15 Anesthesia for Patients with Asthma

Matthew Sisitki, MD,
Christian H. Bohringer, MD,
and Neal Fleming, MD, PHD

Contents

KEY POINTS

- Perioperative bronchospasm in the asthmatic is a rare but potentially catastrophic event.
- The preoperative evaluation of the asthmatic patient should identify risk factors for bronchospasm or acute asthma exacerbation.
- Optimization of preoperative asthma management can reduce the incidence of perioperative bronchospasm.
- Asthmatic patients may experience sudden and severe bronchospasm during anesthesia.
- Regional anesthesia is preferred when possible because it avoids tracheal instrumentation and other potential triggers of bronchospasm.
- Histamine releasing drugs should be avoided.
- Exacerbation of asthma during general anesthesia and positive pressure ventilation may cause air trapping from dynamic hyperinflation that will impair venous return, decrease cardiac output and, in severe cases, lead to pulseless electrical activity.
- Light levels of anesthesia may precipitate bronchospasm and this complicates the management at the end of the operation.
- Deep extubation at the end of surgery should be considered if appropriate.
- Optimization of postoperative pain relief to facilitate early mobilization should decrease the incidence of postoperative respiratory complications.

From: *Bronchial Asthma: A Guide for Practical Understanding and Treatment, 6th ed.*
Edited by: M. E. Gershwin and T. E. Albertson, DOI 10.1007/978-1-4419-6836-4_15

INTRODUCTION

Patients with asthma have a small but definite increase in the risk for major complications during anesthesia *(1, 2)*. The information presented here is intended to help nonanesthesiologists provide perioperative care and consultation that will minimize these risks. The essentials of preoperative assessment are reviewed along with the goals and possible approaches to preoperative optimization. The possible choices for anesthesia (general or regional) are reviewed along with the options for airway management and intraoperative techniques with an emphasis on avoiding bronchospasm or air trapping and dynamic hyperinflation. The management of acute intraoperative bronchospasm is reviewed as well as the critical components of the immediate postoperative care that should be emphasized to minimize the incidence of perioperative complications.

PREOPERATIVE ASSESSMENT

The goal of the preoperative assessment in patients with asthma is to risk-stratify the severity of asthma and assure optimal medical management to minimize the potential for perioperative complications *(3)*. The NIH Guidelines for Asthma Education and Prevention classify the severity of a patient's asthma as intermittent or persistent and subdivide the latter as mild, moderate, or severe depending upon the frequency of the symptoms *(4)*. This classification can be correlated with the American Society of Anesthesiologists physical status classification to provide a general assessment of the perioperative risks for a patient (Table 1). The patient's own subjective assessment of the control of their asthma symptoms can be simply assessed by the Asthma Control Test *(5)* but their responses are often not reliable if there is a strong desire for a surgical procedure. In addition, pulmonary function studies may normalize or stabilize between exacerbations of their symptoms. The preoperative assessment should therefore attempt to objectively quantify the baseline severity of the patient's disease. The peak expiratory flow (PEF) is a useful monitor of preoperative asthma control. The normal range for the PEF is quite variable (200–600 L/min) and dependent upon the patient's age, gender, height, and weight. It is more useful to make comparisons with the patient's previous personal best performances. A decline in PEF may herald worsening airway obstruction. In general, values ≥80% of usual predicted peak flow are considered normal variation,

Table 1
Asthma Severity Classification

ASA physical status	*NHLBI asthma guidelines severity classification*	*Frequency of symptoms*
1. Normal, healthy	–	–
2. Mild systemic disease	Intermittent/persistent (mild)	<2× per week/>2× per week, but not daily
3. Severe systemic disease	Persistent (moderate)	Daily
4. Constant, life-threatening disease	Persistent (severe)	Daily with frequent nighttime awakenings
5. Moribund		

while values <80 to <50% of predicted should alert the examiner to potentially significant changes and values that are <50% of previous or predicted usually signifies that medical attention is needed.

The severity of the asthma is not necessarily correlated with the risk of intraoperative complications; rather it is the quality and stability of the medical management and control of symptoms that are more critical. Complications are reported to be more frequent in older patients and in patients with more poorly controlled symptoms *(1, 3, 6)*. The preoperative assessment should consequently detail the patient's exercise capacity and ability to perform activities of daily living. Poor exercise tolerance has been correlated with an increased risk of postoperative complications. The preoperative evaluation should also characterize any markers of changes in the severity of the patient's symptoms or any incubating infections that could exacerbate symptoms. An increase in rescue inhaler use, a history of emergency room visits or hospitalizations for the treatment of asthma, or past history of difficulties during anesthesia should alert the practitioner to the potential of poorly controlled asthma. Other symptoms such as fever, cough, or increased sputum production that suggest a developing infection and consequent worsening of asthma symptoms may warrant the postponement of an elective operation.

