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Acute Intraoperative Pulmonary Aspiration

Katie S. Nason, MD, MPH

Division of Thoracic and Foregut Surgery, Department of Cardiothoracic Surgery, University of Pittsburgh, Pittsburgh, PA

Synopsis

Acute intraoperative aspiration is a potentially fatal complication with significant associated morbidity. Patients undergoing thoracic surgery are at increased risk for anesthesia-related aspiration, largely due to the predisposing conditions associated with this complication. Awareness of the risk factors, predisposing conditions, maneuvers to decrease risk and immediate management options by both the thoracic surgeon and the anesthesia team is imperative to reducing risk and optimizing patient outcomes associated with acute intraoperative pulmonary aspiration. Based on the root-cause analyses that many of the aspiration events can be traced back to provider factors, having an experienced anesthesiologist present for high-risk cases is also critical.

Keywords

Anesthesia; Intratracheal; Intraoperative Complications; Prevention & Control; Pneumonia; Aspiration; Respiratory Aspiration of Gastric Contents

INTRODUCTION

While anesthesia is generally safe, respiratory complications such as anesthesia-related aspiration can be fatal.[1, 2] Occurring as often as 1 in every 2–3,000 operations requiring anesthesia,[3] almost half of all patients who aspirate during surgery develop a related lung-injury, such as pneumonitis or aspiration pneumonia.[4] This issue is of particular relevance to thoracic surgeons; Sakai and colleagues retrospectively compared characteristics of patients with and without anesthetic-related pulmonary aspiration and found that aspiration occurred three times more often in thoracic surgical procedures than any other specialty. [5] As such, understanding the potential impact of anesthesia-related aspiration on peri-operative outcomes, factors that contribute to an increased risk of this complication and strategies for

Corresponding Author: Katie S. Nason, MD MPH, 5200 Centre Ave, Suite 715, Shadyside Medical Building, Pittsburgh, PA 15232, nasonks@upmc.edu, 412-623-2025.

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preventing the occurrence of or minimizing the sequela from an anesthesia-related aspiration are imperatives for the thoracic surgeon.

PULMONARY ASPIRATION: DEFINITION, CONSEQUENCES AND RISK FACTORS

Definition and Consequences

Defined as the entry of liquid or solid material into the trachea and lungs, anesthesia-related aspiration occurs when patients without sufficient laryngeal protective reflexes passively or actively regurgitate gastric contents. Pulmonary syndromes of differing severity result, ranging from mild symptoms such as hypoxia to complete respiratory failure and acute respiratory distress syndrome (ARDS), and even cardiopulmonary collapse and death. The types of pulmonary syndromes include acid-associated pneumonitis, particle-associated aspiration (e.g. airway obstruction), or bacterial infection, with subsequent development of lung abscess, exogenous lipoid pneumonia, chronic interstitial fibrosis, and *Mycobacterium fortuitum* pneumonia.[6] Which of these syndromes develops depends on the composition and volume of the aspirate.

The most common lung injury is aspiration pneumonitis. Initially described by Mendelson in 1946, aspiration pneumonitis is damage to the lung parenchyma resulting from inhalation of sterile, acid (or bile) gastric contents. The severity of pulmonary parenchymal injury is modified by the degree of acidity, the volume of the aspirate, and the presence or absence of particulate matter in the aspirated fluid. Low volume aspirate with a very low pH can rapidly lead to fatal pneumonitis, whereas higher volumes of aspirate that are buffered (i.e. higher pH) can be better tolerated. As little as 50 ml of regurgitated gastric contents can be considered a ‘severe’ aspiration.[7] When the aspirate is not sterile or when particulate matter are present in the aspirate, mechanical airway obstruction and infectious complications can develop, with the most common pathogens being staphylococcus aureus, pseudomonas aeruginosa, enterobacter species, anaerobes, klebsiella species and escherichia coli.[8]

Risk Factors

There are a number of patient and procedure-related characteristics which place some patients at higher risk for an anesthesia-related aspiration event.

Risk Factors: Medications—In and of itself, anesthesia places patients at risk for aspiration. This risk results from the effects of medications on the lower esophageal sphincter, level of consciousness, and loss of protective reflexes.

