Sedation in Bronchoscopy
A Review

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KEYWORDS

• Bronchoscopy • Sedation • Anesthesia • Review

KEY POINTS

- Sedation is generally recommended for all patients undergoing bronchoscopic procedures unless contraindications exist.
- Topical sedation is frequently used as an adjunct to systemic medications to optimize the procedure. Lidocaine is currently the most popular topical anesthetic.
- The use of a combination of benzodiazepines and opiates for bronchoscopic sedation is common, as it offers the antitussive properties of opioids, with the amnestic effect of benzodiazepines. This co-administration allows for an overall improved sedation with a smaller required total dose.
- Propofol is increasing in popularity because of its amnestic properties, with a quicker onset and faster recovery time and improved patient perception of sedation, anxiolysis, procedure tolerance, and overall reduction in cough.
- Several other agents are emerging as acceptable alternatives for sedation during bronchoscopy, such as ketamine and dexmedetomidine.

METHODS

A literature search was conducted on MEDLINE from 1969 to 2017, and appropriate data were reviewed. Randomized, controlled trials and prospective cohort studies were considered of highest impact.

BACKGROUND

Bronchoscopy has long been used as a diagnostic and therapeutic tool in medicine, with a wide range of appropriate sedative options. Flexible bronchoscopy can be performed with or without sedation, the choice of which is generally left to the practice pattern of the performing bronchoscopist. The concept of sedation is complex, with varying degrees of consciousness. These range from anxiolysis (minimal sedation), to conscious sedation (moderate sedation), to deep sedation, to general anesthesia. Most institutions throughout the United States use moderate sedation, defined as a drug-induced decreased level of consciousness in which the patient is able to respond to verbal commands, with adequate spontaneous ventilation and normal cardiovascular function.[1] Some rigid and navigational bronchoscopic procedures are performed under general anesthesia with hopes of producing a higher diagnostic yield with greater patient tolerance, but evolving evidence suggests that moderate sedation may be comparable.[2,3] A consensus statement from the American College of Chest Physicians suggests that "optimal procedural conditions are achieved when patients are comfortable, physicians are able to perform the procedure, and risk is minimized."[4] This article is a comprehensive review of existing data regarding sedation during bronchoscopy.

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NO SEDATION

Initially bronchoscopy was more commonly performed with little or no sedation, owing to concern of associated adverse effects. Studies comparing bronchoscopy with and without sedation found no difference in rates of complication, and, as such, bronchoscopy without sedation was thought to be safe. These studies, however, did not assess patient tolerance, comfort, or willingness to undergo a repeat procedure.[5] The procedure itself is uncomfortable, with patients often experiencing difficulty breathing, cough, pain, fear, anxiety, and airway irritation. The use of sedation during bronchoscopy has improved outcomes, such as patient tolerance, reduction in cough, and patient likelihood to undergo a repeat future procedure, without increased complications.[6,7]

TOPICAL ANESTHESIA

As time and medicine have advanced, so too have the options regarding sedation. Topical anesthesia is commonly used either alone or as an adjunct to systemic medications to optimize the procedure. Topical anesthesia is available in solution, gel, or spray and can be administered in a variety of ways, including syringe, soaked cotton pads, spray, nebulizer, nerve block, or transcricoid or transtracheal injection.

Benzocaine and tetracaine spray were longstanding popular choices for anesthesia of the nasopharynx and posterior oropharynx. These are usually administered before initiation of bronchoscopy in an attempt to decrease the gag reflex and increase patient tolerance. However, the use of these methods is decreasing because of a narrow therapeutic window and concern for toxicity. If topical dosing of benzocaine exceeds 3 sprays, these medications can be associated with methemoglobinemia, in which the presence of elevated levels of oxyhemoglobin prevent oxygen binding and transport to the tissues, leading to cyanosis and potentially fatal complications (**Table 1**).[8–10] These complications are especially more likely in patients with preexisting anemia.[10]

