Chapter

Airway Management in Full Stomach Conditions

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Abstract

Pulmonary aspiration in the perioperative period is one of the well-known complications under anesthesia and procedural sedation. A full stomach condition either due to non-adherence to fasting guidelines or due to various other factors that delay gastric emptying are the most common causes. Following aspiration, a patient may develop a wide spectrum of clinical sequelae. The key factors in preventing aspiration include proper pre-operative assessment, appropriate premedication and operating room preparations. Rapid sequence induction and intubation is the recommended technique for securing the airway in cases of full stomach. Management of aspiration depends on the nature of the aspirate. Pre-operative fasting guidelines have been established by various medical societies which may be modified in special circumstances of high risk of aspiration. Prediction of difficult airway in certain cases of full stomach necessitates clinical expertise in airway management.

Keywords: pulmonary aspiration, full stomach, gastric volume, rapid sequence induction, negative pressure pulmonary edema

1. Introduction

Full stomach is a condition when a patient has ingested a certain amount of food or drink within a certain period prior to anesthetic induction or believed to have an anatomical, hormonal, metabolic or pathological condition that delays the gastric emptying. The amount of food or Full stomach poses a risk of pulmonary aspiration of gastric contents during the perioperative period more than if the patient had been fasting or definitive time has passed to allow the gastric emptying. Pulmonary aspiration poses a significant risk to each individual surgical patient, affecting the outcome of the surgical care and poses high costs for healthcare system. The incidence of pulmonary aspiration during anesthesia is around 1 in every 2000–3000 surgeries. The National Audit Project 4 (NAP4) by the Royal College of Anesthetists in the UK showed that aspiration was 23% among all reported cases to NAP4 either as a primary or secondary event. Unfortunately, more than 50% of the death related to anesthesia in NAP4 was because of aspiration [1].

2. History

The first case descriptions of aspiration under anesthesia had been reported in the late 19th century. In 1861, out of the first 51 reported cases that died under Chloroform, Dr. Sanom reported two cases died following sudden vomiting under anesthesia with an estimate of aspiration related mortality of 2%. In 1876 at the Guy's Hospital in UK, the first reported case of death related aspiration after recovery from anesthesia was reported, when a patient turned cyanotic after vomiting in the recovery area, later undigested meat was retrieved from the upper pharynx and trachea was full of vomitus. In U.S.A., the first case was reported in 1898, a 6-year-old boy who had his dinner 3.5 h before anesthesia, has died from aspiration in the recovery. The autopsy confirmed undigested spinach material in the main bronchus [2].

In the 50s of the twentieth century, the danger of a full stomach was realized based on high aspiration rate, but optimum fasting time was insufficiently recognized. The observational studies have found esophageal pooling of incomplete swallowing of fluid are very common under anesthesia. Aspiration risks were found in early 1950 to be high in hemorrhage, bowel obstruction, peritonitis and multiple abdominal surgeries, using of both narcotics and the belladonna alkaloids, and under obstetrics anesthesia, especially if pain and delivery are prolonged. In 1951, aspiration accounts for 4% of overall maternal death, and have reported that aspiration contributed to more than 50% of the mortality [3]. Surprisingly, the aspiration was not limited to inhalation anesthesia; but also, during spinal anesthesia. In 1946, Dr. Mendelson describes the relationship between aspiration of solid and liquid matter, and pulmonary sequelae in obstetric patients. Another tracer dye-based aspiration study 1950 by Dr. Weiss found the minor regurgitations were very common. Interestingly, the incidence rate of blue dye regurgitation was 26% in the pharynx, 16% in the bronchus as confirmed by bronchoscopy, but the frank vomiting occurred in only 8% [4].

Out of the historical recommendations were stomach decompression by a stomach tube pre induction, hyperventilation, head-up position during induction and recovery in lateral position, but no reliable and safe method has been recommended. Sellick's technique of cricoid pressure was introduced in 1961 to prevent regurgitation and aspiration during induction.

3. Physiology of regurgitation and aspiration

The physiological mechanisms preventing gastric content from regurgitation and aspiration are **lower esophageal sphincter, upper esophageal sphincter** and **protective airway reflex.**

Upper esophageal sphincter is the cricopharyngeal muscle acting on the transition zone between esophagus and hypopharynx. **Lower esophageal sphincter (LES)** is composed of circular muscle fiber at the junction of esophagus and stomach, acting as a true sphincter. The difference between Lower esophageal pressure (LOP) and gastric pressure is called the esophageal barrier pressure. Intragastric pressure is less than 7 mmHg, LOP in conscious patient is 15–25 mmHg higher than intragastric pressure. An incompetent LOS reduces barrier pressure and increase the risk of regurgitation. When esophageal pressure equals intragastric pressure, this will lead to a common cavity which in turn causes spontaneous gastroesophageal reflex. LOP decreases during peristalsis, vomiting, pregnancy and various drugs for instance anticholinergic, inhalational anesthetics, Thiopentone and opioids. Intragastric pressure increases if gastric volume is more than 1000 ml and with raised intra-abdominal pressure. Gastric volume is influenced by the rate of gastric secretion; approximately 0.6 ml/kg/h, swallowing of saliva 1 ml/kg/h, ingestion of solid and food and the rate of gastric emptying. LES can be affected by food as (Chocolate, Ethanol and Caffeine), hormones (as Progesterone, Glucagon, Secretin, Cholecystokinin, and Somatostatin), drugs (as Anticholinergic, alpha-adrenergic antagonist, Beta adrenergic agonist, Calcium channel blocker, Diazepam and Morphine) and smoking. All anesthetic agents except Ketamine as well as muscle relaxants decrease upper esophageal sphincter tone.

Protective upper airway reflexes

1. Coughing which is forceful expiration after brief inspiration.

2. Laryngospasm is a closure of both false and true vocal cords with apnea.

3. Expiration reflex which lead to sudden opening of the glottis and the closure of the false cord.

4. Spasmatic panting which involve a rapid closing and opening of the glottis and shallow breathing of around 60 breath per minute for less than 10 seconds.

Opioids can blunt all these reflexes except laryngospasm. Reduced consciousness level in perioperative period including after emergence will affect these reflexes increasing the risk of aspiration [5].

