The "Other Tube" in the Airway: What Do We Know About It?

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If one were to scan the contents of any anesthesia-related professional journal in publication today, one would undoubtedly notice a number of common themes or "hot topic" areas. These would include the following: medications both new and "old" (indications, dosing, toxicities, complications, etc.); new technology and devices; patient monitoring, safety, and outcomes; and provider education, among many others. "Airway management" in the broadest sense is clearly one of the foundational topic areas in the anesthesia literature, with articles on airway devices, endotracheal intubation techniques, medications to facilitate intubation, and even airway extubation. A cursory literature search or review reveals thousands of articles on endotracheal tubes, endotracheal intubation, and airway management. Also, and increasingly, we live and practice in a world of evidence-based medicine, practice parameters, and practice guidelines. There are algorithms for management of the anticipated and unanticipated "difficult" airway and how to evaluate the patient for tracheal extubation.[1,2] Yet, there is surprisingly little information and scant evidence available in the anesthesia literature, including standard textbooks, that address the "other tube" that is often placed and used in patients' airways: the gastric tube (GT) that may be passed through the esophagus and into the stomach via either the nasal (NGT) or oral (OGT) routes.

In this issue of *Anesthesia & Analgesia*, Salem et al.[3] present a review article titled "Gastric Tubes and Airway Management in Patients at Risk of Aspiration: History, Current Concepts, and Proposal of an Algorithm." The authors point out that although rapid sequence induction and intubation (RSII) and awake tracheal intubation are commonly used anesthetic techniques for the management of patients at risk of aspiration of gastric or esophageal contents, and that some of these patients have a GT placed preoperatively, there are no clinical guidelines to indicate which patients should have a GT placed before anesthetic induction or how the GT should be managed during the induction and perioperative period. The authors provide an interesting history of the use of GTs and a brief review of the current status of these devices. A considerable amount of discussion is devoted to whether to withdraw or allow a preexisting GT (i.e., a GT that was placed before anesthesia induction) to remain in place; likewise, much discussion focuses on the management of GTs with the application of the cricoid pressure ("Sellick") maneuver. The article then focuses on current concepts in the airway management of patients at risk of aspiration and the specific role of GTs, with specific recommendations for patients with esophageal disorders (Zenker diverticulum and achalasia), gastroesophageal reflux, and gastric distension or obstruction. The authors propose an algorithm to guide GT use in adult patients with these disorders at the time of anesthesia induction and tracheal intubation (see below). Finally, a separate section discusses specific considerations in pediatric patients, with examination of key physiologic differences in infants and small children and brief review of anesthetic management of 3 conditions in pediatric patients, primarily neonates and infants: congenital pyloric stenosis, esophageal atresia with tracheoesophageal fistula, and esophageal fundoplication.

The GT is a vital piece of equipment that is used in daily practice, often with little thought of whether or not the patient meets particular criteria for a GT. The use of GTs has become a sort of ritual for the anesthesiologist, alongside another commonplace ritual in airway management of some patients: the application of cricoid pressure (Sellick maneuver). The review contains a significant amount of information regarding the effectiveness of cricoid pressure with very descriptive details of how to apply this maneuver most effectively.

The use of cricoid pressure has been critically reviewed by Loganathan and Liu.[4] As they note, and to paraphrase key portions of their review, cricoid pressure can be traced back to the late 18th century when it was used to prevent gas inflation of the stomach during resuscitation from drowning.[4] While the usefulness of cricoid pressure when there is either an NGT or OGT in situ has been questioned, it has been demonstrated that a GT may actually improve the effectiveness of cricoid pressure by "occupying the portion of the upper esophageal sphincter that is not compressed by cricoid pressure."[4] Rice et al.[5] demonstrated in magnetic resonance imaging studies of volunteers that cricoid pressure occludes the distal hypopharynx rather than the esophagus itself. Due to the relatively rare occurrence of clinically significant pulmonary aspiration and a variety

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of ethical concerns, it seems unlikely that prospective, randomized clinical trials examining the success of cricoid pressure in preventing aspiration will ever be undertaken. Similarly, defending the omission of the cricoid pressure maneuver during RSII of high-risk patients given the widespread adoption of this procedure may be untenable. As Loganathan and Liu[4] suggest, future research and teaching should be focused on improving the quality of cricoid pressure and when to release or avoid using this maneuver altogether.

A key feature of this review is a proposed algorithm to guide the use of GTs in adult patients at high risk of aspiration. While sections of the proposed algorithm are helpful for the patient population for which it is intended, to be clear there are situations in which the patient remains at continued risk for aspiration. Under the heading of "Gastric Distension," the algorithm states if there is no NGT in place and there is severe gastric distension, the provider should proceed with placement of the NGT before induction of anesthesia. If there are gastric contents present, aspiration is still a risk for the patient even though they are awake during the GT placement. In the discussion of management of Zenker diverticulum, the authors indicate, "Regardless of the anesthetic choice, straining, gagging, or coughing should be avoided because they may provoke regurgitation." In any awake patient, straining, gagging, or coughing are possible with resultant regurgitation and aspiration, even with protective airway reflexes intact. Are we therefore potentially increasing the risk of aspiration by placing NGTs in awake patients? More research in this area of NGT placement would be beneficial as the evidence supporting current practice is lacking.

The authors advocate insertion of a GT before induction of anesthesia in patients at risk of aspiration, and they note that the NGT can create difficulty with mask ventilation once anesthesia is induced, but there is no explanation of how to proceed if this occurs. A proposed addition to the algorithm would be a section addressing the patient who is difficult to mask with an NGT in place. Do we continue to struggle and allow the patient to become hypoxic and hypercarbic, or do we remove the GT and potentially increase the risk of aspiration?

Although the algorithm is intended to apply to adults, what about the 4- or 5-year-old children who would require gastric emptying with an NGT placed before induction? This is often difficult to accomplish without some degree of sedation, which is what the clinician tries to avoid in patients at risk of aspiration without a GT in situ. Performing an awake intubation in school-aged children who meet the criteria in the proposed adult algorithm without traumatizing the child is an extreme challenge. Clinical guidance for GT management in pediatric patients at risk of aspiration would be helpful either in the form of an addition to the proposed algorithm or a separate algorithm for children.

The pediatric patient considerations section is an excellent overview of 3 specific conditions in which patients are at an increased risk of aspiration during induction of anesthesia. Among pediatric patients, neonates may most readily tolerate the NGT that is placed while awake without sedation. The authors note that pulmonary complications have been virtually eliminated with routine gastric emptying before induction of anesthesia in patients undergoing repair of congenital pyloric stenosis. They then describe airway management of patients with tracheoesophageal fistula or who undergo surgical antireflux procedures such as the fundoplication of Nissen, which are all conditions commonly encountered in neonates. There is no discussion regarding children or adolescents who are at risk of aspiration and how these patients are best managed. Would it be appropriate to use the algorithm written for adults in these older children?

A recent literature review on airway management safety includes a section specifically addressing "aspiration of gastric contents." This review indicates that aspiration is the most common cause of death associated with airway management during anesthesia, accounting for 50% of anesthesia deaths.[6] One of the factors leading to this is the failure to use tracheal intubation or RSII in patients with intestinal obstruction. Rather than to have 2 separate, very important algorithms to follow and possibly complicate emergent situations, perhaps the recommended use of GTs should be incorporated into broader airway management algorithms.