Lidocaine is widely used as a topical anesthetic and can be administered in direct drip solution, nebulized spray, or gel forms. By decreasing ion transport across neuronal membranes, it blocks nerve impulse conduction, affording properties of anesthesia and cough suppression. A randomized controlled trial by Antoniades and Worsnop,[11] compared direct administration of lidocaine through a bronchoscope with placebo and found a significant reduction in both cough and total required sedation. Lidocaine is generally well accepted because of its wide therapeutic safety margin, short half-life, and minimal risk for toxicity.[11] Cardiac and neurologic toxicity are dose related and are often seen when the serum level exceeds 5 mg/L or topical dose is greater than 7 mg/kg.[12] We recommend close monitoring of the amount of lidocaine used, especially for prolonged cases and procedures performed in pediatric patients. Studies have found no significant difference in the anesthetic properties or reduction in cough in 1% versus 2% concentration of lidocaine, suggesting that the lower concentration is less likely to lead to potential toxicity.[13] Greater care must be used in special populations, such as those with congestive heart failure and liver dysfunction, out of concern for further cardiac toxicity or poor metabolism, respectively.

Nebulized lidocaine is another option for analgesia delivery, although supporting evidence in this area remains less convincing. One study found no difference in cough frequency or patient discomfort when comparing nebulized lidocaine to the placebo, nebulized saline.[14] Notably, the onset of action of nebulized lidocaine is approximately 15 to 20 minutes, whereas direct drip lidocaine typically works within seconds of administration.

Although useful for its vasoconstrictive properties leading to shrinkage of nasal mucosa (best for transnasal approach), cocaine has fallen out of favor because of the increased risk of myocardial infarction secondary to coronary vasoconstriction and intracoronary thrombus formation, as well as its habit-forming properties and abuse potential.[15,16]

Transcricoid or transtracheal direct injection of topical anesthetics, such as lidocaine or lignocaine is another alternative option to achieve effective topical anesthesia. The upper trachea is anesthetized by injection via the cricothyroid membrane or between the tracheal rings. This approach is thought to be associated with a reduction in cough and improved patient tolerance when compared with nebulized or directly administered lidocaine through the working channel of the bronchoscope, without an increase in complications.[17] An Irish single-blinded study found that use of transcricoid lignocaine significantly improved patient perceived ease of procedure and frequency of cough.[18] This approach has more potential complications when compared with other routes of topical anesthesia administrations, such as swelling, paratracheal abscess formation, hematoma or bleeding from puncture of the inferior thyroid artery, or subcutaneous emphysema formation. Graham and colleagues[17] only found minimal intratracheal mucosal bleeding and no significant difference in complication rates.

Table 1
Properties of medications used during bronchoscopy

Medication	Dose	Onset of Action	Peak Effect	Duration of Action	Metabolism	Adverse Effects	Toxicity	Reversal Agent
Topical anesthesia								
Benzocaine	10%, 20% 2–3 sprays	15–30 s	7 min	12–15 min	Hepatic	Contact dermatitis, altered taste sensation	Methemoglobinemia	Methylene blue if methemoglobinemia is present
Tetracaine	Solution: 0.25%, 5% Total not to exceed 20 mg	30 s	1–10 min	30–150 min	Hepatic	Bradyarrhythmia, hypotension, GI upset	Cardiac arrest, ventricular arrhythmias	
	Nebulized: 0.5% Total not to exceed 20 mg	5–10 min	8–15 min	30 min	Hepatic	Bradyarrhythmia, hypotension, GI upset	Ventricular arrhythmias	
Lidocaine	Direct (1–2%): 1–2 mL doses, not to exceed 7 mg/kg	<1–3 min	5–10 min	7–10 min	Hepatic	Hypotension, nausea, bradyarrhythmia, headache	Seizures, cardiac arrest If dose >7 mg/kg or serum level >5 mg/L	
	Nebulized (4%): 100–200 mg Max 600 mg	15–20 min	20–30 min	2–3 h	Hepatic	Hoarseness, altered taste sensation, headache	Seizures, cardiac arrest If dose >7 mg/kg or serum level >5 mg/L	
	Nerve block/ direct injection: 3–10 mL	1–3 min	10 min	10–30 min	Hepatic	Edema, abscess, hematoma, bleed, subcutaneous emphysema	Seizures, cardiac arrest If dose >7 mg/kg or serum level >5 mg/L	
Benzodiazepines								
Midazolam	0.01–0.06 mg/kg IV immediately or 1–2.5 mg over two minutes	0.5 to 1 min	5–10 min	1–2 h	Hepatic	Hypotension, respiratory depression, CNS depression, ataxia	Respiratory arrest, coma	Flumazenil
Diazepam	2.5–20 mg over 30 min	1 min	8 min	1–3 h	Hepatic	Respiratory depression, CNS depression, slurred speech, ataxia	Propylene glycol toxicity, respiratory arrest, coma	Flumazenil