3.1 Pathology of lung aspiration

Pulmonary aspiration is defined by the inhalation of oro-pharyngeal or gastric contents into the larynx and the respiratory tract or the presence of bilious secretions or particulate matter in the tracheobronchial tree. Time frame of perioperative pulmonary aspiration starts from preoperative period until 2 h after termination of anesthesia. Diagnosis of perioperative pulmonary aspiration is made by direct examination of the oral-pharynx, bronchoscopy assessment of the tracheobronchial tree, or postoperative chest X-rays showing new infiltrates [6, 7].

During the induction of anesthesia, as the patient loses consciousness and the protective airway reflexes are obtunded, the gastric contents, in case of full stomach, may regurgitate through the esophagus and get aspirated into the lungs. Clinical outcomes of pulmonary aspiration range from benign hypoxia and desaturation, to fatal course of Acute Respiratory Distress Syndrome (ARDS), respiratory failure, cardiopulmonary collapse and death (**Figure 1**). The severity of these pulmonary complications depends on the acidity and the volume of gastric contents as well as the immune response of the patient. Small particulate aspiration induces a foreign body reaction of inflammation and consequently results in granuloma formation. Aspiration of acidic content induces acute inflammatory response and progresses rapidly to pneumonitis over 24–48 h. Hypoxia is common due to either upper airway obstruction or obstructed lower airway by debris, thus leading to high airway resistance and vicious cycle of alveolar collapse, alveolar edema and reflex bronchospasm [8].

3.2 Pathophysiology of pulmonary aspiration

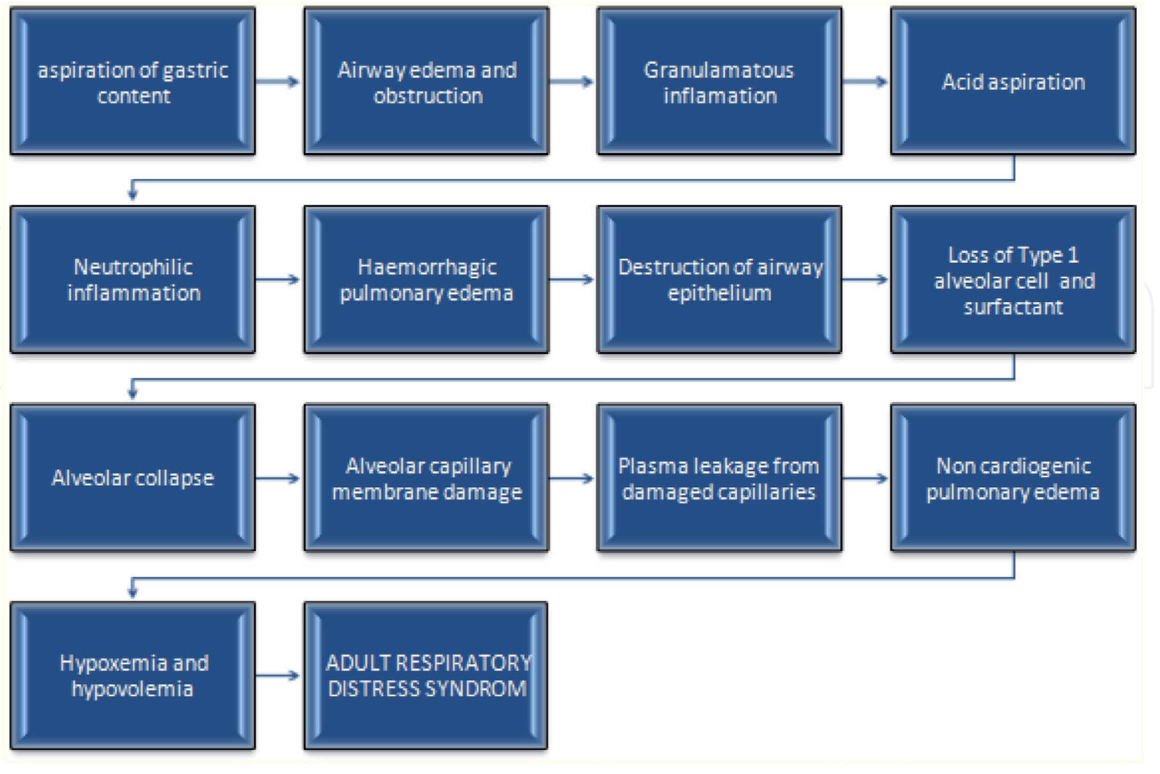

Figure 1.
Summary of pathophysiology of pulmonary aspiration, modified from Dal Santo et al. [8].

3.3 Types of aspiration-related pulmonary complications

1. Aspiration pneumonitis or chemical pneumonitis

2. Bacterial pneumonia

3. Particle-associated aspiration

3.3.1 Aspiration pneumonitis or chemical pneumonitis

Chemical pneumonitis, the most common type of pulmonary aspiration, was first described by Curtis Lester Mendelson in 1946 as inflammation of the lung parenchyma resulting from aspiration of sterile gastric contents. The morbidity and mortality associated with aspiration pneumonitis can be attributed to the acidity and volume of the aspirate. If the pH of the aspirate is less than 2.5 and the volume is >0.3 ml/kg (20–25 ml in adults), it can lead to fatal pneumonitis [9].

The acidity of the aspirate can cause chemical injury to the tracheobronchial tree and the lung parenchyma which can trigger a series of immune responses. The direct corrosive effect of gastric acid on the alveolar-capillary epithelium peaks in 1–2 h. This is followed by an inflammatory response which peaks in 4–6 h which involves neutrophilic invasion of the alveoli and lung parenchyma. This phase is also characterized by the involvement of a spectrum of inflammatory mediators, inflammatory cells, adhesion molecules, and enzymes, including tumor necrosis factor α, interleukin-8, cyclooxygenase and lipoxygenase products, and reactive oxygen species, though the major role in the mechanism of lung injury is played by neutrophils & complement activation [9].

The clinical course may have either of the 3 outcomes [10]:

1. Clinical and radiological improvement.

2. Initial improvement then gradual clinical and radiological deterioration.

3. Refractory severe course.

3.3.2 Bacterial pneumonitis

A contaminated aspirate can lead to bacterial infection of the lung parenchyma, with a course of complete recovery or progress to lung abscess formation, exogenous lipoid pneumonia or chronic interstitial fibrosis. The most common pathogens are *Staphylococcus aureus*, *Pseudomonas aeruginosa*, Enterobacter species, Klebsiella species and *Escherichia coli*. The major anaerobes that have been isolated from pulmonary infections include Pepto streptococcus, Fusobacterium nucleatum, Fusobacterium necrophorum, Prevotella, Bacteroides melaninogenicus [11].