Known triggers of asthmatic symptoms for each patient should be detailed including specific allergies, response to cigarette smoke, cold air, or dust as airway reactivity to these antigens may correlate with intraoperative bronchoreactivity. Avoidance of any precipitants and treatment of allergies in the preoperative period may prevent later attacks. Medications and previous reactions to medications must be reviewed in detail. In particular, bronchoreactivity to aspirin or other nonsteroidal anti-inflammatory drugs may be seen in the triad of aspirin-induced asthma and would preclude the use of these drugs for perioperative analgesia. Commonly associated comorbidities including congestive heart failure, chronic obstructive pulmonary disease, and obstructive sleep apnea should also be carefully evaluated.

Comprehensive assessment and preoperative preparation that optimizes control of asthmatic symptoms minimizes the risk of perioperative complications *(7)*. The patient's compliance to their treatment regimen and avoidance of potential triggers such as known allergens or smoking are central to this effort. All therapies should be continued up to and including the day of surgery. Key components of the preoperative evaluation of patients with asthma are summarized in Table 2 *(8)*.

PREOPERATIVE PREPARATION

The physical examination of the asthmatic patient on the day of surgery is critical, but may be misleading and provide a false sense of security. An absence of wheezing does not predict the likelihood or severity of an acute exacerbation. In the setting of severe air trapping, wheezing may not be auscultated at all due to the complete lack of airflow. Elderly patients and patients with long-term chronic asthma may not experience the sensation of dyspnea until symptoms are severe. The respiratory rate and rhythm should be observed. Signs and symptoms of right heart failure should be assessed. If there are concerns, a preoperative chest X-ray may demonstrate signs of air trapping and may be invaluable for comparison should complications occur in the perioperative period, but also may be normal even in the setting of severe bronchoconstriction.

Table 2
Preoperative Anesthetic Evaluation of Patients With Asthma

Presentation	*Concern*	*Risks*
Asymptomatic asthma	Minimal	Possible bronchospasm secondary to common triggers
Chronic asthma	Possibility of irreversible airway disease and chronically decreased reserve	Possible perioperative pulmonary complications, especially with thoracic or upper abdominal surgical site
	Possibility of suboptimal medical control	As above
Asthma history with acute symptoms	Possibility of poor compliance with chronic therapy or onset of new respiratory tract infection	As above – risk may be reduced by delay for preoperative treatment or initiating treatment immediately for emergency surgical procedures
Unexpected preoperative wheezing (no previous asthma diagnosis)	Undiagnosed medical problem	Possible mistaken diagnosis of asthma and incorrect treatment
	No prior treatment	Possible perioperative pulmonary complications, especially with thoracic or upper abdominal surgical site
		Risk may be reduced by delay for preoperative treatment or initiating treatment immediately for emergency surgical procedures

Comprehensive pulmonary function tests including spirometry, lung volume, and diffusion capacity measurements in addition to bronchodilator testing may aid in the prediction of operative outcomes *(9)* and may reveal other respiratory limitations such as chronic obstructive disease or restrictive ventilatory disorders, but these tests are logistically difficult to obtain and of less help in the immediate preoperative setting. The measurement of the PEF rate and comparison to the patient's previous performance may be helpful and if a peak flow meter is not available a forced expiratory time can be measured by instructing the patient to exhale forcefully from maximal inspiration while listening for gas flow over the trachea. The time to the end of expiration should be shorter than 6 s.

If poor asthma control is identified prior to an elective surgical procedure, the case should be canceled and medical optimization should be coordinated in consultation with the patient's primary care physician or pulmonologist. If the surgical procedure is more urgent, a short course of oral steroids may be indicated to stabilize the acute asthmatic symptoms. Oral methylprednisolone 40 mg daily for 5 days prior to surgery has been shown to decrease postintubation wheezing in newly diagnosed or poorly compliant patients with reversible airway obstruction *(10)*. If the surgical procedure is emergent, an intravenous steroid regimen would be similarly indicated though controlled trials

validating this approach are lacking. Concerns over wound healing and increased risk of infection as a side effect of administration of corticosteroids in the preoperative period have not been supported by clinical reviews *(7, 11)*. In this setting, the 2009 Global Strategy for Asthma Management and Prevention (GINA) guidelines recommend systemic glucocorticosteroid use during the operative period with rapid reduction within 24 h of surgery. However, this recommendation is based on observational studies and nonrandomized trials *(12)*. Preoperative assessment of the patient with asthma should also include a review of the plasma electrolytes. High doses of β-agonist drugs are associated with the development of hypokalemia, hyperglycemia, and hypomagnesemia. These should be normalized prior to any surgical procedure.

Premedication becomes an important component of the preoperative preparation for the patient with asthma because anxiety may exacerbate asthmatic symptoms. Benzodiazepines such as midazolam are commonly used for this indication, but the α_2-agonist dexmedetomidine is increasingly recommended as an alternative with distinct advantages in this setting. It is an anxiolytic but also sympatholytic and an antisialagogue, both desirable actions in these patients, and it does not have the respiratory depressant effects of a benzodiazepine *(13)*. There are multiple case reports demonstrating the ability of dexmedetomidine to suppress upper airway responses to stimulation during awake intubations, but there are no trials to date of its use for premedication in patients with asthma. Takasaki et al. *(14)* report the successful use of dexmedetomidine as a sedative in patients requiring noninvasive positive pressure ventilation for treatment of asthma.

