14 breaths/min (9) (Figures 2 and 3). Respiratory rate and duration of breath are determined by the anesthesiologist, who monitors chest rise and O<sub>2</sub> saturations to determine adequacy of oxygenation and ventilation during the procedure. Manual jet ventilation is the most widely used mode of ventilation in patients undergoing rigid bronchoscopy today (10). The second mode of jet ventilation uses an automated system at respiratory rates substantially higher than physiologic (between 60 and 300 breaths/min, often termed HFJV) to allow for a nearly motionless operative field as well as freeing the anesthesiologist from ventilation during the procedure. The operator controls the applied pressure, respiratory rate, and inspiratory time to maintain adequate oxygenation (12).

Ventilation can be difficult to assess using both types of jet ventilation, and P<sub>CO</sub><sub>2</sub> can be monitored by repeated arterial blood gas measurements during the procedure or by transcutaneous capnographic monitoring (13). Advantages and disadvantages of each approach are discussed below (Table 1).

**Gas Exchange with Jet Ventilation**

The procedural advantage of jet ventilation is that the airway is left open to provide...
a conduit for a variety of tools to complete the needed intervention while maintaining adequate gas exchange. Application of a high-pressure gas through the open airway results in entrainment of surrounding air mixing with the gas jet via the Venturi effect (14). At conventional respiratory rates, gas exchange is achieved by bulk flow similar to conventional ventilation using a cuffed endotracheal tube. However, as respiratory rates increase to those used in HFJV, breath-to-breath VTs may fall to below dead space ventilation, and alternative mechanisms of gas transport predominate (15). These include: direct alveolar ventilation, laminar flow, longitudinal dispersion (Taylor dispersion), pendelluft, and molecular diffusion near the alveolar-capillary membrane (15). Further discussion of these mechanisms is beyond the scope of this review, but is excellently presented by Chang (15).

**Anesthetic Considerations**

Any anesthetic requires the combination of hypnosis, analgesia, and muscular relaxation, and total intravenous anesthetic is required with jet ventilation due to the open-circuit nature of this technique. Specific considerations for airway surgery via rigid bronchoscopy include the need for rapid and complete offset of anesthetic agents to allow full return to baseline respiratory function in these patients who often have marginal pulmonary status.

A rigid bronchoscope can be inserted in a nonparalyzed patient, but only under deep sedation typically requiring high doses of hypnotic or analgesic agents, risking cardiovascular instability or residual drug effects impairing pulmonary function after the procedure. Therefore, our local preference is for a balanced anesthetic technique using neuromuscular blocking agents to permit the use of lower doses of short-acting hypnotics. Anesthesia is induced with propofol and maintained with propofol and remifentanil infusions, with either vecuronium or cisatracurium (in the setting of renal impairment) being the muscle relaxants of choice. Of note, the commonly used paralytic agent rocuronium has a longer half-life than the above agents and must be used with care; similarly, pancuronium is long-acting and an inappropriate choice.

Alternative induction agents include etomidate or ketamine supplemented by short-acting opioids (fentanyl, alfentanil, or remifentanil), although a propofol infusion is preferred for maintenance. The anesthesiologist should be cognizant that use of a total intravenous anesthetic technique may be associated with increased risk of patient awareness (16).

Because post-procedural pain is often minimal, longer-acting opiates may induce respiratory depression at completion of the bronchoscopy (17). Procedures are generally close to 60 minutes, requiring short-acting neuromuscular blocking agents to avoid prolonged paralysis at completion of the procedure. Monitored reversal of neuromuscular block using neostigmine and an antimuscarinic agent (glycopyrrolate or atropine) is strongly recommended, as this patient population lacks the respiratory reserve to tolerate any degree of residual neuromuscular blockade (18).

At the completion of the procedure, anesthesiologists typically transition the rigid bronchoscope to a laryngeal mask airway or a cuffed endotracheal tube before reversal of anesthesia. The latter offers the advantage of more sophisticated ventilator weaning modes and a conduit for flexible bronchoscopy for additional pulmonary toilet if indicated. Similar to any other procedure requiring general anesthesia, recovery needs to be in an appropriately staffed and equipped postanesthesia recovery area or an intensive care unit.

