Bronchospasm: Successful Management

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Experienced anesthesiologists have felt the anxiety that occurs when one of their patients develops acute severe bronchospasm. Much of the emphasis in articles and lectures on this topic has been directed towards prevention of the problem. Unfortunately, acute increases in airway resistance still may occur, either because of severe disease, because of previously unidentified reactive airways, because of non-specific bronchial hyperresponsiveness (NSBH) or because of a drug reaction/anaphylaxis. This lecture will discuss prophylaxis initially, but will focus on the physiology and management of the acutely bronchospastic patient.

While mild wheezing and elevation of peak inspiratory pressure are relatively common, life-threatening bronchospastic attacks under anesthesia are relatively uncommon. A retrospective review of patients in Minnesota who carried the diagnosis of asthma revealed very few intra- or post-operative respiratory complications (Warner, 1996). The retrospective nature of that study and the fact that many of the patients appeared to have very mild disease may underestimate the incidence of problems (Bishop, 1996). Studies from our operating room, where there is a high incidence of smokers, found an eight percent incidence of wheezing following induction of anesthesia. However, other studies suggest a 0.5% or less incidence of bronchospasm noteworthy enough to have been recorded as part of quality management studies. Most anesthesiologists have experienced at least one episode of severe bronchospasm in a patient, however, and adverse outcomes are well documented. In the ASA Closed Claims Study, two percent of all respiratory claims were related to bronchospasm and 70% of those claims were for death (Cheney). Consequently, the possibility of a severe adverse outcome must be recognized.

Anecdotally, many of the cases of severe bronchospasm do not have pre-existing histories of bronchospastic disease. Conversely very few asthmatics have adverse outcomes—a fact that seems almost obvious when we consider that the disease probably has a 6-8% prevalence in the population. Given this, routine pre-operative evaluation with pulmonary function tests would be expensive and time-consuming. However, in patients with moderate persistent or severe persistent asthma (per the definitions of the Expert Panel Report of the NHLBI Asthma Education and Prevention Program), an objective assessment of function with a peak flow rate or FEV1 may help detect patients who are not in optimal condition. Such patients may not perceive the severity of their condition and are at risk for severe attacks (Magadle).

While occasional cases of intra-operative bronchospasm may be due to allergic or anaphylactic reactions to drugs or latex, the majority are probably the result of non-specific bronchial hyperresponsiveness (NSBH). NSBH may be present in 10-20% of the population while only 6-8% of the population has asthma. Chronic inflammation, such as that seen in smokers, renders the airway more susceptible to non-specific stimulation.

Bronchospasm intra-op is probably usually cholinergically mediated. Afferent receptors in the bronchial mucosa can be an initiating event although such an event is not always identifiable. Efferent parasympathetic fibers travel to bronchial smooth muscle and then can result in bronchoconstriction by stimulation of the M3 cholinergic receptors on bronchial smooth muscle. Following release of acetylcholine at the M3 receptor, the ACh will stimulate the M2 muscarine receptor which is an inhibitory receptor that limits further release of ACh. Alterations of M2 receptor function may contribute to bronchospasm.

I. PREOPERATIVE CONSIDERATIONS

A. Pathophysiology of bronchospasm

The concept of smooth muscle contraction as the cause of increased airway resistance in patients with reactive airways is overly simplistic. While an exaggerated bronchoconstrictor response to a trigger is characteristic of asthma, the increased reaction to a trigger consists of a complex response including airways edema, increased secretions, and smooth muscle contraction. Studies of airway caliber in patients dying of asthma show marked thickening of the submucosa (Dunnill), and recent studies demonstrate that inflammation is present even in patients with mild asthma (Laitinen, Beasley). Bronchoalveolar lavages also demonstrate increased inflammatory cells in the lungs of asthmatics (Godard). In addition, bronchial hyperresponsiveness appears to be increased by the airways inflammation (Barnes).

B. Role of recent infection

Following upper airway viral infections, especially influenza infections, even normal subjects may have increased airway reactivity. Following viral infections, M2 receptor function may be abnormal for several weeks. In patients with asthma, exacerbations are most commonly linked to viral infections. There is suggestive evidence that anesthesia following a recent URI results in a higher incidence of problems with airway reflexes.

C. Medications

Beta-adrenergic agonists have traditionally been the mainstay of treatment both chronically and acutely in the patients with mild to moderate reactive airways. Inhaled beta-2 adrenergic agonists, including albuterol, terbutaline, fenoterol, pirbuterol, and salmeterol have LD50's orders of magnitude greater than their therapeutic doses. There remains significant controversy as to whether there are detrimental effects of chronic use of beta-adrenergic agonists, especially high potency drugs such as fenoterol (Barrett). Many clinicians have begun using inhaled corticosteroids as first line therapy with beta-adrenergic agonists reserved for PRN use.