There are a number of medications that are routinely used during anesthesia that are known to decrease lower esophageal sphincter tone.[9] These include:

- Propofol
- Volatile anesthetic agents
- β-agonists
- Opiods

- Atropine
- Thiopental
- Tricyclics
- Glycopyrrolate

In addition to effects on lower esophageal sphincter pressures, these medications by design induce a progressive loss of consciousness with subsequent decline and then loss of protective reflexes.[10] This risk is even greater when topical anesthesia to the larynx is employed, because the cough reflex is compromised.[11]

Risk factors: Predisposing Conditions—It is important to note, however, that the majority of patients undergoing anesthesia do not suffer from an aspiration event; predisposing conditions must also exist which, in combination with progressive loss of consciousness and diminished protective reflexes, create a favorable environment for aspiration. These predisposing conditions include: [12]

- Gastrointestinal obstruction
- Need for emergency surgery
- Previous esophageal surgery
- Lack of coordination of swallowing or respiration
- Esophageal cancer
- Hiatal hernia
- Obesity

Consistent with the upper gastrointestinal stasis and/or obstruction associated with most of these conditions, passive regurgitation with induction of general anesthesia is far more common than active vomiting,[13]

Risk Factors: Provider expertise—At least one study found that provider factors such as improper decision making, lack of experience and lack of knowledge were responsible for the majority of intraoperative aspiration events.[14] Provider expertise is also implicated in failure of preventive measures, such as the use of cricoid pressure during rapid sequence induction[15] (see below) and wide variation in the execution of these approaches to anesthesia induction in the high risk patient. In the retrospective review of anesthesia-related aspirations by Sakai and colleagues, 10 of the 14 cases were attributed to improper anesthesia technique. In their critical review of anesthetic management, they found that cricoid pressure was not applied at the time of induction in 4 cases and provider inexperience contributed to aspiration in a high risk patient in another patient.[5] Kluger and Short reported similar concerns regarding provider specific factors in their review of 133 cases drawn from the New Zealand Anesthetic Incident Monitoring Study database. As with other studies, passive regurgitation was three times more common than active vomiting and the majority of cases had at least one predisposing risk factor for regurgitation. Despite this, only 14% of the patients who aspirated had any anti-aspiration prophylaxis (defined in the

study as cricoid pressure, acid-suppression therapy, and prokinetic agents) utilized prior to and during induction. Factors contributing to the aspiration event were taken directly from the reports submitted to the database and included error in judgment (n=43; including inadequate anesthesia), fault of technique (n=35), inadequate patient preparation (n=25), communication problem (n=14), inadequate assistance (n=14), and provider inexperience (n=13).[13]

PREVENTION

Preoperative Risk Assessment

The key to minimizing the impact of acute intraoperative aspiration is to prevent it from happening. A thorough knowledge of the patient and their predisposing conditions, including a physical exam and review of current symptoms, are vitally necessary for both the anesthesiology and the surgical team. According to the American Society of Anesthesiologists, the interview should include, at a minimum, assessment for predisposing risk factors which contribute to increased risk of volume regurgitation, including:[16]

- Gastroesophageal reflux disease
- Esophageal dysmotility
- Difficulty swallowing
- Diabetes
- Gas bloat or other signs of delayed gastric emptying
- Obstructing cancer causing stasis within the esophagus

Preoperative fasting

Preoperative fasting is also critical. Current recommendations from the American Society of Anesthesiologists Committee on Standards and Practice Parameters[16] allow:

- Consumption of a light meal or nonhuman milk up to 6 hours prior to elective procedures
- Clear liquids up to 2 hours prior to elective procedures (e.g. water, clear tea, carbonated beverages, pulp less fruit juice and black coffee).