**Figure 2.** Sanders manual jet ventilator.

**Figure 3.** Manual jet ventilator showing attachment to the side port of rigid bronchoscope.
Manual Jet Ventilation

**Technique.** Manual jet ventilation is applied via hand-triggered devices using a narrow-bore, noncompliant cannula that may be attached to the rigid bronchoscope at one of the accessory ports on the head of the instrument (9). Alternatively, the cannula may be longer, with the tip residing deeper in the bronchoscope or within the airway itself (19, 20). However, if this approach is used, particularly if gas is instilled distal to an airway stenosis, airway pressures must be carefully monitored and adequate expiratory time allowed to avoid development of excessive airway pressures and pneumothorax (9).

The driving gas source is high-pressure oxygen. This is passed through pressure-reducing valves and can be further adjusted via a regulator located on the activation valve to a pressure that produces the desired chest wall excursion and maintains oxygenation and adequate gas exchange (9). The delivered oxygen level may be attenuated using a gas blender to reduce \( F_{\text{IO}} \), to less than 0.4 to prevent airway fire during use of endobronchial laser or other heat-based modalities. However, given the variability in the amount of entrainment of room air, absolute \( F_{\text{IO}} \), delivered to the patient is difficult to determine. The nozzle or cannula should also be aligned along the axis of the airway to be effective and prevent gastric distension if positioned above the glottis, and the resulting \( V_T \) is the sum of the injected and entrained volumes (9, 19). A jet frequency of 8 to 10 per minute allows adequate time for exhalation via passive recoil of the lung and chest wall and prevents air trapping and the danger of barotrauma (9).

**Monitoring.** Careful observation of the patient’s chest movements is necessary to ensure adequate \( V_T \)s without causing overdistension. A tracheal pressure of 30 cm H\(_2\)O usually results in normocarbia in patients with healthy lungs and chest wall compliance (21). The pressure generated at the tip of the bronchoscope is not influenced by the volume or compliance of the lungs, although the effective \( V_T \) and alveolar ventilation are proportional to lung and chest wall compliance. During insertion of the suction catheter or biopsy forceps into the lumen of the bronchoscope, the generated inflation pressure increases; however, as long as complete occlusion is prevented between the bronchoscope and the inside of the airway, barotrauma will be unlikely (22). The rigid bronchoscope is uncuffed, and a leak between the scope and the tracheal wall or larynx, if present, further protects against barotrauma. In children and infants, the starting driving pressure should be approximately 0.5 psi/lb adjusted according to chest expansion (21).

Automated Jet Ventilation

Automated jet ventilation uses a commercially available ventilator to deliver oxygen, often at supraphysiologic respiratory rates, via a rigid catheter as described above. This system frees the anesthesiologist from performing ventilation during the procedure, allowing focus on other aspects of the case. Additionally, as respiratory rates increase, \( V_T \)s fall, resulting in a nearly motionless procedural field that can be advantageous for fine manipulations during bronchoscopy (23, 24). Finally, automated jet ventilation can achieve adequate oxygenation and ventilation using airway pressures that are substantially lower than those encountered in conventional ventilation (25). This can be beneficial in patients with bronchopleural, bronchoesophageal, or bronchomediastinal fistulae, who may develop significant complications with positive pressure ventilation (12).

**Technique.** Similar to manual jet ventilation, the clinician manipulates ventilator driving pressure, frequency, inspiratory time, and \( F_{\text{IO}} \), albeit with greater precision and reproducibility. Our practice is to begin with driving pressures of 12 to 18 psi, respiratory rate of 60, with an inspiratory time of 25%. However, gas flow at a given driving pressure can vary substantially between ventilator models, and so settings may need to be adjusted accordingly (12).

Ventilation efficacy is assessed by chest wall rise, which should be just visible or palpable by placing a hand on the patient’s chest, and the chest should come to resting position between breaths. Desaturations should prompt reevaluation of observed chest rise and can often be managed with increase in driving pressure, respiratory rate, or inspiratory time to increase mean airway pressure and functional residual capacity (26). Obese patients may be placed in reverse Trendelenburg position to decrease abdominal pressure on the diaphragm. Hypercarbia can often be managed by increasing driving pressure, with or without decreases in respiratory rate to increase \( V_T \), and complete exhalation between breaths (14). However, if adequate expiratory time is not provided, hypercarbia can be exacerbated by these maneuvers.