INTRAOPERATIVE MANAGEMENT

Some of the intra- and postoperative risks associated with anesthesia in the patient with asthma are summarized in Table 3. Severe intraoperative complications in patients with asthma include hypoxia and cardiac arrest. Bronchospasm and mucus secretions may compromise oxygen delivery with consequent tissue hypoxia. Cardiac arrest may occur as a result of hypoxemia, as a side effect of the drugs used to treat severe bronchospasm, secondary to underlying electrolyte abnormalities, or as a result of dynamic hyperinflation. Intraoperative management is therefore designed to minimize the risk of bronchospasm by avoiding known triggers (Table 4). Closed claims analysis demonstrates that bronchospasm leading to severe complications is a rare occurrence *(15)*. In addition, bronchospasm occurs in nonasthmatic patients as well so the guidelines for perioperative management presented here have applications beyond this specific patient group.

Foremost among the recommendations for anesthetic management of the patient with asthma is to avoid instrumentation of the airway by using a regional anesthetic when possible. This does not, however, guarantee the absence of bronchospasm. Referring back to the close claims analysis, 20% of the claims in which bronchospasm led to severe complications occurred during a regional anesthetic *(15)*. In addition to avoiding instrumentation of the airway, regional techniques minimize the use of cold, dry medical gases that can provoke bronchospasm. Although supplementary oxygen via nasal prongs or a simple mask is still frequently used, since the patient's upper airway is not bypassed the inspired gases are warmed and humidified before they arrive in the patient's lungs. Inadequate suppression of visceral reflexes and patient anxiety are two

Table 3
Risks of Anesthesia for Patients With Asthma

Risk	*Optimize*	*Avoid*
Intraoperative	Preoperative disease management	Emergency surgery
Respiratory	Bronchodilator therapy	Potential triggers
Bronchospasm	Mechanical ventilation pattern to avoid dynamic hyperinflation	Pulmonary edema
Hypoxemia		
Cardiac		
Right heart failure	Preoperative disease management	Increased pulmonary vascular resistance
Left heart failure	Preoperative disease management	Hypoxemia Decreased preload
Dysrythmias	Plasma electrolytes Adrenergic therapy	Electrolyte abnormalities Aminophylline
Postoperative	Postoperative analgesia	Postoperative mechanical ventilation
Hypoxemia	Consider dexmedetomidine	Residual respiratory depression
Atelectasis	Postoperative respiratory function	Inadequate analgesia
Pneumonia	Prophylactic antibiotics Ambulation	Prolonged bed rest

Table 4
Intraoperative Bronchospasm

Potential triggers	*Suggested alternative or mitigation*
Airway manipulation	Regional anesthesia
Laryngoscopy, intubation	LMA
Suction	Limit, only under deep anesthesia
Cold, dry medical gases	Low flows, airway humidification
Histamine releasing drugs	Limit drug selections
Latex exposure	Avoid exposure
Inadequate anesthesia	Volatile anesthetics, α_2 agonist adjuncts

common triggers of bronchospasm during regional anesthesia. Our own clinical experience has confirmed that the α_2-agonist dexmedetomidine is an excellent choice for an anxiolysis and sedation in these patients because it produces bronchodilator and analgesic effects without causing significant respiratory depression *(16)*.

Many surgical procedures will, however, require general anesthesia for optimal patient management. In these cases, a graded approach can be taken with respect to airway management with an eye towards minimizing the risks if at all possible. In a small number of

cases, general anesthesia can be administered by placement of a mask alone over the patient's nose and mouth. After correct jaw positioning or placement of an oropharyngeal device, the soft tissue obstruction of the airway that may occur in the obtunded state can be avoided. This method avoids stimulation of the subglottic area which can provoke bronchospasm. Although the ideal surgical patient has been fasting and is at low risk for aspiration, mask anesthesia has the disadvantage of not providing any airway protection against possible aspiration of gastric contents. The next step up in airway instrumentation would be placement of a laryngeal mask airway (LMA). This device has an inflatable rim that forms a partial seal around the glottic opening. The LMA also avoids subglottic stimulation as compared to an endotracheal tube. It can be used for longer surgical cases, provides better control of an airway than mask ventilation, and may provide some degree of protection against aspiration. The LMA is not appropriate in cases that require muscle relaxing agents and prolonged positive pressure ventilation or for patients who are at high risk for aspiration. If endotracheal intubation is required for the safe completion of the general anesthetic, it should be stressed that induction and intubation are the most common triggers of bronchospasm. Care should be taken to assure an adequate depth of anesthesia has been reached before beginning laryngoscopy. Many adjuncts have been shown to decrease the sympathetic response to laryngoscopy and intubation including larger doses of narcotics, intravenous lidocaine, and dexmedetomidine. If possible, one or more of these should be included as part of the induction regime *(17)*.