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Table 1
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Medication	Dose	Onset of Action	Peak Effect	Duration of Action	Metabolism	Adverse Effects	Toxicity	Reversal Agent
Lorazepam	Bolus: 0.02–0.06 mg/kg Continuous: 0.01–0.1 mg/kg/h	10–15 min	15–30 min	4–8 h	Hepatic	Respiratory depression, CNS depression, ATN, lactic acidosis, ataxia	Propylene glycol toxicity, respiratory arrest, coma	Flumazenil
Opioids								
Fentanyl	0.5–20 mcg/kg	5–10 min	5 min	1–2 h	Hepatic	Respiratory depression, rigidity, bradycardia, constipation	Respiratory arrest, hypotension, shock	Naloxone
Alfentanil	Wide range of dosing depending on depth of anesthesia desired	Immediate	Immediate	1–2 h	Hepatic	Hypertension, tachycardia, Respiratory depression, constipation, rigidity	Respiratory arrest, bradycardia, acute lung injury, hypoxic seizures	Naloxone
Remifentanil	Induction: 0.1–1 mcg/kg/min Maintenance: 0.05–2 mcg/kg/min	1–3 min	3–5 min	3–10 min	Blood and tissue esterases	Hypotension, GI upset, headache, rigidity, respiratory depression	Respiratory arrest, hypoxic seizures, bradycardia	Naloxone
Other								
Propofol	Bolus: 1 mg/kg followed by 0.5 mg/kg every 3–5 min Maintenance: 25–75 mcg/kg/min	30 s	2 min	3–5 min	Hepatic	Injection site irritation, bradycardia, hypotension, respiratory depression, muscle spasm	Propofol infusion syndrome, cardiac arrest, hypoxia, CNS depression	
Fospropofol	Bolus: 6.5 mg/kg Maintenance: 1.6 mg/kg every 4 min	6–7 min	10–12 min	20 min	Hepatic	Paresthesias, hypoxemia, hypotension, pruritis	Ventricular tachycardia, apnea, cardiac arrest, CNS depression	

Ketamine	Bolus: 1–4.5 mg/kg Maintenance: 0.01–0.03 mg/kg/min infusion	30–40 s	1 min	5–10 min	Hepatic	Hypertension, tachycardia, apnea, laryngeal spasm, emergence hallucinations, rigidity, elevated intracranial and intraocular pressures	Coma, heart failure, respiratory arrest, seizures	
Dexmedetomidine	Bolus: 1 mcg/kg over 10 min Maintenance: 0.7–1 mcg/kg/h	5–10 min	15–30 min	1–2 h	Hepatic	Hypotension, bradycardia, fever, GI upset	Oversedation, AV block, hypotension	
Dextromethoraphan	90 mg PO	15–30 min	2–2.5 h	5–6 h	Hepatic	Dizziness, somnolence	Bromide poisoning, coma, respiratory distress	
Gabapentin	800 mg PO 90 min prior	30–90 min	2 h	4–6 h	Not metabolized	Nausea, ataxia, fatigue	Profound CNS depression, hypotension	
Anticholinergics[a]								
Atropine	Inhaled: 0.025 mg/kg Intramuscular: 0.01 mg/kg	5–15 min	15–50 min	Nebulized: <1 h Intramuscular: 1–5 h	Hepatic	Tachyarrhythmia, hyper/hypotension, constipation, xerostomia	Psychosis, anticholinergic toxodrome, QRS widening	± Physostigmine
Glycopyrrolate	Inhaled: 1 capsule Intramuscular: 0.005 mg/kg	15–30 min	30–45 min	2–3 h	Hepatic	Flushing, constipation, nasal congestion, tachyarrhythmia	Malignant hyperthermia, nystagmus, somnolence, anticholinergic toxodrome, respiratory arrest	± Physostigmine

[a] We recommend against the routine use of these medications.