Patients with restrictive lung disease, poor chest wall compliance, and significant obesity can be difficult to ventilate using an automated jet ventilator. In addition, these patients may develop atelectasis during longer procedures due to low \( V_T \)s and mean airway pressures associated with this ventilation strategy. Patients with obstructive lung disease may become hyperinflated due to air trapping, although clinically this seems to be less common than with manual jet ventilation, likely due to the low mean airway pressures developed during automated jet ventilation. Other patients who can prove challenging to ventilate are those with significant airways stenosis, particularly tracheal stenosis due to the high airway resistance (19). Adequate ventilation may require higher-than-anticipated driving pressures with longer inspiratory times than would normally be required. The physician must remain mindful of the ventilator settings as the stenosis is alleviated and adjust them accordingly to prevent barotrauma (27). Anticipated atelectasis can be reversed by brief endotracheal intubation and positive pressure ventilation with positive end-expiratory pressure after removal of rigid scope if believed to be clinically indicated.

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**Table 1.** Manual jet ventilation versus high-frequency jet ventilation

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<th>Manual Jet Ventilation</th>
<th>Automated Jet Ventilation</th>
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<td><strong>Equipment cost</strong></td>
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<td><strong>Assessment of ventilation</strong></td>
<td>Easy</td>
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<td><strong>Anesthesiologist effort to ventilate</strong></td>
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<td><strong>Airway movement</strong></td>
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Monitoring. Standard operative monitoring is used during jet ventilation; however, monitoring VT is difficult, because the system is open and ambient air entrainment is unpredictable. External chest impedance or inductance bands may be used to assess VT, although most operators find use of periodic CO₂ measurement with arterial blood gas collection or transcutaneous capnography adequate to assess ventilation (17). Airway pressures are monitored using a catheter placed in the distal trachea and attached to the ventilator pressure port to prevent barotrauma. Peak pressures should be maintained below 35 cm H₂O.

Safety and Complications

Common complications of jet ventilation include hypercarbia, hypoxia, and hypotension (28–30). Golden and colleagues (29) examined respiratory consequences in 100 consecutive patients undergoing rigid bronchoscopy with manual jet ventilation. Oxygenation was adequate throughout the examination and after removal of the bronchoscope, with all PaO₂ values above 63 mm Hg. However, eight patients had a PaCO₂ greater than 45 mm Hg, with one as high as 75 mm Hg at completion of the procedure (29).

Fernandez-Bustamante and colleagues performed a paired retrospective–prospective cohort study to examine risk factors for procedural complications including hypercarbia, hypoxia, and hypotension in a total of 316 patients undergoing rigid bronchoscopy with HFJV (28). The authors found that hypercapnia and hypoxemia were common, present in 22 and 18% of the retrospective cohort, respectively, whereas in the smaller prospective cohort both of these complications were present in 32% of patients. In addition, hypotension was noted in up to 20% of patients in the prospective cohort. Multivariate analysis identified baseline oxygen saturation as measured by pulse oximetry of 95% or less on room air and American Society of Anesthesiologists status IV as significant risk factors for development of hypoxia, with relative risk of 11.46 and 3.92, respectively, whereas relative risk of any complication was 3.79 and 2.53, respectively (28). Finally, Biro and colleagues examined risk factors for development of hypercarbia in 172 patients undergoing rigid bronchoscopy as part of a study examining the accuracy of transcutaneous capnography and found strong associations with obesity and restrictive, and to a lesser extent obstructive, lung disease. Overall sensitivity for development of hypercarbia with these risk factors was 76%; however, specificity is low at 44% in the studied population (13).

There are numerous case reports of barotrauma associated with jet ventilation with rigid bronchoscopy (28, 30, 31), ranging from uncomplicated cervical emphysema to tension pneumothorax. Fortunately, these complications are rare, occurring in less than 1% of procedures (28, 32). To examine factors contributing to pneumothorax during HFJV with rigid bronchoscopy, Biro and colleagues (22) measured changes in airway pressure (Paw) caused by microsurgical instruments introduced into the rigid bronchoscope. Pressure measurements proximal and distal to an artificial obstruction were compared with 3 degrees of obstruction (0, 50, and 90%) and with two different driving pressure settings. They concluded that short-term near-total occlusion of the airway during jet ventilation beyond the tip of the rigid bronchoscope may slightly increase proximal peak Paw and increase distal end-expiratory pressure, but not to a degree sufficient to result in barotrauma (22).

Conclusions

Rigid bronchoscopy can be an effective tool to alleviate airways obstruction in malignant and benign disease. The cases can be challenging and require close collaboration between the anesthesiologist and the proceduralist to select optimal conditions to safely complete the procedure. A variety of options are available for ventilation of the patient, and selection of an approach should be determined by local expertise, equipment availability, and patient factors that may make one approach more advantageous over another. Given the resurgence in rigid bronchoscopy, establishing or reestablishing the skills necessary to perform these procedures may become more frequent in the future. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

References