Although theophylline has bronchodilating action, it does not add to the therapeutic effects of beta-adrenergic agonists in the face of an acute attack. Of interest to anesthesiologists is work in dogs demonstrating that aminophylline did not provide bronchodilation in dogs anesthetized with halothane when bronchospasm was provoked with histamine (Tobias). Its primary role now appears to be in the prophylaxis of acute attacks in the chronic asthmatic and in the prevention of nighttime episodes of bronchospasm. In patients with chronic lung disease, its beneficial effects on mucociliary clearance and diaphragmatic contraction may contribute to the improvement many patients report. Theophylline has a very low toxic/therapeutic index. Toxic effects are seen at levels below maximal therapeutic effects. Theophylline also appears to increase arrhythmias during halothane anesthetic induction, although similar effects are not seen with enflurane or isoflurane (Stirt 1981, 1983).

The inflammatory nature of asthma has led to greater appreciation of the importance of steroids in controlling the incidence of attacks and in aborting acute attacks. The onset of benefit is within a few hours, making steroids useful as preoperative medication in patients with moderate to severe asthma and a history of requiring steroids in the past (Parker). In the face of ongoing wheezing and scheduled elective surgery, a steroid course in the week(s) prior to surgery may be useful. The concern that steroids will increase the rate of wound-healing problems or of infection are not well-founded. A study of asthmatics treated with steroids preoperatively found no increase in the incidence of wound infections or wound-healing problems (Kabalin). The anesthesiologist looking for support for the

need for steroids in the asthmatic can cite the 1991 NIH Expert Panel recommendation that asthmatics with an FEV1 less than 80% of predicted should receive a preoperative course of oral steroids (Sheffer).

Leukotriene receptor antagonists or synthesis inhibitors are not intended for acute use but for chronic maintenance and offer only mild benefits.

II. CHOICE OF ANESTHESIA

A. Regional anesthesia vs. general vs. mask vs. LMA

Since instrumentation of the airway is the major trigger for wheezing during anesthesia, any measures to avoid intubation are useful. Shnider and Papper found that 6.4% of asthmatics developed wheezing during general anesthesia following intubation, whereas less than 2% did so with either general anesthesia without intubation or with regional anesthesia. Following LMA insertion, airway resistance decreases less than following ETT insertion (Kim, 1999). A criticism of neuraxial blocks for the patient with bronchospastic disease is the possibility of a high block obliterating the strength of the accessory respiratory muscles. The major change in pulmonary function seen with a high spinal is an average 48% reduction in expiratory reserve volume which translates clinically into a decreased cough. In the patient with chronic bronchitis or current URI this could be a problem, but for most patients with reactive airways, regional anesthesia is ideal. Concerns about high block leading to sympathetic blockade and consequent bronchospasm also appear to be unfounded. A study of parturients with asthma demonstrated no differences between those anesthetized with high epidurals (T2-T4) and those undergoing general anesthesia with ketamine/isoflurane (Ramanathan). A study of volunteers with documented bronchial hyperreactivity found that high thoracic epidural anesthesia did not alter airway resistance and attenuated the response to inhaled acetylcholine (Groeben). The attenuation of the response may have been due to systemic absorption of the local anesthetic, rather than any direct effect from the epidural. Two surveys published in the last several years from Japan both found significantly lower incidences of asthmatic attacks with epidural anesthesia than with general anesthesia (Tanaka). However, it is important to note that several cases in the ASA Closed Claims Study with adverse outcomes had received regional anesthesia. The usual scenario was failed regional anesthesia followed by intubation. Presumably, this is a situation in which light anesthesia is often used with subsequent airway irritation. Similarly, several of the OB cases occurred following failed regional.

B. Induction agents

Thiopental rarely may cause bronchospasm. However, because it provides only a light plane of anesthesia, airway instrumentation under thiopental anesthesia alone may trigger spasm. Experimentally, in isolated sheep airways, thiopental caused tracheal contraction and bronchial relaxation (Mustafa). Ketamine produces smooth muscle relaxation both via neural mechanisms and via release of catecholamines (Brown, 1999). Lidocaine prevents reflex bronchoconstriction and has little toxicity at doses of 1.5 mg/kg given 1-3 minutes prior to intubation. Direct tracheal lidocaine spray carries the hazard of triggering airway reaction and should be avoided in favor of the intravenous route. Induction of asthmatics with 2.5 mg/kg propofol resulted in a significantly lower incidence of wheezing following tracheal intubation when compared with induction with 6 mg/kg thiamylal or with an equivalent dose of methohexital (Pizov). A study from our hospital found that in unselected patients, propofol resulted in a significantly lower respiratory resistance following tracheal intubation than did induction with thiopental or etomidate (Eames, 1996). Controversy exists as to whether propofol preparations containing sulfites may be less effective bronchodilators (Rieschke).

C. Inhalation agents

A study of the bronchodilating effect of inhaled anesthetics following intubation found that sevoflurane was as effective a bronchodilator as halothane and more effective than isoflurane (Rooke). Desflurane has not been shown to have the same bronchodilating effects as the other inhalation agents. At low doses (<1.7 MAC), isoflurane was less effective than halothane (Brown).