Following induction, maintenance of anesthesia requires the use of medical gases (oxygen, air, nitrous oxide) which are both dry and cold. Exposure of an asthmatic patient's lungs to these gases may precipitate bronchospasm and a drying out of lung secretions, further impairing ventilation and gas exchange. Employing low fresh gas flows and placing an in-line heat and moisture exchange filter (artificial nose) will minimize this risk.

The administration of even a simple general anesthetic may include the use of nearly two dozen drugs. Many of the drugs used during anesthesia may trigger the release of histamine and consequent bronchospasm. Avoiding rapid administration and carefully selecting the drugs used for specific indications can minimize this risk. Among the intravenous induction agents, sodium thiopental should be administered with caution in asthmatics because of its potential for precipitating bronchospasm from histamine release. Propofol is now the most commonly used intravenous induction agent for anesthesia and for all practical purposes has completely replaced thiopental. Current formulations of propofol do not appear to trigger the release of histamine. Etomidate may be preferred in some circumstances when hemodynamic stability is critical, but small clinical trials have shown a greater airway resistance after intubation with etomidate as compared to propofol *(18)*. Ketamine has been advocated as the induction agent of choice for intubation for the patient with status asthmaticus or hemodynamic instability because of its bronchodilator and sympathomimetic side effects. Unfortunately, it is also associated with intraoperative tachycardia and postoperative hallucinations that have limited its widespread adoption. If it is used, midazolam should be administered concurrently to reduce the incidence and severity of postoperative hallucinations.

Neuromuscular blocking drugs are also classic triggers of histamine release, but this side effect was most commonly associated with curare and other drugs in the benzylisoquinolinium class (atracurium, mivacurium) that are no longer available for clinical use.

The steroid-based neuromuscular blocking drugs (pancuronium, vecuronium, rocuronium) do not trigger histamine release and therefore are preferred. Similarly, cis-atracurium, the lone remaining curariform drug, does not induce histamine release. It is the drug of choice in renal failure, and can be safely administered in asthmatics without a risk of bronchospasm *(19)*. In a small number of cases in which there is a high risk of aspiration or potentially difficult intubation such that a rapid onset time and short duration of action are critical. Succinylcholine may still be the relaxant of choice despite the fact that it may trigger bronchospasm in these patients; the benefits may outweigh the risks. The need for succinylcholine for emergency intubation in asthmatic patients may be eliminated by the introduction of sugammadex, the selective binder for rocuronium. However, the approval of sugammadex by the FDA was recently deferred pending further evaluation of the incidence of bronchospasm associated with this drug. European clinical experience suggests this is a rare occurrence, but the use of this drug in asthmatic patients requires further evaluation *(20)*.

Analgesics are frequently administered intraoperatively. Opioids remain the most commonly used drugs for this indication. Rapid administration of large doses of morphine is associated with significant histamine release and can provoke bronchoconstriction. The synthetic opioids (fentanyl, sufentanil, remifentanil) or the longer acting hydromorphone may be a better choice for asthmatics because they do not trigger histamine release. Nonsteroidal anti-inflammatory drugs (ketorolac) are generally safe and commonly used as adjuncts for perioperative analgesia, but given the subset of asthmatics with aspirin-induced asthma, this class of drugs should be avoided in these patients. Acetaminophen is preferable because it does not interfere with cyclo-oxygenase and leukotriene pathways and the recent FDA approval of intravenous acetaminophen for use in the United States should increase the experience with the utility of this drug in this patient population.

Antibiotics are frequently used in the perioperative period both therapeutically and prophylactically and among them vancomycin is one of the more commonly administered infusions during surgery for prevention of staphylococcal infections. It is a potent histamine releaser and may provoke bronchospasm. Slow administration of the antibiotic infusion may prevent significant histamine release but asthmatic patients should be under constant monitoring with attention to airway pressures and the capnograph trace during its administration.

Despite all precautions, intraoperative bronchospasm may still occur. The general axiom that "not all that wheezes is asthma" holds true just as much inside the operating room as outside it. An open mind needs to be maintained whenever evaluating new onset of wheezing in a patient even when there is a previous history of asthma attacks. A differential diagnosis for intraoperative wheezing is presented in Table 5. Each of the potential etiologies should be considered.

Exacerbation of asthma is a common cause of wheezing especially following intubation and during emergence from anesthesia. Typically there are high peak-airway pressures and there is no plateau phase on the capnograph tracing. Instead of a horizontal line during the plateau phase there is a slope that is directed upwards. The steepness of this slope is an indicator of the severity of the bronchospasm and the degree of the ventilation perfusion mismatch. Significant arterial desaturation is usually not associated with an acute asthma attack until severe V/Q mismatching and shunting occurs.