These recommendations are based on studies which show that clear liquid intake in the 2–4 hours prior to induction of anesthesia was associated with a lower gastric residual volume than fasting more than 4 hours, though the differences in volume were clinically insignificant.[17] Summarized in a Cochrane review in 2003, the authors concluded that there was no evidence supporting the standard ‘nil by mouth from midnight’ fasting compared to a shortened fluid fast (2–4 hours) and encouraged providers to consider shorter periods of for clear liquid fasting. For the thoracic surgeon, however, it is critical to note that these recommendations were accompanied by a very important caveat; there is little to no data available regarding the appropriate preoperative fasting times in populations that are considered to be at increased risk of anesthesia-related regurgitation and aspiration. Conditions such as large paraesophageal hernia, achalasia and obstructing esophageal

cancers warrant consideration of several days of clear or full liquid diet, given the poor emptying and likelihood of retained solid food matter that accompany these conditions.

Preemptive nasogastric tube placement

Preemptive nasogastric tube placement has been proposed as an option for reducing aspiration risk at the time of induction. However, evidence to support this practice is lacking. There are no prospective and/or randomized data evaluating the efficacy of preemptive nasogastric tube placement and limited retrospective data. Mellin-Olsen and colleagues retrospectively reviewed more than 85,000 anesthetics over a 5-year time frame and identified 25 cases of pulmonary aspiration. Aspiration events were 4 times more likely in emergency procedures and all occurred in patients receiving general anesthesia. They found no evidence to support routine preoperative gastric emptying, even in emergency cases, except for patients with suspected ileus/obstruction.[18] As such, use of a nasogastric tube should be determined by the operating surgeon and the anesthesiologist based on the patient's condition and the factors necessitating operation. Careful consideration of the risks and benefits should be undertaken, as placement of the nasogastric tube may actually contribute to vomiting and subsequent aspiration in some patients. In addition, nasogastric tube insertion in patients undergoing esophageal surgery carries high risk for injury, particularly in patients with incarcerated, obstructed paraesophageal hernia or obstructing esophageal cancer. In these cases, the surgeon should be consulted or, optimally, be present in the room during the induction of anesthesia to provide immediate guidance to the anesthesia team. Obviously, if a nasogastric tube is already in place, suctioning of the stomach should be performed.[9]

H_2 Blockers, Proton Pump Inhibitors (PPIs), and Prokinetics

Histamine (H_2) antagonists such as cimetidine, famotidine, nizatidine, and ranitidine and proton pump inhibitors (PPIs) such as dexlansoprazole, esomeprazole, lansoprazole, omeprazole, pantoprazole, and rabeprazole have been shown to be effective in increasing the pH and reduce the volume of gastric contents. Prokinetics such as domperidone, metoclopramide, erythromycin, and renzapride promote gastric emptying and in turn should reduce the risk of aspiration [19]. This theory, however, is not supported by a large amount of quality evidence. Puig and colleagues evaluated the efficacy of H2-receptor antagonists and proton pump inhibitors for reducing aspiration risk in a meta-analysis of the literature in 2012. Eighteen studies were identified.

Aspiration risk was defined in all but one study as a gastric pH below 2.5 and gastric volume above 25 ml. The data revealed a non-significant trend toward H2-receptor antagonists being more effective than proton pump inhibitors. When given as a single, oral dose immediately prior to operation, the H2-receptor antagonist was significantly more effective whereas two doses or intravenous dosing was similarly effective between the two drugs.[20] It should be noted that the end-point for these studies (gastric pH and gastric volume) are surrogates for the clinically important end-point of pulmonary aspiration and that the efficacy of premedication for reduction in actual aspiration events is unproven. In addition, it is important to remember that increasing the pH of gastric contents does not completely eradicate aspiration pneumonitis. Milk and bile have been shown to do as much damage to

the respiratory track as gastric contents.[9] In the current guidelines from the American Society of Anesthesiologists, routine use of gastrointestinal stimulants (e.g. metoclopramide), gastric acid secretion blockers (e.g. famotidine, ranitidine, omeprazole), antacids, antiemetics, and anticholinergic agents to reduce the risk of pulmonary aspiration are not recommended.[16]

Rapid Sequence Induction (RSI)

Kluger and colleagues evaluated the timing of regurgitation and aspiration during anesthesia and found that the vast majority of events occurred during induction of anesthesia; a smaller proportion occurred during the maintenance phase of anesthesia and during emergence from anesthesia.[13] As such, it is critically important for surgeons and anesthesiologists to have an algorithm for minimizing aspiration events in patients who are deemed high risk. One approach is to use rapid sequence induction, a method of anesthesia induction that was developed to quickly achieve a protected airway in emergency or high-risk cases while minimizing risk of aspiration of regurgitated gastric contents.