3.3.3 Particle-associated aspiration

If particulate matter is present in the aspirate it can lead to variable degrees of airway obstruction. The severity of airway obstruction depends upon the size of the particle and the caliber of the airways. Aspiration of a larger particle can even lead to complete airway obstruction with subsequent sudden respiratory distress, cyanosis, and aphonia that may lead to sudden death if the obstruction is not immediately relieved. Smaller particles in the distal airways cause less severe obstruction and gradual course of respiratory symptoms as irritative cough, wheezing, dyspnea and superimposed bacterial pneumonia if the distal obstruction persists for more than 1 week. Chest X-Ray could show atelectasis or obstructive emphysema with a mediastinal shift and elevated diaphragm as shown in **Figure 2** below.

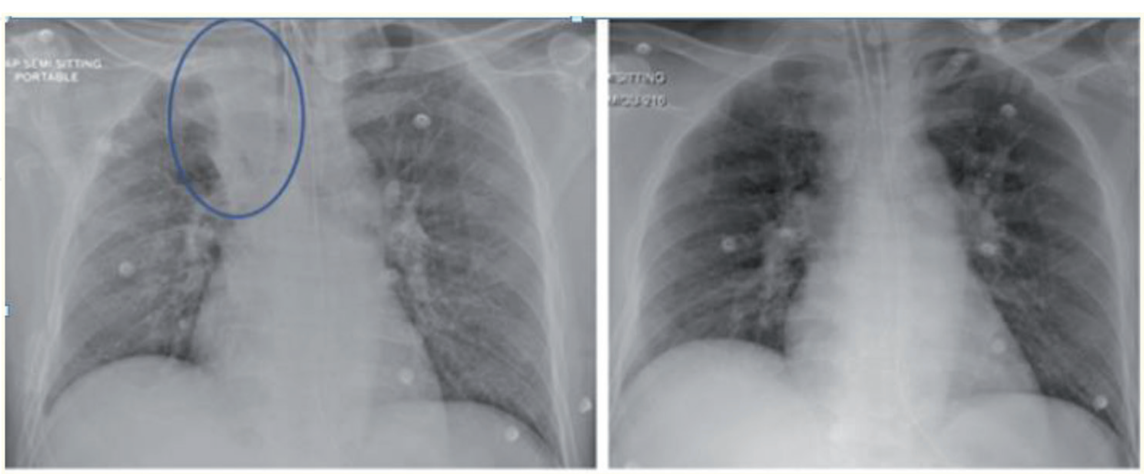

Figure 2.
A chest radiograph (on the left) for a patient with a witnessed aspiration of food particles after neuro-intervention procedure under sedation, showing right upper lobe atelectasis and bilateral pulmonary edema and infiltrates. (On the right), the resolution of collapse and infiltrates after 2 days of respiratory support with invasive ventilation and Tazocin antibiotics in ICU. Picture courtesy of Dr. El Sayed E lKarta with his permission, Hamad Medical Corporation, Doha, Qatar.

4. Outcome-driven anesthesia related morbidity and mortality

In American Society of Anesthesiology (ASA) closed claims, the three leading respiratory events related to death or brain damage before 1990 were all non-aspiration related as; inadequate oxygenation/ventilation, difficult intubation and undetected esophageal intubation. Fortunately, the overall proportion of other non-aspiration respiratory-related death or brain death events have dramatically decreased over time, from 30% of the claims in the 1970s to 15% in the 1990s, possibly, due to incorporation of pulse oximetry, capnography and advent of supraglottic device and videoscopes into general clinical practice [12].

In ASA closed claims, the occurrence of aspiration has remained constant over time around 3.5%, with reduction of other non-aspiration respiratory claims. The mortality and brain death related to non-aspiration respiratory events have been decreasing since 1970 to 1990 from 50–30%. Surprisingly, to date still 60% of death and brain injury was attributed to aspiration compared to 43% for the remainder of the ASA claims [12].

In NAP4, among all respiratory claims, pulmonary aspiration contributed to only 5% of all claims. The topmost contributors to the NAP4 respiratory claims as 60% of the whole claims; were Inadequate ventilation, esophageal intubation and difficult intubation, all are considered as common risk factors for aspiration pneumonia. Still, the aspiration in NAP4 constitutes over 50% of airway-related deaths in anesthesia exceeding the feared consequence of cannot intubate cannot ventilate (CICV) scenario. 23% of all NAP4 claims have aspiration as either primary or secondary event. Cases not leading to mortality commonly resulted in significant morbidity and prolonged stay on intensive care [1].

4.1 Risk factors of aspiration

Risk factors cannot be ignored or easily overlooked in the preoperative assessment as 93% of aspiration cases in NAP4 have identifiable risk factors however the aspiration risk have been identified in only 40% of the primary anesthesia related aspiration. Thus, it mandates more judicious preoperative assessment [13] (**Table 1**).

4.1.1 Poor airway assessment

Poor assessment could lead equally to difficult airway scenarios and aspiration.

4.1.2 Poor planning and prophylaxis

Unstructured, inorganized and unplanned sequence for airway management.

4.1.3 First generation supraglottic airway devices (SAD)

Numerous cases of aspiration occurred during use of a first-generation SAD in patients who had multiple risk factors for aspiration and in several in whom the aspiration risk was so high that rapid sequence induction and intubation (RSII), should have been used [14].

4.1.4 Obesity and after bariatric surgery

Obesity is an independent risk factor for full stomach and airway management may be difficult in these patients, preoperative gastric ultrasound is recommended to assess the risk of aspiration. Complications in obese patient included an increased

Surgical factors • Emergency surgery (trauma) • Upper abdominal or laparoscopic surgery • Positioning (lithotomy or Trendelenburg) • Prolonged surgery >2 h
Patient factors
• Hiatal hernia • Gastrointestinal obstruction/abdominal distension • Pregnancy • Morbid obesity • Upper gastrointestinal hemorrhage • Intracranial hypertension • ICU patients • Diabetes mellitus or those with gastroparesis • Gastroesophageal reflux / Incompetent lower Esophageal Sphincter • Opioids
Patient factors
• Light depth of anesthesia • 1st Generation of Supra Glottic Device "SGA" • Insufflation of stomach with bag mask ventilation or LMA • Anesthesia delivered by Trainees

Table 1.
Summary of the factors for aspiration pneumonia per Asai's risk factors [12].

frequency of aspiration and other complications during the use of SAD, difficulty at tracheal intubation and airway obstruction during emergence or recovery [15].

