IMMEDIATE CONCERNS

Major Problems

Aspiration is a potentially critical event, occurring in patients often suffering from reduced consciousness with decreased pro-
tective airway reflexes. Signs and symptoms of aspiration de-
pend on the quantity and the nature of the aspirate. Owing to
a large, number of aspiration events involving gastric con-
tents, a high awareness is essential in those situations in which
patients are at higher risk for this problem (i.e., ileus, trauma,
premature infants, etc.). The pathophysiologic changes ob-
erved depend on the type of aspiration. In general, particulate
obstructive aspiration results in significant hypoxemia, which
rapidly progresses to cardiovascular collapse if the obstruction
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is discussed in Chapter 138. Furthermore, inhalational injury by noxious gases is discussed elsewhere.

### Stress Points

1. Inhalation of any amount of fluid with a pH less than 2.5 is likely to damage lung tissue extensively by chemical inflammation.

2. Blood in the lungs may occur as a consequence of hematemesis, intrapulmonary hemorrhage, and surgical procedures involving the upper airway, pharynx, or maxillofacial areas. Immediately after aspiration of blood, patients will have an increased pulse and respiratory rate, and may become cyanotic if the amount of inhaled blood is sufficient to cause significant intrapulmonary shunting. Otherwise, blood is relatively harmless.

3. Ingestion of hydrocarbons such as kerosene, furniture polish, lighter fluid, gasoline, and other petroleum solvents account for 18% of accidental poisonings in children. Pulmonary toxicity occurs only if the hydrocarbon is aspirated either during ingestion or after it is regurgitated.

### Essential Diagnostic Tests and Procedures

1. Success in diagnosing pulmonary aspiration depends on maintaining a high index of suspicion for its occurrence in at-risk patients. In 65% of cases, regurgitation is witnessed; 37% of patients have either silent or unwitnessed aspirations.

2. When clinical findings suggest pulmonary aspiration, further evaluation is essential. Arterial blood gas and pH analysis afford the most useful initial laboratory test.

3. Approximately 88% to 94% of people who aspirate gastric contents eventually demonstrate pulmonary infiltrates on chest radiograph (2). Thus, a normal finding on chest radiograph does not completely exclude the possibility of aspiration.

4. Because the initial physical findings and blood gas volumes may be identical in acid and nonacid aspiration, determination of the pH of any remaining gastric or pharyngeal fluid can be helpful. If the fluid is highly acidic, anticipate a worsening course.

### Initial Therapy

1. Initial management depends on whether aspiration is imminent, occurring, or completed. When regurgitation occurs in an obtunded patient, the airway must be cleared, and the patient's head must be tilted down and to the side.

2. Suction equipment must be available and ready to use in areas where this problem is likely to occur (e.g., the operating room, delivery, and emergency rooms; postanesthesia care unit; and intensive care unit (ICU)).

3. Oxygen should be administered immediately to all patients suspected of pulmonary aspiration.

4. The airway should be secured by intubating the trachea, and then one must attempt to clean the airway immediately by suctioning any particulate aspirate. Suctioning has no beneficial effect with acid aspiration because the injury is immediate.

5. No benefit is derived from alkaline tracheal lavage. In fact, the practice is detrimental.

6. Removal of large particulate matter usually requires rigid bronchoscopy. Fiberoptic techniques permit only the removal of small particles.

### HISTORICAL BACKGROUND

Beginning with Aristotle's observation of the association between meconium staining of the amniotic fluid and a sleepy fetal state (3), aspiration pneumonitis was recognized as a clinical problem as early as 400 BC when Hippocrates realized "Dangers of Aspiration" (4). More than 2,000 years later, in 1848, Simpson reported the first anesthetic death under chloroform caused by pulmonary aspiration and asphyxiation (5). In 1946, Mendelson presented 66 cases of aspiration occurring among 44,016 obstetric patients undergoing general anesthesia for vaginal deliveries (6). His description was so complete that aspiration in this setting is commonly termed the "Mendelson syndrome." Subsequently, his laboratory investigations led him to the conclusion that two entirely separate clinical entities existed. One followed the aspiration of solid food and resulted in a clinical picture of laryngeal or bronchial obstruction, whereas the other resulted from direct acid injury to the lung and caused the "asthma-like" syndrome (7). Teabeaut, in 1952, showed that a liquid aspirate with a pH below 2.5 would produce pneumonitis in rabbits (8). The concept of a critical pH and a certain aspirate volume was introduced in 1974 by Roberts and Shirley from data obtained in rhesus monkeys (9). The results were calculated for humans in order to identify patients at risk of pulmonary aspiration. Subsequent animal studies demonstrated that larger volumes of acidic aspirates produced higher morbidity and mortality (10). The critical pH of 2.5 and critical volume of 0.4 mL/kg body weight (or approximately 25 mL in an adult) have since been challenged as inducing aspiration pneumonitis.