There are other questions that focused investigations or a broader review of GTs might address in greater detail. What are the relative merits of OGTs versus NGTs? Which maneuvers are actually effective in facilitating successful passage of a GT? It would be the rare anesthesia provider who has not encountered difficulty with satisfactory insertion of a GT via either the nasal or oral routes in some patients. As the authors of the review point out, adjusting the relative positions of the patient's head and neck (usually by flexing the neck), decreasing the volume of air in a cuffed endotracheal tube (if present), and the use of direct laryngoscopy and Magill forceps are all maneuvers that may be used to facilitate appropriate positioning of a GT. What is the reliability of various techniques that are used to verify proper placement of a GT? Auscultation of the left upper abdomen as air or isotonic fluid is injected through the GT is commonly performed, with unproven accuracy and reliability. In abdominal procedures, the GT may be palpated or visualized in the stomach by the surgeon. In cases where radiography of the abdomen is performed, the radiopaque GT can be visualized in the esophagus and stomach. How are GTs most effectively secured? How effective (if at all) are various other types of tubes such as respiratory suction catheters or feeding tubes in suctioning and emptying the stomach? During the course of anesthesia and surgery, and particularly before extubation at emergence, it is common practice for the anesthesia provider to pass a single-orifice suction catheter into the esophagus and stomach that is intended for oral or endotracheal tube suctioning. Is this effective in emptying the stomach of gas and/or liquid gastric contents? What changes in patient position before or during gastric suctioning are effective in improving the efficacy of this maneuver? What are the incidences and proper management of complications associated with GT insertion and use in the perioperative period? When should an indwelling NGT or OGT be considered for conversion to a longer-term surgical gastrostomy tube? Clearly, these and other questions call for more studies and additional comprehensive and detailed reviews of GT use.

The article by Salem et al.[3] provides a useful and focused review of existing medical literature and practice concerning a commonly used implement, the GT, that is occasionally mentioned but seldom thoroughly discussed in professional anesthesia journals and textbooks. The purpose of our editorial is therefore an attempt to underscore the areas in which we have little or no good clinical outcome data and perhaps encourage scientific discovery. For instance, the proposed algorithm for GT use in adults is a helpful start, yet appropriate guidance for pediatric patients of all ages is still required. There is a considerable number of remaining questions regarding GT use that merit further study and detail, and we applaud the authors for getting this initial discussion started.

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REVIEW ARTICLE

CME

Gastric Tubes and Airway Management in Patients at Risk of Aspiration: History, Current Concepts, and Proposal of an Algorithm

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Rapid sequence induction and intubation (RSII) and awake tracheal intubation are commonly used anesthetic techniques in patients at risk of pulmonary aspiration of gastric or esophageal contents. Some of these patients may have a gastric tube (GT) placed preoperatively. Currently, there are no guidelines regarding which patient should have a GT placed before anesthetic induction. Furthermore, clinicians are not in agreement as to whether to keep a GT in situ, or to partially or completely withdraw it before anesthetic induction. In this review we provide a historical perspective of the use of GTs during anesthetic induction in patients at risk of pulmonary aspiration. Before the introduction of cricoid pressure (CP) in 1961, various techniques were used including RSII combined with a head-up tilt. Sellick initially recommended the withdrawal of the GT before anesthetic induction. He hypothesized that a GT increases the risk of regurgitation and interferes with the compression of the upper esophagus during CP. He later modified his view and emphasized the safety of CP in the presence of a GT. Despite subsequent studies supporting the effectiveness of CP in occluding the esophagus around a GT, Sellick's early view has been perpetuated by investigators who recommend partial or complete withdrawal of the GT. On the basis of available information, we have formulated an algorithm for airway management in patients at risk of aspiration of gastric or esophageal contents. The approach in an individual patient depends on: the procedure; type and severity of the underlying pathology; state of consciousness; likelihood of difficult airway; whether or not the GT is in place; contraindications to the use of RSII or CP. The algorithm calls for the preanesthetic use of a large-bore GT to remove undigested food particles and awake intubation in patients with achalasia, and emptying the pouch by external pressure and avoidance of a GT in patients with Zenker diverticulum. It also stipulates that in patients with gastric distension without predictable airway difficulties, a clinical and imaging assessment will determine the need for a GT and in severe cases an attempt to insert a GT should be made. In the latter cases, the success of placement will indicate whether to use RSII or awake intubation. The GT should not be withdrawn and should be connected to suction during induction. Airway management and the use of GTs in the surgical correction of certain gastrointestinal anomalies in infants and children are discussed. (Anesth Analg 2014;118:569–79)

Rapid sequence induction and intubation (RSII) and awake tracheal intubation are commonly chosen anesthetic techniques for the management of patients at risk of aspiration of gastric or esophageal contents. Because of the associated pathological condition, some of these patients may have a gastric tube (GT), usually a nasogastric tube (NGT), placed preoperatively. There are no clinical guidelines regarding which patient should have a GT placed before anesthetic induction. Furthermore, clinicians are not in agreement whether to keep the GT in situ, withdraw it to the esophagus, or remove it completely before induction of anesthesia.[1–3] Surveys and several reviews related to RSII have not addressed issues related to GTs.[4–7] We used PubMed/MEDLINE to search the English literature up to September 2012 for articles containing the following key words: "gastric tubes" and "anesthetic induction"; "gastric tubes" and "general anesthesia"; "gastric tubes" and "rapid sequence induction"; "pulmonary aspiration" and "anesthetic induction." We could not find any randomized clinical trials that addressed the questions of when GT placement should be performed or how to manage a previously placed GT during anesthetic induction. There were 3 prospective clinical trials that investigated the incidence of gastroesophageal (GE) reflux with GTs in trauma patients undergoing general anesthesia,[8] in volunteers,[9] and in patients undergoing elective abdominal laparotomy.[10]

This review will discuss the history of GTs and their use during induction of anesthesia in patients at risk of

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pulmonary aspiration. Given the paucity of hard clinical data, some literature discussed and recommendations made in this review are based on various authors' clinical experiences. On the basis of available information, an algorithm for the airway management in patients at risk of aspiration due to the presence of esophageal lesions, GE reflux, or gastric distension will be presented to aid in decision making regarding the use of a GT. The Discussion will also address special situations in pediatric patients.

HISTORICAL PERSPECTIVE

Gastric Tubes

The first account of placement of a GT in humans is credited to Aquapendente in the 17th century, who used a silver tube for the sole purpose of feeding. Other sources contend that it was Hunter in the 1790s who successfully fed a patient via a hollow leather tube made of eel skin that had been stretched over whale bone.[11–14] The use of a tube as a "stomach pump" for washing out stomach contents of poisoned patients was described in the 1800s. In 1921, the Levin single-lumen rubber tube was introduced for gastric decompression and feeding. In 1934, Miller and Abbott introduced an extended balloon-tipped intestinal 2-lumen tube, with one tube having a rubber balloon at its tip and the other tube with holes near its tip.[11–14] The problems associated with the use of rubber tubes, including difficulty in insertion, frequent obstruction, and allergy, eventually led to the development of tubes made of plastic in the 1950s, first polyethylene, then polyvinyl and silicone, and finally polyurethane. The Salem-Sump tube introduced in the 1960s is a 2-lumen tube: a drainage lumen and a smaller secondary lumen that is open to the atmosphere to allow air to be drawn into the stomach and prevent the suction seal effect on gastric mucosa during suctioning.[11–14]

A vast array of GTs are currently available with different lengths, sizes, pliability, and special purposes. The radiopaque marker offers the advantage of radiographic localization. Typically, sizes 14 to 20 F are used in adults, whereas smaller sizes are used in infants and children. Large sizes are available for special uses. For example, laparoscopic gastric plication or its modifications, for the surgical treatment of morbid obesity, require the placement of a large GT or a bougie. Sizes varying between 32 and 36 F are used for this purpose.[15]

The route of insertion of the GT, nasal or oral, depends on many factors. These include whether its use is limited to the intraoperative period or extends to the pre- and postoperative periods; whether the patient is alert or unconscious, whether the patient is tracheally intubated before GT insertion, or whether there is nasopharyngeal pathology or trauma.[11–16] The route chosen for the GT placement also depends on the size selected, and the relative risks associated with each route.