D. Muscle relaxants

Rapacuronium was withdrawn from the market after a number of reports of severe bronchospasm, most likely due to antagonism at the M2 receptor (Jooste). Mivacurium releases significant amounts of histamine and leads to mast cell degranulation and should be used extremely cautiously if at all in patients with a history of atopy or asthma (Bishop). Studies in France and Norway have suggested a high incidence of anaphylaxis with rocuronium although this does not appear to be supported in literature from other countries.

III. ANALYSIS OF A BRONCHOSPASTIC CRISIS

A. Why do peak airway pressures rise?

The simplest explanation is that the airways constrict, increasing resistance. In addition, the patient is often coughing and bucking. Secretions and mucosal engorgement further contribute to the problem. In severe cases, air trapping (auto-PEEP, see below) may occur. The chest becomes overdistended and less compliant.

B. What is auto-PEEP and why is it a problem?

As resistance increases, longer inspiratory times are often required to deliver adequate tidal volumes. The shortened expiratory time combined with airway compression during exhalation may result in incomplete exhalation. Clinically this may be noted on a spirometer as ongoing exhalation at the time the ventilator initiates the next inspiration. The in-line manometer is not helpful since the pressure in the circuit may be near zero while there is still a substantial positive pressure in the chest. This occurs because effectively there is a resistor between the alveoli and the circuit (the airways). In the patient whose volume status is marginal, an increase of just a few cmH_2O in intrathoracic pressure can greatly decrease venous return and result in hypotension. The treatment of the hypotension in this situation is discussed below.

C. Why does the oximeter show a dropping saturation?

The obvious conclusion is that secretions and spasm have resulted in airway closure and underventilation of perfused airways. However, hypoxia is generally not a major problem in pure reactive airways disease. The problem may well be one of inadequate perfusion resulting in a falsely low reading on the oximeter. Keep this in mind if the low saturation is accompanied by hypotension. Trying to treat the low saturation with PEEP could just make things worse.

D. Why does pCO_2 go up and $ETCO_2$ go down?

Differences in resistance result in overdistention of some lung units, underventilation of others, and an overall increase in ventilation perfusion mismatch. Overdistended alveoli may not be perfused at all, especially in the face of hypotension, resulting in large increases in dead space.

Equally important and often under recognized is that despite changes made in the minute ventilation settings on an anesthesia ventilator, the large compressible volume and limited flows may make increasing tidal volumes difficult (Marks). Changing to a more powerful ICU type ventilator may be the better approach.

IV. RESPONDING TO THE CRISIS

A. Deepen anesthesia

Even when there is a drop in blood pressure, deepening the anesthetic is useful, especially since it may lower intrathoracic pressures and improve venous return. Paralysis will decrease the respiratory impedance associated with bucking. Experimental evidence suggests that halothane or sevoflurane may be a better choice of inhaled anesthetic than isoflurane, especially at lower levels of MAC (Brown, Rooke).

B. Don't spare the beta-2 agonists

As discussed above, these are very safe agents. Unlike theophylline, beta-adrenergic agonists do appear to provide further bronchodilation during halothane anesthesia in an animal model (Tobias, 1990). Although it might seem that little drug could be delivered by inhalation in the severely bronchospastic patient, studies in emergency room patients suggest that the inhalational route is just as effective as parenteral therapy with fewer side effects. (An exception to this is in anaphylaxis when intravenous epinephrine is the drug of choice). Spacer devices deliver drugs efficiently, even via endotracheal tubes (Bishop). A study in intubated, mechanically ventilated patients in an intensive care unit found that maximum benefit occurred after 15 puffs of albuterol via a spacer with no patient benefiting from more puffs (Manthous). Terbutaline is available as a subcutaneous preparation, but there is no evidence this is superior to the inhaled route. The beta-adrenergic agonist salmeterol has a long duration of action and is used by many asthmatics prophylactically. It is important to recognize that this drug should not be used in acute interventions because it takes 20 minutes to have a significant onset of action. A drug with a more rapid onset of action should be used in the face of an acute attack.

Although giving atropine might make intuitive sense given the presumed cholinergic mechanism of much intra-operative bronchospasm, atropine's lack of M3 selectivity limits its utility (by acting at both M2 and M3 receptors, atropine results in continued ACh release at the M3 receptor). At low concentrations, atropine may actually preferentially inhibit M2 receptors.

C. Ketamine

An incremental dose of ketamine may be a quick way of maintaining blood pressure, rapidly deepening anesthesia, and avoiding the problem of delivering an inhaled anesthetic to a patient with poor ventilation.

D. Bring in an ICU ventilator

A not uncommon story is the patient with severe spasm who can't be ventilated in the OR, but improves rapidly in the ICU. It's not that anything has really changed. It's that our anesthesia ventilators are not designed for patients with respiratory failure. Even with the most powerful ventilator, an anesthesia circuit has too much compressible volume to make adequate ventilation possible in the face of a high impedance. With an ICU ventilator, pressures as high as 120cm H_2O are feasible. High flows allow for shorter inspiratory time with adequate time for greater exhalation and lower auto-PEEP. This in turn often results in improved circulation. The major disadvantage of ICU ventilators is the need to switch to intravenous from inhalation anesthetics.

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