4.1.5 Difficult airway and failure of airway management

The 13% of the ASA aspiration claims have occurred during difficult airway management. In NAP4, still the topmost contributors to respiratory claim were inadequate ventilation, esophageal intubation and difficult intubation report as 60% of the claims, and all that are common risk factors for aspiration pneumonia [1].

4.1.6 Number of intubation attempts

The NAP4 registry has found the number of attempts, and trials are significantly associated with higher rate of aspiration 22% regurgitation, 13% aspiration were reported after the second attempts [1].

4.1.7 Underlying pathologies

4.1.7.1 Diabetes mellitus

Diabetes is a common metabolic and endocrine disease, complicated with diabetic gastroparesis, known as gastric paralysis. It was found that hemoglobin

A1c value of more than 7%, could lead to delayed gastric emptying, by decreasing the frequency of gastric contraction, while the risk score of aspiration increase significantly [16].

4.1.7.2 Advanced age

Old age is an independent risk factor for delayed gastric emptying, as it is common in elderly patient to have anorexia, dyspepsia and impaired gastric peristalsis [17].

4.1.7.3 Gastrointestinal disorder

Functional delayed gastric emptying (FDGE) and Ileus are common complications following abdominal surgeries especially bowel resection, colon and rectal surgery, all lead to impaired contractility, motility and gastric emptying [18].

4.1.7.4 Specific anesthesia time

ASA closed claims have identified that aspiration cases were associated with anesthesia induction in 60%, maintenance in 18% and during emergence in 11% and in PACU in 5% anesthesia related claims, indicating that aspiration commonly occurs during induction, but the risk is still high even till PACU [12].

4.1.8 Type of anesthesia

Mainly the aspiration is during general anesthesia; however, 7% of aspiration in ASA closed claims have occurred during regional anesthesia or monitored anesthesia care. 18% of the aspiration that occurred during maintenance of anesthesia was either by facemask, laryngeal mask [12].

4.1.9 Gastric volume

It was found that when gastric volume (GV) was less than 0.4 ml/kg, the incidence of vomiting was only 6.7%. Once the volume exceeded 0.8 ml/kg, the incidence of vomiting was as high as 44.1%. In supine position, patients with cross-section area (CSA) less than 340 mm^2 was considered as fasting. On the contrary, CSA was greater than 340 mm^2 indicates GV of greater than 0.8 ml/kg [19].

4.1.10 Determination of critical volume of gastric contents

A critical volume of gastric contents required to produce severe aspiration pneumonitis has been even more debatable than determining critical PH. In one study, pulmonary injury became independent of pH as the volume of aspirate was increased from 0.5 to 4.0 ml/kg in dogs. Nevertheless, it was generally accepted that the volume of gastric fluid of 0.4 ml/kg places a subject at risk for developing aspiration pneumonitis based on experimental instillation of gastric fluid into the right main stem bronchus of a single Rhesus monkey [20].

However, The ASA Task Force on Preoperative Fasting, despite extensive screening of the current data, has been unable to establish a link between residual gastric volume and pulmonary aspiration [21].

5. Perioperative anesthesia management in full-stomach patients

Identification of patients who are at risk for pulmonary aspiration is the first step toward minimizing the incidence of perioperative pulmonary aspiration. Two patient risk categories exist: those with a full stomach (i.e., history of ingestion of a meal with less than 6 h fasting time) and those designated as having a full stomach despite a prolonged preoperative fast. **Aspiration prophylaxis goals in preoperative period** are summarized in **Table 2**.

5.1 Fasting recommendations

Guidelines for preoperative fasting are formulated in order to reduce the risk of aspiration under general anesthesia or procedural sedation. They apply to all patients undergoing elective surgeries or procedures under general anesthesia, regional anesthesia, procedural sedation and monitored anesthesia care (MAC). Aspiration can happen during all the above-mentioned types of anesthesia as the anesthetic and sedative drugs can obtund the protective airway reflexes which can in turn result in aspiration of gastric contents. It is not applicable to patients undergoing minor surgeries or procedures solely under local anesthesia.

2017 American Society of Anesthesiology (ASA) task force fasting recommendations are summarized in the **Table 3**. For certain procedures like intragastric balloon removal or repositioning, fasting time up to 12 h is recommended. (Please refer to other chapter for more details). Other circumstances and comorbidities as listed in 4.1 might necessitate certain modifications in the fasting guidelines.

Gastrointestinal factors
• Enhancing gastric emptying • Decreasing gastric volume • Minimize the volume of gastric contents • Increasing pH of gastric contents • Reduce gastroesophageal reflex
Fasting time
• Adequate preoperative fasting based on age and food type specific recommendation
Pharmacologic therapies
• Decrease gastric acidity • Facilitating gastric emptying/drainage • Maintenance of competent lower esophageal sphincter tone
Anesthesia techniques
• Preoperative (History – Optimization of risk factors) • Intraoperative (Preoxygenation + RSI + Cricoid maneuver) • Postoperative and recovery (awake during extubation)

Table 2.
Summary of aspiration prophylaxis goals in preoperative period.

Consumed meal/drink	Minimum hours of fasting required
1.Clear fluids	2 h
2.Breast milk	4 h
3.Infant formula/non-human milk	6 h
4.Light meal	6 h
5.Heavy meal (fried food, fatty food, meat)	8 h

Table 3.
2017 ASA fasting guidelines recommendations.

5.2 Pharmacologic therapies

To increase gastric pH, **Histamine antagonist (H2)** and **proton pump inhibitors (PPIs)** are commonly used. H_2 antagonists as Ranitidine, Famotidine, and Cimetidine, act by blocking the H_2 receptors of gastric parietal cells inhibiting the stimulatory effect of histamine on gastric acid secretion. **Proton Pump Inhibitors (PPIs)** as Omeprazole, Lansoprazole and Pantoprazole, irreversibly blocking the Hydrogen/Potassium ATPase of parietal cells and prevent the release of hydrochloric acid [22].