The indications for the placement of GTs are in 2 categories: diagnostic and therapeutic. Diagnostic indications include: detecting gastrointestinal (GI) hemorrhage, testing for ingested toxins, obtaining culture specimens, measuring gastric pH and volume, monitoring drainage, and identifying esophagus, stomach, and associated pathology on a chest radiograph.[11–16] Therapeutic uses include: feeding, drug administration, lavage of hemorrhage, treatment of hypothermia, and evacuation of contents after drug overdose. GTs are commonly placed to remove gastric and esophageal contents, reduce the risk of aspiration, decrease postoperative vomiting, prevent and treat postoperative gastric dilation and paralytic ileus, relieve symptoms of bowel obstruction, avoid stomach injury during laparoscopy, and improve ventilation.[11–18]

With the development of the laryngeal mask airway (LMA), the problem of malpositioning of the LMA cuff became recognized. Some newer types of LMAs incorporate a gastric port to separate the respiratory from the GI tract. Successful placement of a well-lubricated GT (up to 16 F) via the gastric port to the stomach accomplishes 2 functions: gastric access, and more importantly, facilitation of proper LMA positioning.[19]

Because it was believed that gastric distension can lead to pulmonary aspiration, anastomotic leak after GI procedures, and wound dehiscence, it has been common practice since the 1930s to decompress the stomach in patients undergoing abdominal surgery.[10] William W. Mayo once wrote "it is more important for a surgeon to carry a nasogastric tube than a stethoscope in his pocket"![20] Some studies supported the routine use of GTs for abdominal and other surgeries. A meta-analysis revealed more frequent abdominal distension and vomiting in patients without GTs.[21] Another randomized controlled trial found that the prevalence of vomiting was reduced after cardiac surgery in patients who had GTs as compared with patients without GTs (10% vs 24%).[22] Conversely, 1 study suggested that early GT removal after cystectomy with urinary diversion is not correlated with the occurrence of ileus.[23] There has been concern that GTs can cause GE reflux. Some studies showed that GTs have no effect,[9] whereas others showed a decrease[8] or an increase.[10]

With the common use of GTs, a plethora of complications emerged, varying in degrees from mild to severe.[12,13,20,24,25] Severe complications include: coughing and vomiting resulting in undesirable hemodynamic responses and pulmonary aspiration; knotting the GT around itself or around the endotracheal tube (ETT) or epiglottis, causing airway obstruction; tracheobronchial placement leading to severe hypoxemia; airway, esophageal, gastric, pulmonary and mediastinal bleeding, ulcerations, and perforations; intracranial and middle ear placement; and injuries to ophthalmic arteries. Because of these adverse effects, the decision to place a GT in abdominal cases should be made on a selective rather than routine basis.[10,26,27] It is beyond the scope of this review to provide a comprehensive discussion of the various uses of GTs (and esophageal bougies) and the complications arising from their use. The reader is referred to alternate sources that address these topics.

Pre-Sellick Era

Before Sellick described the cricoid pressure (CP) maneuver in 1961,[28] several techniques were used to minimize the potential for pulmonary aspiration of esophageal and gastric contents, such as:[29–36] regional (and spinal) anesthesia; awake tracheal intubation; induced hyperventilation; IV induction of anesthesia (thiopental) followed by or combined with a muscle relaxant, while the patient was positioned in a 40° head-up tilt. Each of these techniques had its advantages and drawbacks. The use of high spinal anesthesia did not prevent pulmonary aspiration, especially in heavily sedated patients.[29,30,33,34] This risk was further

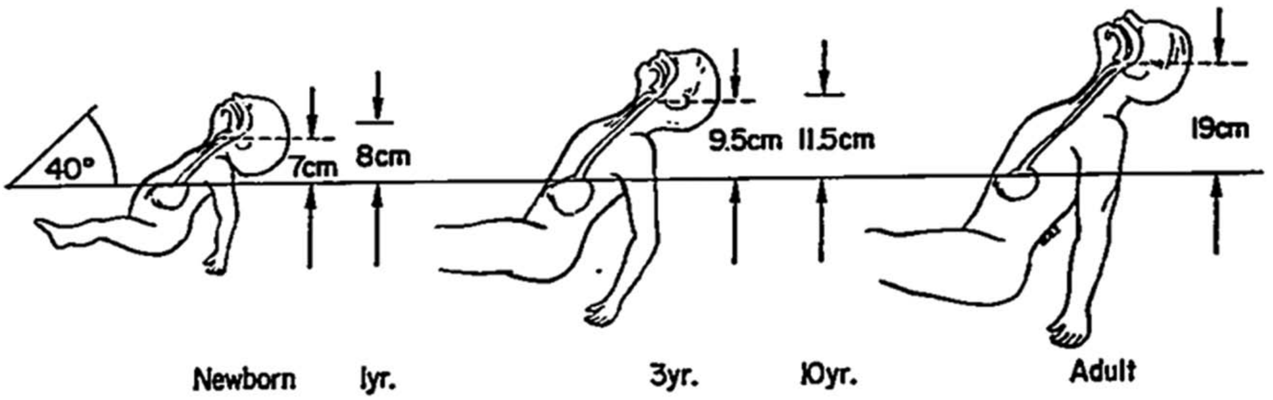

Figure 1. Distance of the larynx above the cardia with 40° head-up tilts in infants, children, and adults. On the basis of a larynx–cardia distance of about 27 cm in the adult and a 10° inclination of this line to the vertical axis of the body, a 40° head-up tilt raises the adult larynx 19 cm above the gastroesophageal junction. Corresponding figures at different ages were calculated. Placing infants and children in 40° head-up tilts fails to raise the larynx sufficiently to overcome increased intragastric pressure. Reproduced with permission from Salem et al.[1]

enhanced by the increased gastric motility induced by sympathetic block.[29,30,33,34] Furthermore, hypoventilation occasionally occurred, requiring assisted ventilation.