Table 5
Differential Diagnosis of Intraoperative Wheezing

Asthma exacerbation
Anaphylaxis
Aspiration
Partial airway obstruction
Endotracheal tube compression
Obstructive mucus secretions
Endobronchial intubation
Foreign body in airway
Subglottic mass
Pulmonary edema
Pneumothorax
Pulmonary embolus
Pneumonia

If hypoxemia is present then other causes for the wheezing should be considered. Bronchospasm increases the resistance to airflow during the expiratory phase of ventilation leading to a prolonged expiratory phase time. If another breath is initiated either by the patient or the ventilator before the full tidal volume has been exhaled, air remains "trapped." This is known as breath stacking or dynamic hyperinflation. This will generate a buildup of pressure inside the lungs and thoracic cavity that increases with each subsequent breath. The increased pressure will compromise venous return and decrease cardiac output, leading to hypotension and organ hypoperfusion *(21)*. It should be noted that with severe resistance to airflow the expiratory phase may be so long and slow as to not generate enough turbulence to create audible wheezing. Adjustments to the ventilator can help reduce or eliminate breath stacking. Reduction of the respiratory rate, if possible, may be the simplest strategy. This will create more time for the tidal volume to be exhaled before the next inspiration occurs. However, reducing the number of breaths per minute may not always allow for adequate minute ventilation so this strategy can be quickly exhausted and permissive hypercapnea may be required. Increasing the inspiratory flow rate or reducing the inspiratory time also effectively changes inspiratory-to-expiratory ratio in favor of prolonging expiration. A brief disconnection of the ET tube from the ventilator may sometimes be necessary to let the trapped residual air equalize and restore normal cardiac output.

Anaphylaxis usually presents with vasodilatation and profound hypotension and bronchospasm may also be a prominent feature. Other signs include diffuse erythema, angioedema, and urticaria. A high index of suspicion should be maintained when evaluating for anaphylaxis as bronchospasm or hypotension alone may be the only presenting sign. If anaphylaxis is suspected epinephrine is lifesaving and should be given immediately. Treatment should be continued as anaphylaxis often has a bimodal phase increase hours later *(22)*. A serum tryptase level should be collected as well. Tryptase is a mast-cell specific protease which peaks within the first hour and remains elevated for about 4–6 h. The test has a high sensitivity and specificity for mast-cell activated anaphylaxis but the results are not immediately available so clinical recognition and

immediate management are still critical. The tryptase level will be useful in the investigation of an episode of isolated severe bronchospasm, especially when it occurs in a patient without a prior history of asthma, because identifying the allergen could potentially avoid a fatal reaction during their next anesthetic.

Aspiration of gastric fluids during induction may be the cause of postintubation wheezing in itself or may provoke bronchospasm in an asthmatic. The pneumonitis that occurs may cause significant ventilation-perfusion mismatching and hypoxemia. Bronchodilator therapy and postoperative ventilation may be indicated if the symptoms are immediate and severe.

A *partially obstructed airway* can produce intraoperative wheezing. Mechanical kinking of the endotracheal tube by external compression or positioning the patient in unusual positions may produce this effect. Similarly excess mucus secretions, an endobronchial intubation, foreign body (tooth, food particles), or a subglottic mass can have a similar effect. Fiberoptic bronchoscopy can be used to evaluate these possibilities. Foreign body obstruction should be strongly suspected when the wheezing is unilateral. A chest X-ray may demonstrate asymmetric air trapping or a radiopaque object in an airway.

Pulmonary edema is not infrequent in operations which have significant fluid shifts. It may be associated with high peak airway pressures and wheezes similar to asthma. Crackles or ronchi heard on auscultation and fluid coming out of the endotracheal tube, together with a large alveolar to arterial oxygen gradient may help distinguish pulmonary edema from bronchospasm. Pulmonary edema is often diagnosed following extubation when the patient has lost the protective effect of positive pressure ventilation and positive end expiratory pressure (PEEP). In situations such as these, extubation to BiPAP to maintain positive pressure may be helpful. Diuresis or other fluid management strategies can then be initiated to reduce the edema.

Pneumothorax may result from trauma, subclavian or internal jugular vein line insertion, or ventilation with high airway pressures. Signs and symptoms generally include diminished breath sounds and paradoxical movement of the chest wall on the affected side. Tension pneumothorax may cause hypotension and tracheal deviation toward the unaffected side. An abrupt or progressive increase in peak and plateau airway pressures while in volume-control ventilation or decreased tidal volumes and need for increased driving pressures while in pressure-control ventilation mode may signal development of a pneumothorax. When a patient with severe asthma develops decreased oxygen saturation, a pneumothorax should be suspected.

Pulmonary embolism should not be forgotten in the differential of intraoperative wheezing. Although the vascular obstruction itself is not responsible for the wheezing, the subsequent vascular congestion, edema, and atelectasis that can occur may result in partial narrowing of airways which may be heard as a wheeze. Anesthesia and surgical procedures place patients at higher risk for thrombosis by creating conditions of blood stasis, endothelial injury, and hypercoagulability, known as Virchow's triad. Air embolus should also be considered with surgical procedures with an operative field higher than the right atrium and following central line placement.