The goal for enhanced gastric emptying is achieved by **prokinetics** such as Metoclopramide [23]. It stimulates the motility of upper GI and is used in risk patient to reduce gastric volume such as Gastroesophageal reflux disease (GERD), Diabetic and pregnant patients and in emergency patients who had no time to be NPO. It also has a peripheral and central Dopamine receptor antagonist activity and might reduce the risk of postoperative nausea and vomiting. Oral antacid can be used in patients with risk of regurgitation and aspiration. Antacids work by neutralization of gastric acid content, single dose 15–30 min before surgery will increase PH above 2.5. Sodium Citrate 0.3 M is non-particulate antacid that itself will not cause pulmonary damage if aspirated with the gastric fluid. Antacids increase gastric volume especially in repeated doses, but this side effect is less important than its action on increasing gastric pH. Decrease gastric volume can be achieved by 6 h fasting before surgery, naso-gastric (NG) tube used to aspirate the gastric content before anesthesia or the use of PPI like Omeprazole to inhibit gastric acid secretion.

5.3 Role of preoperative point of care ultrasound

Ultrasonography has been recommended as a reliable, noninvasive, bedside tool to determine gastric volume and content in the perioperative period based on many studies [24, 25]. A cutoff of antral cross-sectional area of 340 mm^2 correlates with fluid volume gastric contents greater than 0.8 ml/kg, a high risk of aspiration [19]. However, most studies to date deal with validity considerations and propose that bedside ultrasound accurately determines gastric volume rather than contents [26]. Thus, the use point-of-care ultrasonography in the preoperative period as a screening tool has been recently advocated especially in vulnerable population.

5.4 Anesthesia technique for full stomach

Anesthesia management of patient with full stomach commences from preoperative period through intraoperative and concludes postoperatively.

5.4.1 Preoperative

5.4.1.1 Pre-anesthesia history

A full preoperative history is a critical step for risk assessment. Predisposing factors as Gastroesophageal reflux disease (GERD), esophageal dysmotility, diabetes, bloating and any condition that delay gastric emptying, history of bariatric surgery or any pathological conditions in upper GI could increase risk of volume regurgitation.

5.4.1.2 Preoperative fasting

Generally, it is recommended to take clear fluid for up to 2 h preoperatively and stop solid food for 6 h before the surgery as per ASA recommendations described in detail in (**Table 2**) [21].

5.4.1.3 Preemptive nasogastric tube placement

No evidence to support routine preoperative gastric emptying to reduce aspiration risk even in emergency cases except patients suspected ileus or obstruction [27].

5.4.2 Intraoperative

The meticulous and skillful airway management is the main goals in preventing gastric aspiration into the lungs during general anesthesia. Airway management techniques intraoperatively involve the following:

1. Adequate preoxygenation with 100% oxygen

   Preoxygenation is administered by face mask for 3 minutes of normal tidal volume breathing that will increase oxygen reserve in the functional reserve capacity (FRC) and provide additional safe apnea time. Passive oxygen insufflation by a nasal canula with 10 l/min during laryngoscopy can prolong the apnea time until desaturation in high risk patient of difficult intubation during airway management [28, 29].
   High frequency nasal canula (HFNC) or trans-nasal humidified rapid insufflation ventilatory exchange (THRIVE) with up to 60 l/min oxygen can be used in critically ill patient that have shorter safe apneic time [30]. It was found that THRIVE will not cause gastric distension or increase the risk of regurgitation. Oxygen flow of 70 l/min will generate a nasopharyngeal pressure of 7 cm H_2O, with this pressure it is unlikely to cause gastric distension. In a study 80 patient underwent RSI with the use THRIVE for preoxygenation, no patient shows any sign of regurgitation [31].

2. Definitive airway device by a cuffed endotracheal tube

3. Use of rapid sequence induction during tracheal intubation (RSII) with effective cricoid pressure application

   All equipment should be ready for intubation as variable size facemask, different types of laryngoscopes, different sizes of endotracheal tubes, oral and nasal airways, video laryngoscope, supraglottic airway of different sizes, and a bougie. Anxiolytic might be used to relieve anxiety; Opioid dose should be used carefully to avoid respiratory depression and loss of airway reflexes [32]. Patient head should be positioned in sniffing position to facilitate intubation, the operating table head part to put it up to make the larynx above the level of lower esophageal sphincter. Short acting Opioids Fentanyl 1–3 mcg/kg IV 3 min before induction will reduce sympathetic response to intubation. Induction of anesthesia can be done by Propofol 1.5–2.5 mg/kg IV, Etomidate 0.2–0.6 mg/kg IV or Ketamine 1–2 mg/kg IV depending on the patient general condition. Intravenous Lidocaine 1 mg/kg can be given 2 min prior to intubation to blunt the sympathetic response of intubation. Succinylcholine 1–1.5 mg/kg provide complete relaxation in 30–60 s or Rocuronium 0.9–1.2 mg/kg achieve maximum neuromuscular block in 55–75 s if Succinylcholine is contraindicated.

Sellick's maneuver or cricoid pressure of approximately 30 N or 3 kg is applied on the cricoid ring against the cervical vertebra to occlude the lumen of the esophagus to prevent regurgitation of the stomach content to the pharynx. It is routinely applied during RSII until confirmation of Endotracheal Tube (ETT) position and inflation of the tube cuff [33]. Assistant should be directed to apply cricoid pressure by the intubating physician either to shift or release the pressure if the laryngeal view is disturbed or active vomiting has happened. It is advised to leave the NG tube in place while doing RSII, connect it to suction to drain stomach contents then leave it open to air and to suction the stomach before emergence [34].

If difficult intubation is expected, or patient might desaturate with apnea e.g. obese patients, patients with high intraabdominal pressure or those with sepsis or fever, it is advised to use **modified RSII.** Modified RSII refers to cricoid pressure and gentle mask ventilation before intubation [35].

Number of studies shows that application of cricoid pressure will prevent gastric insufflation even if mask ventilation pressure is up to 60 cm H2O [36]. Some patients cannot tolerate preoxygenation such as agitated patients due to hypoxia, hypercapnia or underlying medical condition. In those patients it is advisable to intubate them using **delayed sequence intubation (DSI)**. DSI is done under procedure sedation using a dissociative dose of Ketamine (1–1.5 mg/kg) to sedate the patient sufficiently to allow mask preoxygenation with his airway reflexes being reserved. Small observational studies in ICU show some improvement in preoxygenation using DSI [37]. Another study shows that using Ketamine to facilitate preoxygenation will decrease peri-intubation hypoxia from 44 to 3.5% [38].