Both "awake" oral tracheal intubation, by direct laryngoscopy and "awake" blind nasal intubation were commonly practiced in patients at risk of aspiration.[30,31] Tracheal intubation was performed after topical anesthesia or nerve blocks, while the patient was breathing spontaneously.[30–32] The rationale for induced hyperventilation during inhaled induction was to prevent breath-holding, a prerequisite for active vomiting.[33,34] In this technique, hyperventilation was provoked early and rapidly with carbon dioxide, unconsciousness was quickly obtained, and intubation was performed in an unhurried manner, while spontaneous breathing was preserved.[33,34] It was also believed that the antireflux mechanism at the GE junction was intensified with deep inspiration.[33,34]

The basis for IV induction of anesthesia combined with the use of a muscle relaxant in the head-up tilt "or sitting position" was the finding that the maximal intragastric pressure (IGP) in an anesthetized and paralyzed individual is 18 cm H_2O.[37,a] Because positioning an average-height adult patient in a 40° head-up tilt raises the larynx 19 cm above the GE junction[1,29,35–38] (Fig. 1), it was theorized that in this position, gastric contents could not reach the laryngeal level, even if the contents were forced into the esophagus.[1,29,35–38] This technique, described by Morton and Wylie in 1951[35] and by Snow and Nunn in 1959,[36] differed only slightly from the currently used RSII in that the head-up tilt (or foot-down tilt) was used instead of CP.

Delaying surgery, removal of gastric contents by a wide-bore GT, and the use of emetics such as apomorphine before anesthetic induction, were all practiced at that time.[29] Because of its side effects, the use of apomorphine was quickly abandoned. It was realized that in cases of GI obstruction, the stomach may continue to fill, having once been emptied, and it was necessary to ensure that removal of gastric contents continued up to and during anesthetic induction.[28,29,33–36] The use of GTs was common in patients likely to have a distended stomach.[33–36] In fact, the lack of complications from vomiting and regurgitation in the series reported by Hodges and Tunstall,[39] and Snow and Nunn[36] was attributed to the use of GTs. The GTs were kept in place during anesthetic induction. Preoperative placement of a GT was done routinely for surgical emergencies but was not considered acceptable for women in labor.[28,33,36,39]

Investigators attempted to prevent regurgitation by using a cuffed GT and inflating the cuff at the GE junction.[40,41] However, this technique was found to be unsafe because of the difficulty in maintaining a reasonable seal by inflating the cuff without producing esophageal damage.[1,40,41] When vomiting occurred, the increase in the esophageal diameter rendered the seal less efficient and the cuff became dislodged.[1,40,41] A newly improved GT with an inflatable balloon to occlude the cardia was introduced.[42] Despite the inventor's enthusiasm, the use of the device never gained popularity.

The Cricoid Pressure Maneuver

In 1961, Sellick introduced CP "to control regurgitation of gastric or esophageal contents until intubation with a cuffed endotracheal tube was completed."[28] The maneuver consisted of "occlusion of the upper esophagus by backward pressure on the cricoid cartilage (CC)." He demonstrated that CP obliterated the esophageal lumen at the level of the 5th cervical vertebra after the lumen had been distended by soft latex tubing filled with contrast medium to a pressure of 100 cm H_2O.[28]

Because Sellick's maneuver was designed for patients at risk of aspiration, many of his patients had NGTs placed before anesthetic induction. Sellick stressed that "all reasonable steps should be taken to empty the stomach and esophagus before anesthesia is induced, but it is dangerous to assume that the stomach can be completely emptied by means of the Ryle's tube (NGT)."[28] In his first publication, he wrote "after final aspiration, the Ryle's tube should be withdrawn." He hypothesized that by "tripping the sphincters at the upper and lower end of the esophagus, a NGT increases the risk of regurgitation, and interferes with the compression of the upper esophagus." The NGT was then replaced after intubation and the stomach drained before the end of the operation.[28] After gaining experience with CP, Sellick modified his view regarding the necessity for withdrawal of the NGT immediately before anesthetic induction.[43] In a second publication and in a personal correspondence to 1 of

[a] 1 cm H_2O = 0.735 mm Hg

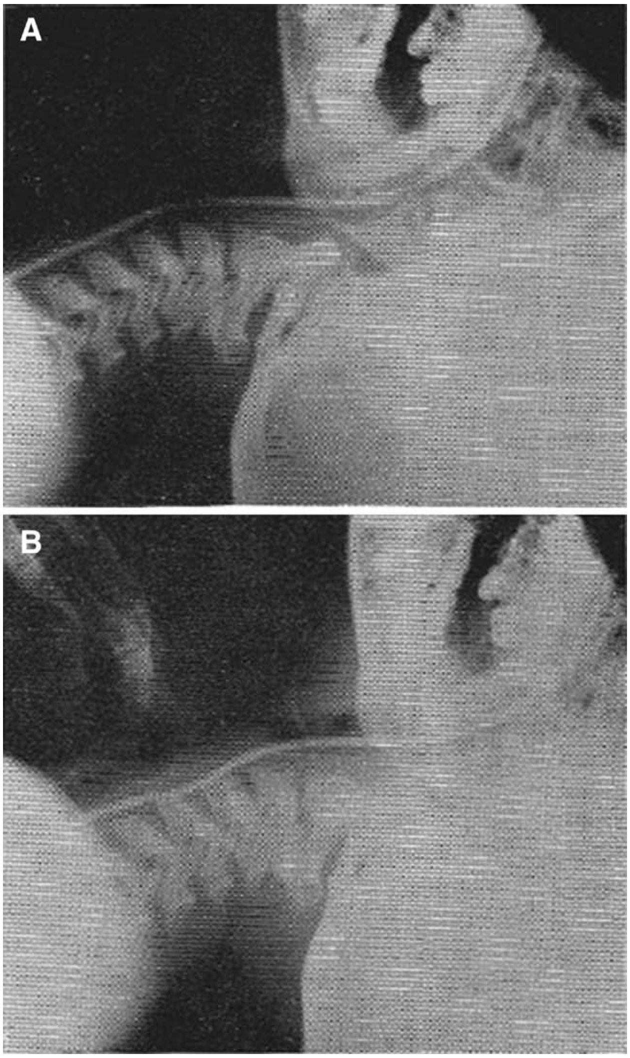

Figure 2. A, Radiograph of an anesthetized 5-year-old child showing a nasogastric tube in place. The tube was previously filled with contrast material and tied at both ends. B, Cricoid pressure did not result in occlusion of the nasogastric tube. Reproduced with permission from Salem et al.[53]

the authors (MRS), he emphasized "the safety of CP in the presence of a NGT," as had been demonstrated in a patient undergoing esophagogastrectomy.[43]

Post-Sellick Era

Sellick's maneuver was met with an enthusiastic reception, and rapidly became an integral component of the RSII.[1,7,29,44] The new RSII with CP was extended not only to emergency surgical and obstetrical procedures and the critical care setting, but also to elective procedures in adult and pediatric patients at risk of aspiration.[1,7,29,44] The wide acceptance of CP was primarily because it had overcome the disadvantages of the head-up tilt.[1,28,29,45] First, IGPs higher than 20 cm H_2O were observed in patients with gastric distension,[46] and in these patients, a 40° head-up tilt did not consistently prevent gastric and esophageal contents from reaching the pharynx. Second, once gastric contents reached the pharynx during head-up tilt, aspiration was likely.[1,28,29] Third, head-up tilt was undesirable in hypovolemic patients.[28] Fourth, head-up tilt may not be effective in children.[1] Because of their short esophagus, the placement of children in a 40° head-up tilt does not raise the larynx sufficiently above the GE junction so as to overcome increases in IGP[1] (Fig. 1). Furthermore, resting IGP may be higher in anesthetized children than it is in adults due to the relatively small size of the stomach, encroachment of abdominal organs, excessive air swallowing during crying, and strenuous diaphragmatic activity during spontaneous breathing.[1]