Pneumonia may also present as wheezing in the anesthetized patient. An intraoperative X-ray may be useful in distinguishing this from other causes.

Treatment of intraoperative bronchospasm should be initiated as soon as other etiologies of wheezing are ruled out to prevent the progression to hypoxemia and more severe complications. The depth of anesthesia should be increased to eliminate inadequate anesthesia as a possible trigger. The inspired oxygen concentration should be increased to compensate for the ventilation perfusion mismatches and increased oxygen demands. Oxygen delivery is seldom the rate limiting step. The use of helium/oxygen mixtures has been suggested when severe airway constriction limits flow but this approach has met limited clinical success, most likely because the addition of helium limits the maximum inspired oxygen concentration to about 30%. Nebulized β_2 agonists remain the mainstay for the treatment of intraoperative bronchospasm. Their delivery is suboptimal when administered through an endotracheal tube. Ten puffs or more of a metered-dose inhaler are required to produce a therapeutic concentration *(7)*. For refractory bronchospasm, intravenous steroids should be administered. Their onset is not immediate, but they will improve the perioperative course if the spasm persists. Nebulized anticholinergics may be of some benefit as well though their onset time is slightly slower than the beta agonists. Nebulized magnesium sulfate has been suggested for refractory bronchospasm and shown to be effective in a few small trials, but further evaluation is necessary. In the patient who is not responsive to nebulized treatments, intravenous therapy should be added. Intravenous aminophylline provides no additional benefit and is associated with an increase incidence of side effects. Low dose intravenous epinephrine (0.007–0.03 μg/kg/min) may be of some help. Intravenous magnesium sulfate and leukotriene receptor antagonists have been suggested to provide therapeutic benefits in a few small trials, but further evaluation of these therapies is needed before they can be confidently recommended *(23)*.

In truly refractory cases of status asthmaticus the volatile anesthetics have been used as a therapy of last resort. All of the volatile anesthetics cause smooth muscle relaxation in isolated tissue preparations. In a clinical setting, the responses are a bit more varied as some are more pungent and irritate the lungs and upper airway when administered in higher concentrations. Classically halothane was used in this setting, but it is no longer available for clinical use in many countries so sevoflurane is the volatile anesthetic of choice among those agents currently available because it is the least irritant among them and has a favorable pharmacokinetic profile *(24, 25)*. Even when rapidly administered in high concentrations the incidence of laryngospasm is negligible.

EMERGENCE FROM ANESTHESIA AND EXTUBATION

Emergence from anesthesia is the second most common time to encounter significant bronchospasm because the patient loses the bronchodilator effect of the volatile anesthetic and the lower anesthetic concentrations do not ablate the response to the noxious stimulus of the endotracheal tube. Prior to decreasing the anesthetic agent concentrations a number of interventions should be considered to decrease the incidence of bronchospasm upon emergence. Any residual neuromuscular blockade should be antagonized with an anticholinesterase such as neostigmine. Although the muscarinic side effects can potentially exacerbate asthmatic symptoms and precipitate bronchospasm, these reversal agents are co-administered with an antimuscarinc drug (atropine, glycopyrrolate) and

clinical experience has demonstrated this to be a safe practice in asthmatic patients and it avoids the potential residual neuromuscular paralysis in the postanesthesia care unit. If bronchospasm has been a recurrent problem during the anesthetic, an additional dose of an inhaled β_2-agonist should be administered via the endotracheal tube prior to discontinuing the anesthetic. It may also be useful to extubate a patient directly to a nebulized bronchodilator. A bolus dose of intravenous dexmedetomidine *(26)* or lidocaine *(27)* may help to suppress airway reflexes during extubation and may be a useful adjunctive therapy. Lastly, suctioning of the airway to remove secretions may trigger bronchospasm so this should be done prior to decreasing the anesthetic gas concentrations. Extubation may also be done during a deeper level of anesthesia, essentially converting an endotracheal general anesthetic to a mask anesthetic to prevent bronchospasm on emergence. This strategy of deep extubation makes sense when there have been periods of significant bronchospasm during the operation and there are no contraindications to mask ventilation. Risks of deep extubation include airway obstruction, laryngospasm, and aspiration, all of which can lead to reintubation. A full stomach in an emergency case or a history of sleep apnea usually contraindicates deep extubation.

In the asthmatic with severe bronchospasm during or persisting after a case, or with other confounding issues such as a difficult airway or a full stomach, foresight may dictate continued intubation and mechanical ventilation. Tenacious airway secretions can be present in some asthmatics. When combined with a blunted cough reflex, hypoventilation, and suboptimal pain control impairing ventilation, the inadequate clearance and depressed respiratory drive may make postoperative respiratory failure inevitable. Reintubation of an active asthmatic can be difficult and manipulation of the airway can further exacerbate an ongoing attack. Continuing intubation and mechanical ventilation while the neuromuscular blockade wears off and the bronchospasm diminishes with further treatment can avoid these complications.