4. Wide bore suction (Yankeur) must be immediately available

The importance of suction cannot be overemphasized in airway decontamination. It has been incorporated with the laryngoscopy steps in the **Suction Assisted Laryngoscopy Airway Decontamination procedure** (SALAD) which was developed by Dr. James DuCanto. SALAD is performed using a rigid suction catheter to decontaminate the oral cavity and to depress or lift the tongue for better laryngoscope position then further decontamination of the hypopharynx followed by further insertion of the catheter into the proximal esophagus for continuous drain of emesis. The suction catheter is placed to the left corner of the mouth so that it will be easier to be pinned in place by the laryngoscope. Intubation and inflation of the tracheal tube will be performed while the suction catheter in upper part of esophagus so that any pharyngeal soiling or regurgitated contents could be removed instantaneously (**Figure 3**).

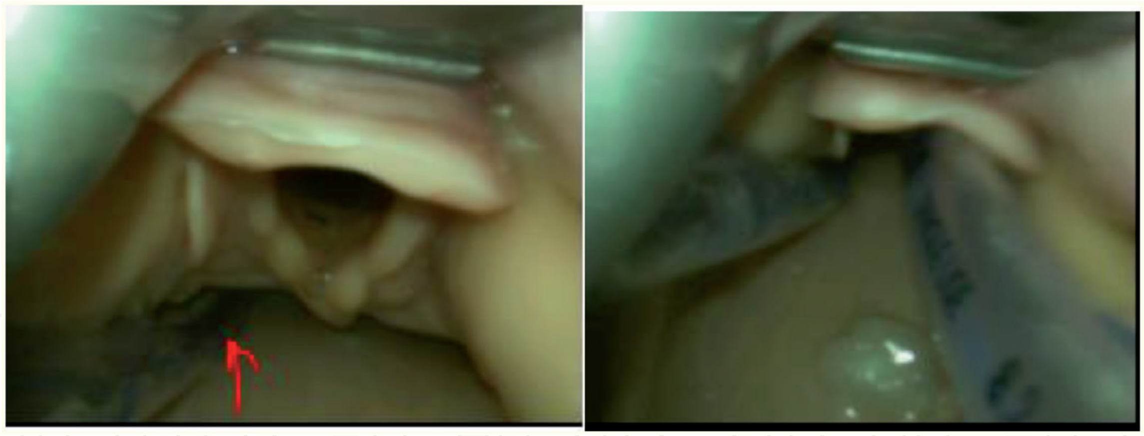

Figure 3.
A videoscope picture showing the SALAD technique. On the left, suction catheter advanced in upper esophagus. On the right, ETT in place while the suction catheter in upper esophagus. Picture courtesy of Dr. Nabil Shallik with his permission, Hamad medical corporation, Doha, Qatar.

Suction of pharyngeal contents decrease the volume of aspirates to the lung, thus could decrease the severity [39].

5. Use of airway adjuvant as optical stylet, or a video laryngoscopy in expected difficult airway

   Optical Stylets (OS) are rigid or semirigid tubular devices that fit inside tracheal tube. OS composed of a fiberoptic bundles or a video chip at distal end to convey the image. Different types of Optical stylets are available for instance Shikani Optical Stylets and Bonfils Retromolar Intubation Fiberscope. Optical stylets are useful mainly in patients with suspected difficult intubation. Airway trauma and technical difficulties due to fogging and secretion limit OS use.

Different kinds of laryngoscopes can be used to assist intubation, many studies recommend the use of video laryngoscope use for higher first attempted intubation rate especially for Mallampati 3 and 4, and better glottic view [40].

5.4.3 Postoperative

On extubation, emptying of the stomach using NG tube is recommended before emergence of the patient from anesthesia and it is advised to extubate the patient in a fully awake state, and a full recovery of the airway reflexes. Patient should be transferred to recovery with the head of the bed elevated to reduce the chance of reflux or in lateral position.

6. Management of aspiration

The first step in aspiration management is to be vigilant for any signs and symptoms of aspiration in patients especially in those who are known to have full stomach. Any witnessed gastric or oropharyngeal contents into the trachea during induction, maintenance or emergence from anesthesia, witnessed vomitus through the nose or mouth or sudden elevation of peak airway pressures during ventilation or cough, persistent hypoxia, bronchospasm or abnormal breath sounds following intubation, sore throat, dyspnea at recovery may suggest that a patient has aspirated (**Table 4**). Management in the intensive care unit includes monitoring and supportive therapy and broad-spectrum antibiotics.

Immediate steps in clinically significant aspiration
1. Call for **help** for **senior** anesthesiologist.
2. **Suction** for the fluid/particulate in the oropharynx and trachea.
3. **Definitive** airway management with a cuffed endotracheal tube with mechanical ventilation.
4. **Continuous monitoring** of vital signs, baseline chest radiograph and arterial blood gas
5. **Hemodynamic support** (two wide bore intravenous cannula, vasopressors with conservative fluid administration to avoid pulmonary edema)
6. **Respiratory support** using lung protective ventilation strategy if required which combined low tidal volume with relatively high respiratory rate along with positive end expiratory pressure.
7. **Lung recruitment** to patients to maintain adequate saturation.
8. Portable **chest radiograph** as a baseline documentation.
9. **Stabilization** before surgical incision If the surgery cannot be postponed
10. **Postponing** the surgery is recommended in significant airway obstruction, impaired oxygenation or ventilation or cardiovascular effects such as hypotension and shock.
11. **Multidisciplinary team** of intensivist, Infection disease and pulmonologist for post-operative intensive care.

Table 4.
Summary for immediate steps in aspiration prophylaxis.

6.1 Chemical pneumonitis

The main stay of treatment in chemical pneumonitis includes immediate tracheal suctioning to remove the aspirated material followed by pulmonary support. Use of antibiotics must be revaluated by the team after 48–72 h and its use discontinued if there are no signs of infection [41].

6.2 Bacterial pneumonia

The antibiotic regimen should include aerobic and anaerobic coverage, especially against gram-negative bacilli and *Staphylococcus aureus*. **Carbapenem** (Imipenem, Meropenem) or Piperacillin Tazobactam in resistant Gram-negative bacilli or in patients who have received intravenous antibiotic coverage in the past 90 days. If anaerobic bacteria are suspected, parenteral antibiotic of Ampicillin-Sulbactam 1.5–3 g intravenous every 6 h or **Amoxicillin Clavulanate** (immediate release 875 mg orally twice daily or extended release 2 g orally twice daily) is an appropriate alternative.