In the past 2 decades, clinicians have questioned the effectiveness of CP and therefore its necessity.[47–51] A few suggested abandoning the maneuver on the following grounds: (a) Its effectiveness has been demonstrated mostly in cadavers[52–54] and therefore the maneuver lacks scientific validation;[47] (b) because the esophagus is not exactly posterior to the CC, CP is unreliable in producing midline upper esophageal compression;[55] (c) CP induces reflex relaxation of the lower esophageal sphincter (LES);[56,57] (d) there have been reports of pulmonary aspiration despite the application of CP;[58] (e) CP can initiate nausea and vomiting, and although very rare, esophageal rupture was reported;[45,59] and (f) it can make tracheal intubation, mask ventilation, and LMA placement difficult or impossible.[60–64]

In his original studies, Sellick used soft latex tubes, which required only slight pressure to be occluded,[28] whereas in later studies NGTs made of polyvinyl chloride were used.[53,54] Polyvinyl chloride NGTs are too firm to be occluded by CP (Fig. 2). Studies in infant and adult cadavers demonstrated the effectiveness of CP in sealing the esophagus around the NGT.[53,54] These findings suggest that an NGT need not be removed before anesthetic induction. If a sudden increase in IGP occurs, the open NGT allows release of gastric contents, while CP prevents these contents from reaching the pharynx.

In 1993, Vanner and Pryle[65] shed new light on the effectiveness of CP in the presence of an NGT. They hypothesized that a 30 N force applied to the CC should provide a pressure in excess of 200 mm Hg below the 10 cm^2 area of the lamina of the CC (30,000 N/m^2 = 30 kPa). However, in practice they found that a 30 N force allows regurgitation of esophageal fluid at a pressure exceeding 40 mm Hg.[59] This is because the pressure generated posterior to the CC is not evenly distributed, with some parts only receiving 40 mm Hg pressure.

The anatomy of the area where CP is applied may provide an explanation for this finding. Figure 3 shows computerized tomographic scans at the level of the CC of a male subject with an NGT (filled with contrast) in place first without CP (Fig. 3A) and then with CP (Fig. 3B). When the 2 convex structures of the CC and the cervical body are pressed together, only a part of the alimentary tract lumen can be compressed between them. Slight lateral movement of the CC occurs, which allows the rest of the lumen to be pressed against the longus colli muscle on the side of the vertebral body. The NGT is squeezed sideways to occupy that part of the lumen that is relatively less compressed. These observations suggest that the presence of an NGT does not interfere with compression of the upper esophagus during CP and may actually improve it. In a cadaver study, using measured values of cricoid force, the same authors found that the presence of an NGT increases, rather than decreases, the efficacy of CP.[59]

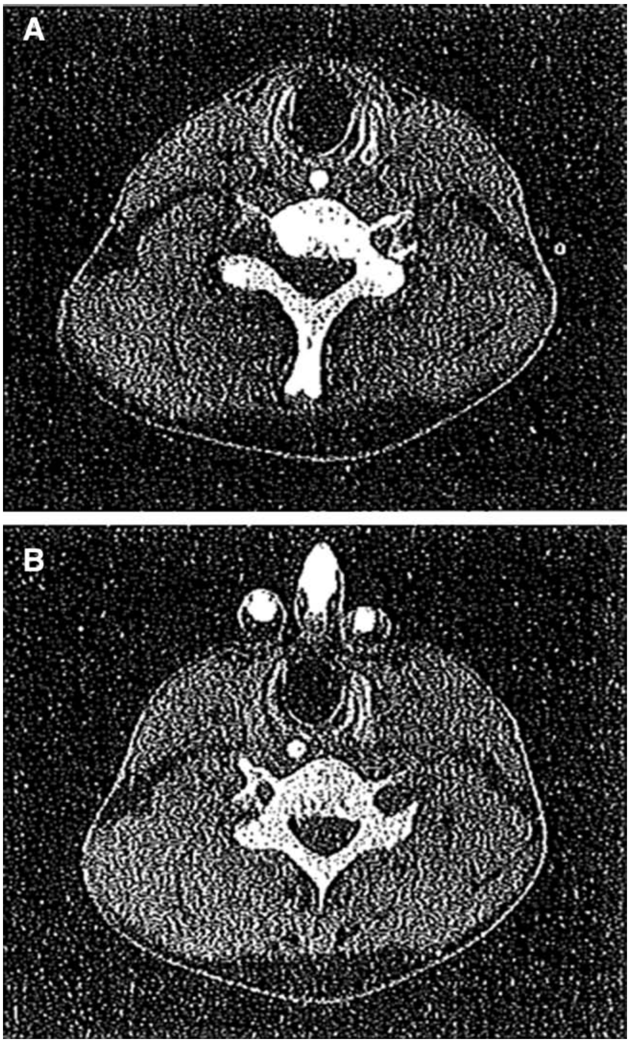

Figure 3. See text for details. Reproduced with permission from Vanner and Pryle.[65]

Despite the aforementioned evidence supporting the effectiveness of CP in occluding the esophagus around the NGT, Sellick's early view on the withdrawal of the NGT has been perpetuated by some investigators. In 1991, removal of the NGT before induction was recommended on the basis that the "presence of a NGT disrupts the esophageal sphincters, and serves as a wick for regurgitation."[2] In their recommendations relating to the use of CP during RSII, Brimacombe and Berry,[3] in 1997, proposed the withdrawal of the NGT into the esophagus, aspirating the NGT, and leaving it open to air. This suggestion was apparently based on the assumption that the presence of the NGT interferes with the competency of the LES.

AIRWAY MANAGEMENT IN PATIENTS AT RISK OF ASPIRATION AND ROLE OF GASTRIC TUBES: CURRENT CONCEPTS

General Measures

The anesthetic induction technique depends on many factors including: operative procedure; type and severity of the esophageal or GI pathology; state of consciousness; potential for difficult intubation and difficult mask ventilation; whether the NGT is in place; associated medical conditions; the presence of possible contraindications to the use of RSII or CP.[1,7,29,33,34,44,66] On the basis of available information, we propose an algorithm for the airway management in patients with esophageal lesions, GE reflux, and gastric distension (Fig. 4). In the algorithm, guidelines for the use of GTs are also addressed.