Local nerve block is also used to decrease gag reflex and cough frequency. Superior laryngeal block is achieved by identifying the hyoid bone and injecting local anesthetic on either side of the hyoid bone around the nerve root, leading to a loss of sensation in larynx, proximal trachea, and posterior epiglottis. To achieve a glossopharyngeal nerve block, one approach is to inject local anesthetic just lateral to the base of the anterior tonsillar pillar. This method affords a loss of sensation in the posterior wall of the oropharynx and the posterior third of the tongue. Clearly, specialized anatomic knowledge is necessary to use this method. When evaluated by DeMeester, and colleagues,[19] this approach afforded appropriate anesthesia and patient tolerance without out significant morbidity. A separate study again found safety and tolerability of a range of advanced diagnostic bronchoscopic procedures using nerve root block in combination with topical lidocaine and intravenous conscious sedation in 136 patients.[20]

BENZODIAZEPINES

Benzodiazepines act via the potentiation of a central inhibitory neurotransmitter. This class of medications has been favored in bronchoscopic procedures because of their anxiolytic, hypnotic, muscle relaxant, and anterograde amnestic properties and the availability of a reversal agent.[21,22] Many options are available, including midazolam, diazepam, temazepam, and lorazepam, but midazolam is most widely favored for its rapid onset and peak effect and short half-life.[21,23,24]

In placebo versus benzodiazepine administration, patients report increased procedural tolerance and increased likelihood of undergoing a repeat procedure.[6,25–27] When compared with opioids, benzodiazepines offer better amnesia and lower risk of respiratory depression although are notably less efficacious at cough reduction or time to baseline mental status.[6,28]

Adverse effects commonly associated with the use of these medications are drowsiness, ataxia, confusion, and falls. When used in bronchoscopy, compared with other forms of sedation, benzodiazepines are not found to have a higher incidence of complications but are associated with longer recovery times.[6] Propylene glycol toxicity is not typically a complication of lorazepam or diazepam continuous infusions as sedation for bronchoscopy. Greater care should be given to the critically ill with renal failure, as they are more likely to accumulate propylene glycol, but this is most commonly noted in infusions exceeding 1 mg/kg/d for more than 48 hours.[29,30]

OPIOIDS

Opioids are also commonly used during bronchoscopy, mainly for their analgesic and antitussive abilities. There is a paucity of research regarding opioids alone in bronchoscopic sedation, but several studies found a complimentary effect when used with benzodiazepines. Of the available opioids, fentanyl is most commonly used because its lipophilic profile allows for rapid onset, and short half-life. Respiratory depression and the associated increase in the apneic threshold is the most concerning side effect of the use of opioids for sedation, so the reversal agent should always be available when using these medications for anesthesia.[21] Decreased ventilatory drive is even more likely when opioids are used in combination with other sedatives, and care must be taken to avoid oversedation.

Although less potent, alfentanil has a shorter half-life and quicker onset than fentanyl and is emerging as a favorite in the bronchoscopy suite. Greig and colleagues[31] studied midazolam versus alfentanil versus midazolam-alfentanil combination, and found that alfentanil alone provided adequate sedation and cough reduction, whereas the combination had no benefit on sedation or patient tolerance, lending only to a greater risk of desaturation. Another study found significant risk of hypoxemia when alfentanil induction is used before propofol target-controlled infusion and recommended further investigation into potentially safe alfentanil induction doses.[32]

COMBINATIONS

The use of a combination of benzodiazepines and opiates is increasing in popularity, as it offers the antitussive properties of opioids, with the amnestic effect of benzodiazepines. This co-administration allows for an overall improved sedation with a smaller required total dose.

Several randomized controlled trials were conducted evaluating the combination of propofol and opioids or propofol and benzodiazepines versus benzodiazepines alone and noted better patient tolerance and cough reduction in the combination arms. These studies also found greater oxygen desaturations in the combination arms compared with benzodiazepines alone but noted no other adverse events that were clinically relevant.[33]

PROPOFOL

Studies have found improved patient perception of sedation, anxiolysis, and procedure tolerance and overall reduction in cough and the sensation of asphyxiation when propofol is administered.[34]

Propofol is becoming increasingly more common in the bronchoscopy suite, as it has amnestic properties, with a quicker onset and faster recovery time than other agents, such as midazolam.[35–38] Propofol can be administered as bolus or a continuous drip, with a similar side effect profile, but one randomized trial found higher doses and longer procedure time associated with infusion therapy.[39] Use as monotherapy for sedation offers no analgesia, so propofol is commonly combined with opioid agents.[33] Propofol has been compared with many other regimens, such as midazolam only, midazolam and hydrocodone, or diazepam and fentanyl. One study found improved patient tolerance in the propofol arm, but otherwise no significant difference has been identified in sedation, cough frequency, overall tolerance, or complications.[40]

It is worth noting that the use of propofol necessitates continuous patient monitoring either by an anesthesiologist or in the intensive care unit by a critical care physician. Propofol has a relatively narrow therapeutic window between moderate and general anesthesia and has no available reversal agent. Its use should only be used by those with advanced airway training.