Other alternative regimens include **Metronidazole** 500 mg orally or intravenous three times daily plus either amoxicillin 500 mg orally three times daily or Penicillin G intravenous 1–2 million units intravenous every 4 to 6 hours. In penicillin allergy Clindamycin 600 mg intravenous every 8 h or **Ceftriaxone** 1–2 g intravenous daily or **Cefotaxime** 1–2 g intravenous every 8 h in combination with Metronidazole. Oral antibiotics switch from parenteral antibiotics is based on clinical improvement, hemodynamic stability, tolerance for oral medications [41, 42].

7. Full stomach in special populations

7.1 Difficult airway management in full-stomach patient

If a difficult airway is predicted, the risk of aspiration may be weighed against the risk of difficult or failed airway management. In such a case, modified rapid sequence induction and intubation (RSII), awake fiberoptic intubation or inhalational induction may be considered. The advantages of awake tracheal intubation are maintenance of protective airway reflexes, uncompromised airway oxygenation and ventilation and maintenance of normal muscle tone, which helps in the identification of anatomic landmarks. It is accomplished by adequate preoperative preparation, use of an intravenous anti-sialagogue to reduce oral secretions, cautious use of intravenous sedation and an experienced skill anesthetist. Topicalization of the airway is controversial, as airway reflexes might be abolished after topical anesthesia of lower airways putting the patient at risk of aspiration as the larynx will no longer be "AWAKE". It is recommended to use topical anesthesia on base of tongue, vallecula and epiglottis while spraying the local anesthesia directly to vocal cord, transtracheal anesthesia and anesthesia to recurrent laryngeal nerve should be avoided in high risk of aspiration [43].

Presently, Supraglottic Airway Device (SAD) is recognized in the ASA difficult airway algorithm. It could be used as ventilation device or serves as conduit for intubation, or both. The **Proseal™** Laryngeal mask airway is potentially useful device especially in patient with high risk for gastric regurgitation and pulmonary aspiration as it has been shown to protect adult and pediatric patients from large-volume aspiration in some studies, however no studies have confirmed its effectiveness comparing to cuffed endotracheal tubes at reducing the risk of aspiration [44, 45].

7.2 Pediatric population

The accurate incidence rate of aspiration pneumonitis in pediatric anesthesia is unknown. However, it has been acknowledged as a rare event, it was reported as three times more common than in adults [46]. A prospective survey between 1978 and 1982 found only four aspirations among 40,240 in pediatric general anesthesia reported with no morbidity or mortality was reported. Other studies based on esophageal pH monitoring and barium contrast have stated that silent pulmonary aspiration may be more frequent in pediatric population with no neurological or anatomical abnormalities than in adults, with no respiratory consequences. Diagnosis of aspiration pneumonia in children should be made only if there are swallowing difficulties, known gastro-esophageal reflux or a witnessed aspiration [47].

7.3 Obstetric population

Mendelson was the first to describe 66 cases of aspiration between 1932 and 1945, with an incidence of 1 in 667 parturient and two deaths, both caused by acute upper airway obstruction. The mortality incidence was estimated about 1 in 22,008 [48]. In ASA closed claims, obstetric related aspiration constituted a 21% of all claims. A dramatic decreasing trend over time, in the 1970–1979; 43% of the respiratory claims compared to 20% in the 1980s and only 7% (two claims) of the aspiration claims in the 1990s. This suggests that benefit of the aspiration prevention strategies in the obstetric populations that introduced into clinical practice in the 1980s. A recent literature review found an incidence of failed tracheal intubation of 2.6 per 1000 obstetric general anesthesia (1 in 390) and associated maternal mortality of 2.3 per 100,000 general anesthesia (one death for every 90 failed intubations) [49].

The main recommendation is to adopt the neuraxial blocks as a main anesthetic technique, optimum pharmacological prophylaxis, avoiding of general anesthesia, minimizing airway manipulation and relying on RSII if general anesthesia cannot be avoided [50].

7.4 Trauma and other life saving/organ saving surgeries

Trauma and life-saving procedures have been proved to delay gastric emptying; thus, the fasting time may not be reliable. The volume of the gastric content is related to the nature of the trauma/emergency event, the interval between the last food intake and the time of acute event. Ultrasound studies have demonstrated that 56% of adult emergency cases have full stomach even though they were fasting (median 18 h). A patient for emergency surgery should always be considered as having a full stomach, thus adequate precautionary measures must be assumed to prevent aspiration. In trauma or other emergency events, prokinetics are not recommended. Erythromycin might facilitate gastric emptying in such patients but with a limited available evidence. Preoperative insertion of nasogastric tube is recommended only in cases of acute bowel obstruction but may not ensure adequate gastric emptying and could be associated with complications. Rapid sequence induction and intubation with cricoid pressure must be practiced in such cases in order to prevent aspiration [51].

7.5 Airway management for patient with NG tube in situ

Routine preoperative nasogastric tube (NG) insertion is not recommended except in selected patient with small bowel or gastric outlet obstruction. Usually those patients present to operating theater with nasogastric tube placed preoperatively. Whether to keep the gastric tube in situ, withdraw it to the esophagus, or remove it completely before induction of anesthesia is a debatable issue. The presence of the gastric tube may diminish the function of the upper and lower esophagus sphincter, with no impairment of the efficacy of cricoid pressure during rapid sequence induction based on cadaveric studies [33]. Enteral feeding usually contains carbohydrates, fat and protein, so it is considered as a full meal, thus should be stopped 8 h prior to surgery in patient that do not have endotracheal tube or tracheostomy tube in place and to continue tube feeding in case post pyloric position of the feeding tube for non-abdominal surgery [52]. As prolonged nutritional restriction may result in catabolic state in severely ill patient, however, continuation of enteral feeding might lead to aspiration, the decision to continue enteral feeding or stop it is a case-based decision with assistance of multidisciplinary team of anesthesiologist, surgeon and the primary physician. In conclusion, the current consensus is that a gastric tube, after stomach is decompressed, should not be withdrawn and left in situ during rapid sequence induction based on available literatures [27].