Maximal oxygen administration before anesthetic induction is essential in patients at risk of aspiration.[67] In most patients, tidal volume breathing for 3 minutes or deep breathing for 1.5 minutes is effective in achieving maximal oxygenation. The presence of an NGT can cause leaks between the face mask and the patient's face, resulting in air entrainment and lower inspired oxygen concentration,[67] which may not be fully compensated for by increasing the fresh gas flow or the duration of oxygen administration. The end point of maximal oxygen administration is an end-tidal oxygen concentration ≥90%.[67] In patients who are difficult to intubate or ventilate, pharyngeal oxygen insufflation (or tracheal, in case of upper airway obstruction) after oxygen administration may provide at least an additional 10 minutes of adequate oxygenation during apnea for laryngoscopy and tracheal intubation.[67] This apneic mass movement oxygenation can be accomplished through a nasopharyngeal or oropharyngeal cannula, via a laryngoscope, or through a needle inserted in the cricothyroid or cricotracheal membrane.[67] Mask oxygen administration should also precede awake fiberoptic intubation and be continued via a nasal cannula or a catheter placed in the mouth. Oxygen insufflation at 3 to 5 L/min via the fiberoptic scope working channel has the benefit of delivering oxygen, clearing secretions, and preventing fogging.[68] However, this technique should be used cautiously. Squeezing of the fiberoptic scope by airway obstruction can limit the egress of gases and result in barotrauma especially in children with narrow airways.[68]

In a comatose patient, the trachea may be intubated before the anesthetic is administered. The associated medical conditions may demand the use of prophylactic measures. In hypovolemic subjects, correction of fluid deficits should be accomplished beforehand, if possible.[33,34] The induction technique may be tailored to attenuate sympathetically induced hemodynamic effects of tracheal intubation, especially in hypertensive patients.[69] When difficulty with tracheal intubation or mask ventilation is anticipated, awake fiberoptic intubation rather than RSII should be planned.[2,7,66] In patients with an unstable cervical spine, where neck manipulation may result in further injury, awake fiberoptic intubation should be considered.[2] CP may be contraindicated in the following conditions: retropharyngeal abscess (because of the possibility of rupture of the abscess); a foreign body in the upper esophagus; or laryngeal trauma and cervical spine injury. In these situations, head-up tilt may be used instead of CP.[1,7,45,48] Studies reported cervical spine movements varying from minimal to significant with CP.[70–73] One study questioned the clinical relevance of any movements by retrospectively analyzing patients who had cervical spine injuries, and found no neurologic sequelae.[70]

Specific Measures

Esophageal Lesions

Zenker diverticulum is an outpouching of the mucosa, which develops in the weak area (Killian dehiscence)

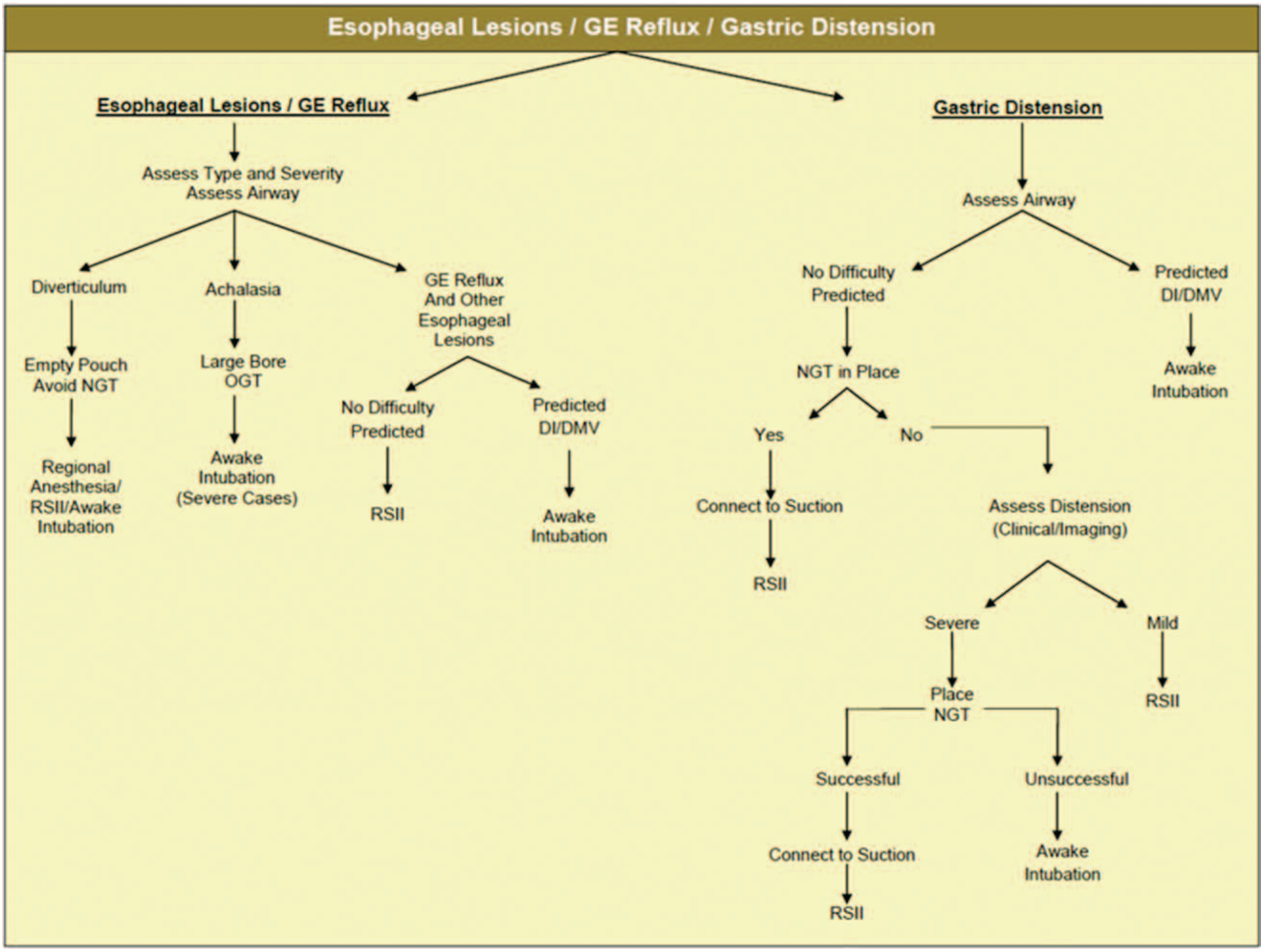

Figure 4. Proposed algorithm for the anesthetic induction and tracheal intubation in adult patients with esophageal lesions, gastroesophageal (GE) reflux, and gastric distension and for decision making in using a nasogastric tube (NGT) or an orogastric tube (OGT). Components of rapid sequence induction intubation (RSII) include: oxygen administration, IV induction, complete muscular relaxation, cricoid pressure, and tracheal intubation. Awake intubation is fiberoptic-aided intubation or tracheal intubation by direct laryngoscopy. If difficult intubation (DI) is encountered, proceed to the ASA difficult airway algorithm. DMV = difficult mask ventilation.

between the thyropharyngeus and cricopharyngeus muscles.[74] Compressible swelling develops as the sac enlarges. Regurgitation of material from the pouch may occur during anesthetic induction, intubation, or even after intubation due to seepage of fluid around the tracheal tube cuff during surgical manipulation.[75–78] Emptying of the pouch by the patient exerting external pressure before anesthetic induction is encouraged.[75–78] The effectiveness of CP depends on the location of the body of the sac in relation to the CC.[75] If the sac is small, the body of the pouch will be at the level of the CC; in such a case, CP will compress the body of the pouch, spilling the contents into the pharynx. If the sac is large, the neck of the pouch will be posterior to the CC, and CP will not empty the contents of the pouch into the pharynx.[75] Review of the barium swallow is helpful in determining whether CP should be used if RSII is chosen.[75]

Various anesthetic regimens including regional anesthesia, awake tracheal intubation, and RSII with CP or head-up tilt have been used successfully for surgical repair of the diverticulum.[75,78] Deep and superficial cervical plexus blocks without complications have been reported in a series of 58 patients.[78] Regardless of the anesthetic choice, straining, gagging, or coughing should be avoided because they may cause external pressure to the pouch and provoke regurgitation.[78] The tracheal tube cuff should be immediately inflated so as to prevent seepage of fluid around the cuff. Insertion of a GT should be avoided because it can cause perforation of the diverticulum.[75–77] If placement of a GT is necessary, caution must be exercised.