FOSPROPOFOL

Fospropofol is a prodrug of propofol, with a shorter half-life but distinctly longer time to onset and duration of action.[41] When given intravenously, it reaches lower and more predictably sustained peak levels in the blood, allowing for a more easily titratable and reliable attempt at moderate sedation.[41,42] Fospropofol is commonly associated with paresthesias and pruritus (package insert, Eisai Inc, Ludestra, Woodcliff Lake, USA, 2009).

Even though fospropofol is more predictably controlled, it is metabolized directly to propofol in the blood and as such should also only be used under circumstances consistent with monitored care by an anesthesiologist or airway-trained pulmonologist.[4]

KETAMINE

As a noncompetitive N-methyl-D-aspartate receptor agonist and partial Mu agonist, the use of ketamine as a sedative affords dissociative anesthesia and, when used alone, does not significantly affect ventilatory drive.[21] Ketamine also has analgesic and bronchodilator properties but can also potentiate airway secretions, sympathetic drive, and emergence delirium.[43]

Hwang and colleagues[33] compared patient-controlled anesthesia combinations of propofol-alfentanil with propofol-ketamine and found superiority in the ketamine arm with regard to patient satisfaction, hemodynamic stability, and improved amnesia of the procedure. Notably the most common side effects in that arm were delirium and hallucinations.[33] Use of ketamine should be avoided in patients with increased intracranial pressure, central nervous system masses, unstable cardiac disease, or acute angle glaucoma because of the known increase in heart rate and blood pressure associated with ketamine administration.[44]

DEXMEDETOMIDINE

A relatively new medication being used for sedation during bronchoscopic procedures is dexmedetomidine.[45] It is a selective α-2 agonist with anxiolytic, analgesic, vagolytic, and hypnotic properties. Unlike propofol or other opioids, dexmedetomidine is not associated with respiratory depression but is found to have prolonged recovery times and is therefore more commonly used in the inpatient setting.[46]

A prospective, randomized trial evaluated patient tolerance and efficacy of sedation of dexmedetomidine versus midazolam and found significantly less hypoxia and lower heart rate and blood pressure in the dexmedetomidine, without significant difference in patient discomfort scores.[47] Similarly, Ryu and colleagues[48] found significantly fewer instances of desaturation but longer recovery time and poorer bronchoscopist satisfaction when using combination propofol-dexmedetomidine compared with propofol-remifentanil. Conversely, a more recent study concluded improved patient tolerance while using intravenous dexmedetomidine under topical anesthesia compared with intravenous midazolam, but this study was not as well powered.[49]

ANTICHOLINERGICS

Atropine and glycopyrrolate act by blocking the muscarinic activity of acetylcholine, thereby inhibiting bronchial smooth muscle and salivary and bronchial glands. These medications stimulate bronchodilation and inhibit nasopharyngeal and oropharyngeal secretion production. Anticholinergics were standard practice in sedation by most bronchoscopists in the past because of their theoretic assistance in prevention of bronchospasm, but recent data have only identified an unsustained improvement in pulmonary function.[50–53] In fact, Cowl and colleagues[54] found no significant benefit in reduced secretions, patient comfort, or cough frequency. A randomized, double blind, placebo-controlled trial by Malik and colleagues[55] reported decreased

secretions, without significant reduction in cough, discomfort, desaturations or procedure time. Conversely, greater hemodynamic instability was noted after anticholinergic administration when compared with placebo.[23,55] Heinz and colleagues[56] found successful use of atropine as an adjunct to ketamine in reducing the oral secretions and emergence emesis associated with ketamine use, although this was not effective in all instances. Noting this exception, we recommend against routine use of these medications.