7.6 Airway management in post-bariatric surgery patient

Currently, the laparoscopic gastric banding and the laparoscopic Roux-en-Y gastric bypass are the most performed bariatric procedures that have proven safe, cost effective with fewer complications [53]. The major changes in gastric anatomy and physiology after weight reduction surgeries are decrease in esophageal sphincter relaxation and change in esophageal-gastric peristalsis, thus there is potential risk of esophageal regurgitation and pulmonary aspiration during general anesthesia [54]. Despite dramatic weight loss, the risk of perioperative pulmonary aspiration in post bariatric surgery patient was 6% [55]. Therefore, Post-bariatric patients must be carefully evaluated preoperatively with attention to signs and symptoms of reflux/regurgitation and delayed gastric emptying. Currently, there are no guidelines on airway and anesthetic management for post-bariatric patients. However, such patients should be encouraged to consume only liquid meals the day before the operation, prolonged pre-operative fasting period maybe helpful in the preoperative period. Intraoperatively, Rapid-sequence induction and intubation (RSII) with definitive airway as the anesthetic technique of choice and insertion of nasogastric tube must be considered. In patients with an expected difficult airway, an awake intubation should be the technique of choice [56].

7.7 Upper airway bleeding

Upper airway bleeding is a catastrophic event that might cause airway related death even in healthy young patients. Airway management in those patients is extremely challenging. Some of techniques used to secure airway such as video laryngoscope or fiberoptic laryngoscopes might be ineffective because of the soiled hypopharynx and equipment with blood, effective preoxygenation might be difficult in an anxious not tolerated patient, THRIVE and HFNO should be used with extreme caution because blood may force in lower airway, use of SAD has limited effectiveness because of the high risk of aspiration, patient swallow the blood and should be considered as a full stomach case and patient cannot lie supine feeling suffocated and difficult to deal with, are the main problems associated with airway management in these patients [57].

Upper airway bleeding might be idiopathic such as nasal bleeding, bleeding tumor and vascular malformation, trauma to face and neck, post-surgery for instance post tonsillectomy bleeding or cancer surgery or iatrogenic such as traumatic airway manipulation.

Airway management started with airway examination and localizing cricothyroid membrane as an emergency solution of cannot intubate scenario. Out of all the airway management ways, only the placement cuffed ETT using RSII might fulfill the desired goals which are; securing a conduit for patient ventilation, protect the patient from blood aspiration in the lungs, and provide good space for the surgeon to address the source of bleeding and controlling it [57].

In case of failure to intubate the patient, SAD devices, retrograde intubation or blind nasal intubation in case of spontaneous breathing patient could be a solution for airway management.

Failure of the above techniques mandate cricothyroidotomy or tracheotomy with a cuffed tube [57].

7.8 Rapid sequence induction and intubation (RSII) for COVID19 patients

There is a high chance of aerosol spread of the virus during airway management of patient with COVID 19. RSII is the preferred way to intubate those patients. Awake intubation should not be done because coughing during intubation increase virus spread. All standard airway equipment should be available plus bag mask with High Efficiency Particular Air filter (HEPA) filter, video laryngoscope with disposable blades, ventilator and tubing with inline adapter and HEPA filter and smooth clamp for ETT. It is preferred to intubate the patient in negative pressure room if available and to limit staff available during intubation to a maximum of three [58].

After strict donning process with full Personal Protective Equipment (PPE), preoxygenate the patient for 3–5 min using 10–15 l/min of 100% O2 and avoid bag mask ventilation (BMV) if possible. If saturation drops and BMV is needed so assure tight mask fitting with no leaks. Use of high dose of muscle relaxant Rocuronium or Suxamethonium to avoid coughing while intubation, use video laryngoscope if it is available, inflate ETT cuff as soon as possible, clamp the ETT before connecting to ventilator, HEPA filter should be placed between the ETT and the ventilator [59] (for more details, kindly refer to Chapter 1).

8. Perioperative negative pressure pulmonary edema versus pulmonary aspiration

Negative Pressure Pulmonary Edema (NPPE) also known as Post-Obstructive Pulmonary Edema (POPE), is a form of non-cardiogenic pulmonary edema that can occur perioperatively due to laryngospasm during anesthesia or following extubation in adults. NPPE is a potentially life-threatening complication following general anesthesia and is manifested by upper airway obstruction, followed by strong inspiratory effort (negative pressure). This occurs in 0.05–0.1% of cases as a life-threatening complication of general anesthesia with tracheal intubation [60]. NPPE was first hypothesized in 1927 by Morre and was described later by Oswalt in 1977. It is essential to notice the potential causes, make differential diagnosis and determine the effective treatment. NPPE usually presents with respiratory distress, hypoxia, cyanosis, frothy pink sputum, and hemoptysis. It is important to distinguish negative pressure pulmonary edema from pulmonary aspiration at the end of general anesthesia, however the diagnosis requires a strong suspicion as the presentation mimics aspiration pneumonia. In general, NPPE often demonstrates marked bilateral perihilar alveolar infiltrates on chest X-ray. Treatment modality includes supportive care such as careful post-op monitoring, reliving airway obstruction, oxygen supplementation, Bilevel Positive Airway Pressure (BIPAP) and assisted ventilation [61, 62].

9. Conclusion

Patients proceeding for surgery should receive the safest anesthesia experience possible. An anesthesiologist should be prepared to manage a patient with a suspected full stomach which includes meticulous attention to airway management during induction, through emergence, and after extubation.

Pre-operative care should include adequate time for gastric emptying for non-emergent cases; administering non-particulate antacids per orally to increase gastric pH and to identify patients who may have delayed gastric emptying. Rapid sequence induction and intubation with or without cricoid pressure are recommended as per institutional guidelines. They should have a wide bore rigid suction device ready during intubation and emergence. A nasogastric tube may be placed to empty the stomach pre-induction if the patient has a suspected ileus or gastrointestinal obstruction. After surgery is completed patients should be emerged until they are fully awake with return of airway protective reflexes and then extubated. It is also recommended to empty the stomach with a nasogastric or orogastric tube prior to extubation. Postoperatively patients must be transferred to recovery and recovered in a head up position or in a lateral position.

Presence of expertise in advanced airway management is essential for awake tracheal intubation and dealing with difficult or failed airway in a patient with a full stomach. Preoperative counseling for patients with high risk for difficult airway management and pulmonary aspiration of gastric contents regarding alternative anesthesia options other than general anesthesia should be sought out.

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