Achalasia is an idiopathic disorder of the esophagus characterized by impaired relaxation of the LES and esophageal aperistalsis resulting in esophageal dilation, and retention of undigested food mixed with air.[79] Food particles may remain in the dilated esophagus for many hours or days regardless of the duration of fasting. This can result in regurgitation, aspiration, respiratory infections, upper respiratory obstruction, tracheal compression, and sudden obstruction of the tracheal tube during anesthesia.[79–83] Treatments include endoscopic pneumatic dilation of the LES, surgical myomectomy, and botulinum toxin injection.[79] Nitrates can cause transient relaxation of the LES and decompression of the esophageal dilation.[82] Removal of material from the dilated esophagus by a wide-bore orogastric tube may lead to prompt resolution of symptoms.[81]

The insertion of a large-bore orogastric tube is advisable before proceeding with the anesthetic, even if it may not be completely effective in removing all food particles.[80,81,83] Although we have used RSII in patients with achalasia, awake intubation may be preferable in severe cases.

Gastroesophageal Reflux

For pulmonary aspiration to occur, gastric contents must flow to the esophagus (GE reflux), the contents must reach the pharynx (esophagopharyngeal reflux), and the laryngeal reflexes must be obtunded.[16,29,84] Two lines of defense prevent gastric contents from reaching the pharynx, the first at the GE junction, and the second at the upper esophageal sphincter (UES).[85–91] Normally, the IGP is 10 to 15 cm H_2O higher than the esophageal pressure, which is subjected to the negative intrathoracic pressure.[84–86] If there were no mechanism to close the lumen between the 2 cavities, GE reflux would readily occur, especially if favored by gravity. Various "antireflux" mechanisms have been proposed, the most important is the tone of the LES, which maintains a pressure higher than the IGP.[84–86] It is the difference between the LES pressure and the IGP, "the barrier pressure," that determines whether regurgitation will occur. An increase in IGP or a decrease in LES tone will facilitate GE reflux.[84–86]

The IGP can increase secondary to an increase in intraabdominal pressure or when the normal capacity of the stomach (1.0–1.5 L in adults), which is determined by the compliance of the stomach and by the capacity of the abdominal cavity to accommodate the increased volume, is exceeded.[16] The tone of the LES is influenced by neural, hormonal, pharmacologic, and pathologic factors.[84–87] An increase in IGP (or intraabdominal pressure) is generally accompanied by an increase in LES pressure. This "adaptive" increase in LES tone occurs with increases in abdominal pressures up to 30 cm H_2O, and in normal individuals typically occurs with succinylcholine-induced fasciculations.[87] Because succinylcholine-induced increases in IGP are accompanied by disproportionate increases in LES pressure, GE reflux normally does not occur.[87] However, this phenomenon may be absent in some patients with GE reflux and gastric distension.[85] In these situations, a further increase in IGP may promote GE reflux. In patients with symptoms of GE reflux and symptomatic hiatus hernia, dysfunction of the LES results in a lower barrier pressure, allowing flow of gastric contents into the esophagus.[85] Pharmacologic approaches to promote gastric emptying, increase barrier pressure, and decrease or neutralize gastric acidity have gained popularity in the preanesthetic management of patients with GE reflux.[88,89] The reader is referred to other sources for more information on this subject. The value of routine use of GTs in patients with GE reflux has not been addressed in the literature.

Certain anesthetic complications or maneuvers can induce GE or esophagopharyngeal reflux. Airway obstruction may cause GE reflux by increasing the pleuroperitoneal pressure difference during strong respiratory efforts and by increasing the IGP due to overaction of the diaphr agm.[1,29,33,34,37] Positive pressure ventilation (in excess of 20 cm H_2O) before tracheal intubation may lead to intermittent opening of the UES and LES, resulting in gastric insufflation and a subsequent increase in IGP.[1,29,33,34,37] Normally, the UES tone creates a sphincteric pressure of about 38 mm Hg in awake subjects.[90,91] This tone is markedly decreased by muscle relaxants and induction drugs, with the exception of ketamine.[91] Relaxation of the UES or its mechanical stretching during intubation can facilitate the flow of esophageal contents, if present, to the pharynx.[90,91] It has been suggested that CP substitutes for the loss of the UES tone, which accompanies anesthetic induction and muscle relaxation.[45,90,91]

Gastric Distension

GI obstruction can be mechanical as in pyloric stenosis or functional as in ileus caused by peritonitis or trauma. Regardless of the cause, GI obstruction ultimately leads to gastric distension, which can cause an increased IGP, GE reflux, and vomiting.[1,16,29,33,34] The decision to insert an NGT before anesthetic induction depends on the degree of distension.[8,16,92,93] Assessment of the degree of gastric distension and bowel obstruction can be made from the clinical and imaging findings.[92,93] Bedside ultrasonographic assessment of the gastric antrum and body can provide quantitative information about the volume of the gastric contents as well as qualitative information regarding its nature (gas, fluid, or solid).[92] An estimated volume in excess of 200 to 300 mL in adults suggests the presence of severe distension and serves as an indication for placement of an NGT before anesthetic induction.[92,93]

Investigators have argued about whether gastric contents can be removed completely with a GT. Some investigators reported that the volume removed via a GT underestimates the true volume of gastric contents.[94] Others demonstrated that this method is a very reliable estimate of the total volume of gastric contents.[95] Obviously, many factors influence the success of blind gastric emptying.[16,94,95] These include size, type, and patency of the GT and its correct placement, position of the patient, use of external abdominal pressure, and consistency of contents. The use of a multiorifice, vented, large (18 F) GT is more effective than the use of a nonvented GT. Multiple distal openings ensure that nearly all gastric pouches are drained. Even if gastric suctioning does not guarantee complete emptying, it reduces the IGP, and the residual volume becomes clinically insignificant as an aspiration risk.[95]

Many measures have been proposed to facilitate proper GT placement, the application of which depends on whether the patient is awake or anesthetized and whether the GT is inserted nasally or orally.[12,13,20,b] These measures include selecting the proper size; generous lubrication; encouraging the awake patient to swallow during insertion; neck flexion or anterior displacement of the thyroid cartilage; advancing the GT along the posterior pharyngeal wall using fingers placed in the pharynx, stiffening the GT by chilling, using a stylet or a Fogarty catheter; guiding the GT through an esophageally placed uncuffed ETT; and advancing the GT under direct-vision laryngoscopy with or without the aid of a Magill forceps. Confirmation of proper GT placement is essential.[12,13,20,b] Radiologic verification is considered the "gold standard"; however, this may not be feasible.

[b]National Patient Safety Agency. Reducing harm caused by the misplacement of nasogastric feeding tubes; Patient Safety Alert 05; February 2005. Available at: www.nrls.npsa.nhs.uk/resources/?EntryId45=59794. Accessed December 18, 2012.

Although not as reliable, other approaches have been used. These include visual inspection and pH testing of aspirate; epigastric/left upper quadrant auscultation for a gurgling noise during air insufflation; manual palpation by the surgeon (intraoperatively); confirmation by direct laryngoscopy or fiberoptic bronchoscopy; and absence of carbon dioxide by capnograph (to exclude tracheal placement). Detection of carbon dioxide implies the presence of the unobstructed GT in the airway. In infants and young children, a GT can often be visually observed "rippling" along the inside of the left abdominal wall during insertion.