OTHER AGENTS

Various other agents have been used by bronchoscopists in attempts to augment sedation during procedures. Schwarz and colleagues[57] found that 90 mg of dextromethorphan led to cough reduction and better patient comfort with less co-administered sedation required. One monocentric prospective trial concluded that use of remifentanil infusion targeted at 2.5 ng/mL (target concentration), and 1.4 μg/kg (total dose) was safe and effective as a sedative in critically ill, spontaneously breathing patients.[58] Bala and colleagues[59] and Ayatollahi and colleagues[60] studied the effects of gabapentin attenuation on the catecholamine surge associated with endotracheal intubation and laryngoscopic or bronchoscopic procedures. Both studies found efficacy in attenuating mean arterial pressure without affecting heart rate when gabapentin was administered at least 90 minutes before the procedure.

COMPLEMENTARY MEDICINE

A few studies have attempted nonpharmacologic means to improve patient comfort and anxiety associated with bronchoscopy. Diette and colleagues[61] used nature sounds and imagery as distraction therapy before, during, and after the procedure, resulting in a decreased sensation of pain but no difference in anxiety. Similarly, Colt and colleagues[62] were unable to find improvement in procedural anxiety in patients randomly assigned to music therapy during the bronchoscopy.

NAVIGATIONAL BRONCHOSCOPY

Electromagnetic navigational bronchoscopy is used for targeting and sampling peripheral pulmonary lesions that are not reachable by means of traditional flexible bronchoscopy. Bowling and colleagues[3] compared general anesthesia with intravenous sedation in patients undergoing navigational bronchoscopy and discovered no difference in success of procedure or complication rate.

RIGID BRONCHOSCOPY

Rigid bronchoscopy is commonly used for interventional pulmonary procedures such as airway stent placement, dilation and foreign body extraction. Most commonly, rigid bronchoscopy is performed under general anesthesia with or without the use of paralysis to assist with decreased respiratory motion. Popular sedation combinations used in this setting have been continuous infusion of propofol and remifentanil or midazolam plus alfentanil.[63] Some institutions have used anesthetic gases, such as isoflurane or sevoflurane, with conversion to intravenous medications once the bronchoscope is in place, as it is an open, shared airway and has the potential to fill the room with volatile gasses.[63,64]

Oxygenation techniques vary in rigid bronchoscopy, and anesthetic strategies partially depend on type of ventilation used. Spontaneous ventilation can be achieved via moderate sedation, wherein the patient maintains ventilation, and supplemental oxygen is supplied via the bronchoscope. Anesthetic is typically administered intravenously either via push or continuous infusion. Perrin and colleagues[65] maintained anesthetic titration with repeated injections of propofol, phenoperidine, and diazepam or midazolam, without neuromuscular blockade. Significant hypoxemia was noted in a subset of patients, but a lower rate of postprocedural reintubation was also noted.[64,65] Another study found efficacy of both remifentanil and fentanyl infusion therapy for use in spontaneous assisted ventilation with faster recovery noted in the remifentanil arm.[66]

Jet ventilation is frequently used because it allows an open airway and increased ease of bronchoscopic manipulation and less airway motion. This is achieved via high-pressure oxygen administration in short bursts through a catheter in the airway. General anesthesia with neuromuscular blockade is typically used in this situation.[64]

SPECIAL POPULATIONS

Administration of anesthesia should always be done thoughtfully to adequately achieve the desired level of sedation. A few special populations exist in which extra precaution and dose adjustments are advised. The elderly typically require smaller doses of sedative medications because of a higher likelihood of poor hepatic metabolism or renal dysfunction and often have prolonged emergence time.[67,68] Similarly, those with known hepatic dysfunction or prolonged circulation time (heart failure) often require reduced doses or slower induction of anesthesia to ovoid

overdose. Post–lung transplant cystic fibrosis patients, those with history of substance abuse, and any patient with a previous stem cell transplant may require higher doses of sedation.[21,23,69,70] Special care should be given to human immunodeficiency virus patients with protease inhibitors in their antiretroviral regimen, as prolonged sedation has been noted when midazolam is used as a sedative.[71–73] Pregnant women also pose a unique risk for sedation in bronchoscopy. If possible, deferral of the bronchoscopy until after the pregnancy has ended is recommended. If the bronchoscopy must be performed, consulting a pharmacist and obstetrician is recommended to support the choice of sedative medications. The lowest effective dose of medication should be administered. If conscious sedation is required, careful avoidance of class D or class X medications (including midazolam and diazepam) is stressed. Cardiac and fetal monitoring are recommended during the procedure.[74]