Additional recommendations for some asthmatic patient groups with special considerations are provided in Table 6 *(8)*.

POSTOPERATIVE MANAGEMENT

In the immediate postoperative period, attention should be focused on minimizing the potentially increased risks of respiratory complications such as atelectasis and pneumonia that can be exacerbated by mucus hypersecretion. Avoiding postoperative ventilation is probably the first step. Attention should then be paid to providing adequate pain relief. Inadequate analgesia may result in shallow inspiration, a delayed phase of expiration, and an expiratory grunt. In small children and patients with a depressed level of consciousness, these clinical features could be misdiagnosed as an episode of bronchospasm because the patient cannot verbalize their pain. Once acute pain control has been achieved analgesia can be maintained with longer acting opioids, but postoperative regional analgesia in the form of epidural or peripheral nerve catheter infusions may be quite effective as well *(28)*. This approach avoids the respiratory depressant and sedative effects of the opioids and the infusion of dilute concentrations of local anesthetics combined with narcotics can often provide excellent pain relief and facilitate early physical therapy, early ambulation, and decreased length of hospital stay, all of which will decrease the incidence of perioperative complications. Postoperative options for analgesia are summarized in Table 7 *(8)*.

Table 6
Asthmatic Patient Groups With Special Considerations

Group	*Problems*	*Management considerations for general anesthesia*
Pregnancy for cesarean section	Emergency procedure requiring rapid sequence induction	Ketamine or propofol for induction
	Aspiration risk	Pretreatment with antacid, anticholinergic and pro-kinetic
Pediatric patients	Frequent/recurrent respiratory tract infections	Immediate preoperative evaluation for possible new symptoms
	Inhalation induction frequently used	Sevoflurane is agent of choice
Morbidly obese patients	Technical difficulties with airway management	Balance control of airway with minimizing bronchospasm triggers
	Increased risk of gastric aspiration	Pretreatment with antacid, anticholinergic and pro-kinetic
	Co-existing obstructive sleep apnea	Possible extubation to CPAP
Geriatric patients	Co-existing diseases, e.g., coronary artery disease	Cautious use of β-adrenergic drugs
	Diminished reserve, altered pharmacokinetics, dynamics and consequent sensitivity to depressant drugs	Titrate drugs to effect, avoid long acting depressant drugs
Trauma patients	Unknown medical problems, possible asthma	Maintain level of suspicion for the presence of asthma but consider full differential list
	Undiagnosed pulmonary injury that can mimic asthma	Titrate drugs to effect, avoid long acting drugs
	Unknown drug history with increased risk of adverse drug interactions	

Table 7
Postoperative Analgesia Considerations in Patients With Asthma

Analgesia technique	*Advantages*	*Disadvantages/risks*
Oral medication	Patient-controlled (within limits)	Intermittent dosing schedule
	Limited potential for respiratory depression	Possible bronchospasm if NSAID combinations are given to ASA sensitive patients
Patient controlled analgesia	Patient-controlled (within limits)	No disadvantages specific for patients with asthma
	Decreases treatment delays	
Continuous epidural infusion	Continuous analgesia with decreased risk of impairment of respiration or ability to cough	No disadvantages specific for patients with asthma
Continuous peripheral nerve block infusion	Continuous analgesia with negligible risk of impairment of respiration or ability to cough	No disadvantages specific for patients with asthma