Attempts should be made to keep the IGP as low as possible until the time of anesthetic induction. The NGT should not be withdrawn and should be connected to suction during induction. Because the use of an NGT does not guarantee removal of all gastric contents, the anesthesiologist should proceed with the contingency that the stomach will not be completely empty.[16,21,29,33,34]

CONSIDERATIONS IN PEDIATRIC PATIENTS

The principles of airway management in adult patients at risk of aspiration are in large part applicable to the pediatric population. However, in infants, physiologic and anatomic factors as well as the presence of congenital anomalies present unique challenges to the anesthesiologist.[1,17,18] Infants typically have a mild form of relaxation of the LES, which can cause GE reflux during the first month of life. But in only 1 in 500 infants does GE reflux persist beyond 6 weeks of age.[1,17,18] The usual manifestations are recurrent regurgitation, apneic spells, paroxysmal coughing, reactive airway disease, pneumonia, and failure to thrive.[17,18] GE reflux may be present after repair of esophageal atresia and gastrostomy.[17,18] It also occurs in children with spastic quadriplegia, brain damage, and trisomy syndrome in which discoordinated breathing and swallowing are present.[17,18] GE reflux resulting in aspiration may occur in dyspneic infants, infants with a weak cough reflex, laryngeal malfunction, or vocal cord paralysis.[1] Patients who fail medical therapy or who have life-threatening diseases are candidates for esophageal fundoplication.[17,18]

Mask ventilation before intubation can result in gastric insufflation in infants and children, especially in the presence of airway obstruction or when airway pressure exceeds 20 cm H_2O.[96–98] Neuromuscular blockade causes paralysis of the UES and facilitates gastric insufflation at lower airway pressures.[98] Gastric inflation can impair ventilation, in addition to inducing GE reflux.[17,18] Decompression of the stomach after intubation can be achieved with a GT. A lubricated suction catheter may be used instead. In laparoscopic procedures, a GT is placed before cannulation of the abdomen to decompress the abdomen and to avoid gastric perforation.[17,18] The GT is usually removed before tracheal extubation.

Anesthetic management of 3 conditions in pediatric patients warrants discussion: congenital pyloric stenosis (CPS), esophageal atresia with tracheoesophageal fistula, and esophageal fundoplication. Since the surgical correction of CPS was attempted in the early 1900s, attention was drawn to the importance of preoperative gastric emptying to remove gastric contents, and barium used to confirm the diagnosis.[17,18,99–101] Palpation of the abdomen for the "pyloric tumor" with the stomach empty was also emphasized. Routine gastric emptying and improved anesthetic and surgical techniques virtually eliminated pulmonary complications.[17,18,100,101] By the mid 1970s, ultrasonography offered a safer diagnostic tool, and the concern about aspiration of barium has been eliminated. In many centers, laparoscopic surgery has replaced open methods for the treatment of CPS.[17,18]

In some countries, contrast media are still used to diagnose CPS. If this is done, only water-soluble contrast media should be used, and the stomach should be irrigated multiple times with warm saline while the patient is in the supine, lateral, and prone positions.[17,18] A thorough evacuation of stomach contents greatly reduces the chance of regurgitation during anesthetic induction, and the GT should be left in place during the surgical procedure. This allows the surgeon to test the integrity of the pyloric mucosa after pyloromyotomy. A small volume of air is injected through the GT and the surgeon directs the bubble into the duodenum, and then occludes the bowel lumen proximal and distal to the incision. Mucosal perforation is present if air leakage is detected. After carefully emptying the stomach, tracheal intubation can be performed after IV induction, inhaled induction, or while the patient is awake.[102,103] There is no evidence that one technique is safer than the other. Inhaled induction is being used in many centers.[100] Cook-Sather et al.[103] found that awake intubation is not superior to RSII for the management of CPS.

Esophageal atresia with distal tracheoesophageal fistula is, by far, the most common of the congenital esophageal anomalies.[104,105] The diagnosis is usually made after birth when a GT (or a suction catheter) cannot be passed into the stomach, but it may be delayed until feeding begins when choking and coughing occur.[105] The diagnosis is confirmed when a radiopaque catheter stops into the proximal esophageal segment at a distance of 10 ± 1 cm from the gumline, as seen in a chest film.[17,18] A small amount of contrast can be used to outline the proximal esophageal segment. The presence of intestinal air implies a distal tracheoesophageal fistula. Occasionally, massive abdominal distension occurs causing respiratory embarrassment.[17,18,104]

A GT is kept in place during the surgical procedure to identify the proximal pouch for the surgeon. Tracheal intubation can be performed after inhaled, IV induction, or rarely while the infant is awake.[104,105] Some anesthesiologists prefer intubation during spontaneous breathing, while others prefer intubation after muscle relaxation.[105] Severe gastric distension can occur after positive pressure ventilation, leading to cardiopulmonary arrest and gastric rupture.[104] Two approaches have been used to prevent this complication: positioning of the ETT in relation to the fistula and preoperative gastrostomy under local anesthesia.[104] Because the fistula is usually located just proximal to the carina, the ETT is advanced to the right main bronchus and then gradually withdrawn to a position above the carina where bilateral breath sounds can be auscultated.[105] Although gastrostomy can prevent gastric distension, it may provide a low-pressure escape route for gas, thereby increasing flow through the fistula, and compromising pulmonary ventilation.[105]

One strategy to solve this problem is to place a Fogarty balloon catheter through a bronchoscope into the fistula and then to occlude the fistula by inflating the balloon.[105] Another strategy is to insert, under fluoroscopic guidance, a Fogarty catheter retrogradely through the gastrostomy into the distal esophagus.[106]

The objective of the surgical antireflux procedures is to create an intraabdominal segment of esophagus and a physiologic angle of His.[17,18,107,108] The fundoplication of Nissen and the partial wrap of Thal-Nissen have been used. The Thal-Nissen partial wrap is more frequently used to avoid the gas bloat syndrome (gastric distension, aerophagia, and inability to belch or vomit).[108] Open and laparoscopic approaches have been used.[108] Preoperative use of H_2 blockers and motility drugs should be continued. These patients may come to the operating room with a GT in place. In children undergoing antireflux procedures, RSII is commonly used.[18] After intubation, the anesthesiologist should maintain access to the head so that the NGT and esophageal dilators can be adjusted without dislodging or obstructing the ETT.[17] Children who have severe respiratory compromise or neuromuscular disorders may require postoperative ventilatory support.[18]

CONCLUSION

Our review of the literature revealed an evolution in the use of GTs in patients at risk of pulmonary aspiration, especially after the introduction of CP into clinical practice. The current consensus is that a GT should not be withdrawn before anesthetic induction. On the basis of available information, we developed an algorithm to serve as a guide for the anesthetic induction and tracheal intubation in patients at risk of aspiration of esophageal and gastric contents. A variety of clinical scenarios were addressed, including Zenker diverticulum, esophageal achalasia, GE reflux, and gastric distension. This algorithm should be viewed as a basic framework, which can be amended and expanded to encompass new information and emerging approaches and strategies with demonstrated clinical effectiveness. Airway management and the use of GTs in the surgical correction of GI anomalies in infants and children are presented.

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