The technique for rapid sequence induction includes:

- Preoxygenation
- Rapid administration of induction and paralytic agents which are not titrated to effect
- Criciod pressure (originally described but not currently recommended for all patients)
- Avoidance of bag and mask ventilation
- Transoral insertion of an endotracheal tube using direct or video laryngoscopy

While theoretically appealing, the impact of RSI on prevention of aspiration, which is the reason that RSI is performed, is unclear. This is due, in part, to the fact that aspiration is a rare event and would require very large numbers of patients to determine whether there was a difference in aspiration rates with and without RSI. In addition, the definition of RSI varies widely and there is not a single, universally applied, technique, which makes comparisons between studies challenging.[21] This question was examined by systematic literature review in 2007.[3] Despite reviewing 184 eligible studies, including 163 randomized controlled trials, the paper concluded that the literature were insufficient to determine whether RSI reduces aspiration during induction of anesthesia. The authors also examined the evidence for use of cricoid pressure; there were no data to support the routine use of cricoids pressure and many studies showing that the esophagus is displaced relative to the cricoid in 50% or more of patients while deforming the criciod and obstructing the airway in 90% and 50% of patients, respectively.[22] Based on the available literature, the systematic review concluded that cricoid pressure is a benign practice and should be used in RSI, but lowered or released if the pressure is creating difficulties securing the airway.[3, 23]

Patient positioning during induction

The optimal patient position to minimize aspiration continues to be refined. Takenaka and colleagues hypothesized that airway contamination by regurgitated gastric contents could be minimized by combining use of a head-down tilt and optimizing the relationship between the head and neck. They performed a prospective study, initially in manikins with colored fluid in the esophagus and then in 30 adult volunteers. They examined aspiration events associated with combinations of a head-down tilt between 0°and 50° in 5° increments and four head-neck positions (neutral, simple extension, sniffing and the Sellick position). They found that a head-down tilt that leveled the mouth with the larynx was necessary to completely prevent aspiration.[24] More than 45° of head-down tilt was required for complete prevention of aspiration with the head-neck in the neutral position and more than 35° was needed when simple extension was used. When examined in the healthy volunteers with normal cervical spine, leveling of the mouth with the larynx was achieved with a head-down tilt of less than 15° in 87% of patients. From these findings, they concluded that a head-down tilt of 15° to 20°, combined with the Sellick position for the head to neck orientation was optimal for minimizing tracheal and bronchial aspiration. They cautioned that intubation using the Sellick position can be challenging, and is contraindicated in patients with cervical spine instability. Their findings, however, provide support for optimizing patient positioning such that regurgitated contents are directed away from the larynx.

Others have examined lateral positioning for patients at risk for aspiration. This position is commonly utilized for esophageal procedures performed under monitored anesthesia and facilitates movement of regurgitated contents away from the airway. Unfortunately, most anesthesiologists have limited experience with intubating patients in this position, rendering it less useful for procedures requiring general anesthesia. Indeed, McCaul and colleagues examined airway management with lateral positioning in a randomized controlled trial and found that the laryngoscopic airway examination deteriorated in 35% of patients. Lateral positioning failed to improve the laryngoscopic examination for any patient. This was most pronounced in patients undergoing endotracheal intubation when compared to laryngeal mask anesthesia.[25] As such, though lateral positioning may optimize the orientation between the airway and the mouth and, thus, minimize aspiration, it is probably not a useful position for induction of anesthesia in the majority of thoracic surgery patients.