REFERENCES

1. Warner DO, Warner MA, Barnes RD, Offord KP, Schroeder DR, Gray DT, Yunginger MD. Perioperative respiratory complications in patients with asthma. Anesthesiology 1996;85:460–7
2. Forrest JB, Rehder K, Cahalan MK, Goldsmith CH. Multicenter study of general anesthesia: III. Predictors of severe perioperative adverse outcomes. Anesthesiology 1992;76:3–15
3. Liccardi G, Salzillo A, DeBlasio F, D'Amato G. Control of asthma for reducing the risk of bronchospasm in asthmatics undergoing general anesthesia and/or intravascular administration of radiographic contrast media. Curr Med Res Opin 2009;25(7):1621–30
4. National Asthma Education and Prevention Program: Guidelines for the diagnosis and management of asthma. 2007 NIH publication number 08–5846 available at: http://www.nhlbi.nih.gov/guidelines/asthma/asthgdln.htm
5. Nathan RA, Sorkness CA, Kosinski M, Schatz M, Li JT, Marcus P, Murray JJ, Pendergraft TB. Development of the Asthma Control Test: a survey for assessing asthma control. J Allergy Clin Immunol 2004;113:59–65
6. Kumeta Y, Hattori A, Mimura M, Kishikawa K, Namiki A. A survey of perioperative bronchspasm in 105 patients with reactive airway disease. Masui 1995;44:396–401
7. Woods BD, Sladen RN. Perioperative considerations for the patient with asthma and bronchospasm. Br J Anaesth 2009;103 (suppl. 1):i57–i65
8. Fung DL. Anesthesia for patients with asthma. In: Gershwin ME, Albertson TE editors. Bronchial Asthma: A guide for Practical Understanding and Treatment. 5th ed Totowa, NJ. Humana Press; 2006. p311–25
9. Burburan SM, Xisto DG, Rocco PR. Anaesthetic management in asthma. Minerva Anestesiol 2007 Jun;73(6):357–65
10. Silvanus MT, Groeben H, Peters J. Corticosteroids and inhaled salbutamol in patients with reversible airway obstruction markedly decrease the incidence of bronchospasm after tracheal intubation. Anesthesiology 2004;100:1052–7
11. Tirumalasetty J, Grammer LC. Asthma, surgery and general anesthesia: A review. J Asthma 2006;43:251–4
12. Global strategy for asthma management and prevention http://www.ginasthma.com/Guidelineitem accessed November 1, 2010
13. Gerlach AT, Murphy CV, Dasta JF. An updated focused review of dexmedetomidine in adults. Ann Pharmacother 2009;43(12):2064–74
14. Takasaki Y, Kido T, Semba K. Dexmedetomidine facilitates induction of noninvasive positive pressure ventilation for acute respiratory failure in patients with severe asthma. J Anesth 2009;23:147–50
15. Cheney FW, Posner KL, Caplan RA. Adverse respiratory events infrequently leading ot malpractice suits. Anesthesiology 1991;75:932–9
16. Ebert TJ, Hall JE, Barney JA, Uhrich TD, Colinco MD. The effects of increasing plasma concentrations of dexmedetomidine in humans. Anesthesiology. 2000;93(2):382–94
17. Scalfero P, Sly PD, Sims C, Habre W. Salbutamol prevents the increase of respiratory resistance caused by tracheal intubation during sevoflurane anesthesia in asthmatic children. Anesth Analg 2001;93:898–902
18. Eames WO, Rooke GA, Wu RS, Bishop MJ. Comparison of the effects of etomidate, propofol, and thiopental on respiratory resistance after tracheal intubation. Anesthesiology. 1996 Jun;84(6):1307–11
19. Jooste E, Zhang Y, Emala CW. Neuromuscular blocking agents' differential bronchoconstrictive potential in Guinea pig airways. Anesthesiology. 2007 Apr;106(4):763–72
20. Duvaldestin P, Plaud B. Sugammadex in anesthesia practice. Expert Opin Pharmacother 2010;11(16):2759–71
21. Mannam P, Siegel M Analytic Review: Management of Life-Threatening Asthma in Adults. J Intensive Care Med 2010;25(1):3–15
22. Lieberman P, Nicklas RA, Oppenheimer J, Kemp SF, Lang DM, Bernstein DI, Bernstein JA, Burks AW, Feldweg AM, Fink JN, Greenberger PA, Golden DB, James JM, Kemp SF, Ledford DK, Lieberman P, Sheffer AL, Bernstein DI, Blessing-Moore J, Cox L, Khan DA, Lang D, Nicklas RA, Oppenheimer J,

Portnoy JM, Randolph C, Schuller DE, Spector SL, Tilles S, Wallace D. The diagnosis and management of anaphylaxis practice parameter: 2010 update. J Allergy Clin Immunol. 2010;126(3):477–80

23. Soar J, Perkins GD, Abbas G, Alfonzo A, Barelli A, Bierens JJ, Brugger H, Deakin CD, Dunning J, Georgiou M, Handley AJ, Lockey DJ, Paal P, Sandroni C, Theis KC, ZidemanDA, Nolan JP. European Resuscitation Council Guidelines for Resuscitation 2010: Section 8. Cardiac arrest in special circumstances: Electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. Resusitation 2010;81:1400–33
24. Tobias JT. Inhalational anesthesia: Basic pharmacology, end organ effects, and applications in the treatment of status asthmaticus. J Intensive Care Med 2009;24:361–71
25. Vaschetto R, Bellotti E, Turucz E, Gregoretti E, Della Corte F, Navalesi P. Inhalational anesthetics in acute severe asthma. Curr Drug Targets 2009;10:826–32
26. Guler G, Akin A, Tosun Z et al Single-dose dexmedetomidine attenuates airway and circulatory reflexes during extubation. Acta Anaesthesiol Scand. 2005 Sep;49(8):1088–91
27. Adamzik M, Groeben H, Farahani R et al Intravenous lidocaine after tracheal intubation mitigates bronchoconstriction in patients with asthma. Anesth Anal 2007 Jan;104(1):168–72
28. Ballantyne JC, Carr DB, deFarranti S, Suarez T, Lau J, Chalmers TC, Angelillo IF, Mosteller F. The comparative effects of postoperative analgesic therapies on pulmonary outcome: Cumulative meta-analysis of randomized, controlled trials. Anesth Analg 1998;86:598–612