BRONCHOSCOPY IN THE PEDIATRIC POPULATION

Flexible bronchoscopy is performed in children primarily for diagnostic evaluation of benign diseases such as airway inflammatory or infectious conditions, or airway anatomic lesions, many of which are dynamic and sleep state dependent. Interventional procedures may also be performed. According to recently published technical standards for flexible airway endoscopy in children, the goals for sedation include (1) provision of patient comfort, (2) maintenance of hemodynamic stability, (3) maintenance of adequate gas exchange, and (4) provision of satisfactory conditions for therapeutic or diagnostic endoscopy.[75] Infants and young children have increased risks, and structured sedation protocols are recommended to reduce morbidity.[76] Upper airway obstruction may occur because of larger tongue size relative to the upper airway, a higher and more anterior larynx, and a greater ratio of instrument size to airway size. Infants and young children have a decreased apneic time because of decreased oxygen stores, increased oxygen utilization, and exaggerated effects on respiratory drive.[77] Immaturity in hepatic and renal function affects metabolism and clearance of intravenous agents in neonates and premature infants.[76,78] Choice of anesthetic or sedative agent can impact risks and diagnostic accuracy.

There are no specific sedation guidelines for pediatric flexible bronchoscopy. Diagnostic procedures are typically done with maintenance of spontaneous breathing, although pediatric bronchoscopy is typically done with deep rather than moderate sedation. This can be accomplished with inhaled sevoflurane, and titration of depth and recovery are brisk.[79–81] Weaknesses include anesthetic pollution of the surgical environment and dose-dependent reduction in airway tone, especially at the level of the soft palate.[82,83] Sevoflurane induction and maintenance of anesthesia can also be supplemented with intravenous agents if desired. Multiple total intravenous anesthesia combinations, most often of a hypnotic plus ultra–short-acting opioid, have been evaluated and found to be safe and provide rapid onset, good control of patient movements, maintenance of oxygenation, and hemodynamic stability.[79,81–84] Comparisons between inhaled and intravenous anesthesia suggest longer recovery times with intravenous management.[79,81] A comparison of sevoflurane and propofol found a higher rate of laryngospasm with sevoflurane and increased cough and expiration reflex with propofol, independent of level of hypnosis by bispectral index score.[85]

The level of sedation is driven in large part by the goals of the procedure. For procedures that are for the primary purpose of obtaining bronchoalveolar lavage or interventional procedures, deeper sedation does not adversely affect the procedural result. For evaluation of dynamic airway obstruction, especially for drug-induced sleep endoscopy (DISE) to plan surgical intervention, sedation level, and effect of agent on airway tone is of paramount importance. A comprehensive review by Ehsan and colleagues[82] details the variable impact of topical and inhaled anesthetics, hypnotics, and opioids on upper airway tone, size, sleep state, and reflexes. Overall, dexmedetomidine simulates non–rapid eye movement sleep and causes less loss of upper airway cross-sectional area than propofol but with a longer recovery time.[86–89] Ketamine causes relatively less upper airway collapsibility or suppression of respiratory drive.[90] A comparison of a dexmedetomidine-ketamine protocol with propofol alone or sevoflurane-propofol for DISE resulted in a lower rate of desaturation and a higher rate of successful completion.[91] Overall, there is no clearly superior approach to sedation for pediatric flexible bronchoscopy, although the approach needs to be tailored to safety, the goals of the procedure, and the surgical environment.

MONITORING SEDATION

Maintaining the desired level of sedation during bronchoscopic procedures is complex, and several studies have evaluated sedation assessment intraprocedurally. Most of these assessments were subjective, based solely on patient response to stimulation, but more recently, bronchoscopists

and anesthesiologists have used the bispectral index scoring (BIS) as an objective measurement of the depth of anesthesia. Fadaizadeh and colleagues[92] suggest a mean BIS level of 40 to 60 for flexible bronchoscopic sedation. Powers and colleagues[93] defined a similar target BIS level in children.

There is ongoing debate about the safety of anesthesia-administered versus proceduralist-administered sedation, but current evidence suggests that both are safe and that endoscopist-administered sedation is more cost effective, especially if a protocol is in place.[94–98]

SUMMARY

Sedation is generally recommended for all patients undergoing bronchoscopic procedures, unless contraindications exist. There is no standardized practice, and almost any combination is acceptable with few adverse effects. The ideal sedative should be safe and predictable, with a rapid onset and recovery, with an available reversal agent. Ultimately the sedation regimen used remains at the discretion of the bronchoscopist.

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