MANAGEMENT OF ACUTE INTRAOPERATIVE ASPIRATION

Successful intraoperative management of pulmonary aspiration requires a high index of suspicion and immediate response. The first step in successful management of an intraoperative aspiration is the immediate recognition of gastric content in the oropharynx or the airways. Additional signs of potential aspiration include persistent hypoxia, high airway pressures, bronchospasm, and abnormal breath sounds following intubation. It is optimal if the gastric contents are visualized in the oropharynx or passing into the airway during intubation as this allows for immediate suctioning prior to application of positive pressure ventilation. In one study, 70% of the intraoperative aspiration events were confirmed by clinical visualization of regurgitation and airway penetration of the regurgitated material.[2] In this setting, the patient should be positioned with the head down and rotated laterally if

possible. Orotracheal and endotracheal suctioning is indicated, either before or after orotracheal intubation, depending on whether regurgitation continues and if the airway is visible. It is recommended that the airway be secured as rapidly as possible to prevent further soilage and to facilitate airway clearance.[2] Flexible bronchoscopy is an important adjunct to orotracheal and endotracheal suctioning; indeed, having a flexible bronchoscope ready for use in patients who are known to be high risk preoperatively is warranted for airway clearance should gastric regurgitation occur. If particulate matter is present in the airway, rigid bronchoscopy may be required. There are also advocates for use of steep trendelenberg positioning after administration of paralytics and prior to insertion of the laryngoscope, with Yankauer suction immediately available. In theory, regurgitated gastric contents would flow away from the airway and, given that the patient is paralyzed and cannot inhale, minimize spillage into the trachea.

The decision to proceed with the operation is at the surgeon and anesthesiologists discretion. Factors influencing the decision include the urgency of the operation, the patient's oxygen saturation and pulmonary compliance, and response to interventions such as bronchodilators and positive end-expiratory pressure. Antibiotics and steroid use should be individualized to the patient and are not recommended for routine use. Maintenance of mechanical ventilation should also be dictated by the usual parameters and the concern for development of ARDS based on the volume of the aspirated contents, which is associated with the likelihood of postoperative pulmonary complications.[5]

In cases of severe aspiration, cardiopulmonary arrest can occur. In these situations, cardiopulmonary resuscitation should be immediately instituted, an orotracheal airway placed and airway clearance maneuvers performed. Early institution of extracorporeal membrane oxygenation (ECMO), if available, may provide a necessary bridge to stabilize the patient and assess potential for lung recovery. There are no published studies to date regarding the success of this strategy in adults who suffer immediate cardiac arrest subsequent to massive aspiration and recovery in this setting is highly unlikely. Based on studies of ECMO for ARDS in adults,[26–28] a theoretical benefit for patients who subsequently develop ARDS secondary to intraoperative aspiration may exist. The decision to implement ECMO in this situation depends on the availability of ECMO, the reversibility of the underlying disease process and the severity of associated comorbid conditions.[28]

SUMMARY

Acute intraoperative aspiration is a potentially fatal complication with significant associated morbidity. Patients undergoing thoracic surgery are at increased risk for anesthesia-related aspiration, largely due to the predisposing conditions associated with this complication. Awareness of the risk factors, predisposing conditions, maneuvers to decrease risk and immediate management options by both the thoracic surgeon and the anesthesia team is imperative to reducing risk and optimizing patient outcomes associated with acute intraoperative pulmonary aspiration. Based on the root-cause analyses (presented above) that many of the aspiration events can be traced back to provider factors, having an experienced anesthesiologist present for high-risk cases is also critical.

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Key Points

- Thoracic surgery patients are at increased risk (threefold) for intraoperative aspiration compared to other surgical specialties
- Aspiration pneumonitis is the most common sequela of significant intra-operative aspiration, followed by aspiration pneumonia
- The severity of pulmonary parenchymal injury is modified by the degree of acidity, the volume of the aspirate, and the presence or absence of particulate matter in the aspirated fluid
- Predisposing conditions include gastrointestinal obstruction, need for emergency surgery, previous esophageal surgery, esophageal cancer, hiatal hernia, impaired coordination of swallowing or respiration, and obesity
- Preoperative assessment, appropriate fasting and use of rapid sequence induction, anti-secretory medications, and rapid recognition/response to gastric regurgitation are critical to prevention and management