### RISK FACTORS

In a healthy and conscious subject, effective protective laryngeal and cough reflexes prevent pulmonary aspiration. Since the reflex status depends on the level of consciousness, it is obvious that aspiration is predisposed by any reduction of consciousness, which, therefore, is the major risk factor for aspiration (11). Common causes of reduced consciousness include different kinds of neurologic pathology such as head injury, stroke, and cerebral hemorrhage, as well as infectious causes such as meningitis or sepsis, or metabolic sources such as diabetes or thyroid crisis, and so forth. Drug and alcohol overdose and the use of sedative medication increase the risk of pulmonary aspiration; interestingly, even during normal sleep, aspiration is not uncommon (12). Another group of patients with an increased risk of aspiration are those with laryngeal incompetence caused by neurologic disturbances such as multiple sclerosis or muscular dystrophy, or by surgery of the hypopharynx and larynx itself. The protecting closure reflex of the larynx against aspiration is also impaired with age (13).

General anesthesia not only reduces the level of consciousness, but also suppresses airway reflexes. Therefore, general anesthesia is a risk factor for aspiration, particularly in emergency cases. Certain patient conditions increase the risk of aspiration in the perioperative setting. Best known is pregnancy,
with its associated increased abdominal pressure and delayed gastric emptying. Another condition is morbid obesity (14), with issues of increased gastric volume and increased abdominal pressure, at least in the supine position. However, more recent studies have questioned the assumption that obesity is a risk factor for pulmonary aspiration during anesthesia (15). An absolute high-risk situation is small bowel obstruction with high gastric pressure. In this condition, the stomach sometimes contains far more than 1 liter of bile and jejunal secretions, and the distended bowel causes abdominal hypertension. Other conditions predisposing to pulmonary aspiration include disorders resulting in (a) reduced lower esophageal sphincter tone, such as gastroesophageal reflux disease; (b) increased lower esophageal sphincter tone (achalasia); (c) increased pyloric tone, such as pyloric stenosis; and (d) diseases with delayed gastric emptying (e.g., diabetes). Each situation, leading to increased gastric pressures, may amplify the incidence of regurgitation and vomiting and, consequently, the risk of pulmonary aspiration.

In the perioperative period, aspiration occurs most often during the induction of anesthesia, when the patient is already unconscious and the endotracheal tube is not yet in place. Some measures can even increase the aspiration risk. For example, mask ventilation with high pressures can further insufflate the already full stomach with air and, thus, increase the intragastric pressure. The fast-acting muscle relaxant, succinylcholine, can cause abdominal muscle contractions and consequently increase the abdominal, and thus gastric, pressure if the patient has not been properly precurarized. A nasogastric feeding tube not only promotes gastroesophageal reflux, but also eventually leads to oropharyngeal swallowing defects. An endotracheal tube causes vocal cord dysfunction and impairs the sensorimotor function of the pharynx and the larynx temporarily. After long-term intubation, swallowing defects are frequent, with a considerable risk of aspiration after extubation (18). A synopsis of the various risk factors is shown in Table 139.1.

A nasogastric feeding tube not only promotes gastroesophageal reflux, but also eventually leads to oropharyngeal swallowing defects. An endotracheal tube causes vocal cord dysfunction and impairs the sensorimotor function of the pharynx and the larynx temporarily. After long-term intubation, swallowing defects are frequent, with a considerable risk of aspiration after extubation (18). A synopsis of the various risk factors is shown in Table 139.1.

### TABLE 139.1

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<thead>
<tr>
<th>Small bowel obstruction</th>
<th>Delayed gastric emptying</th>
<th>Overdistended stomach</th>
<th>Lack of fasting</th>
<th>Obstetric patient/parturition</th>
<th>Emergencies</th>
<th>Outpatients</th>
<th>Nasogastric overfeeding</th>
<th>Hiatal hernia</th>
<th>Obesity (?)</th>
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<tbody>
<tr>
<td>Increased gastric content</td>
<td>Tendency for regurgitation</td>
<td>Laryngeal incompetence</td>
<td>Other reasons</td>
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CNS, central nervous system; ASA, American Society of Anesthesiologists.

### Aspiration in the Perioperative Period

Although general anesthesia is principally a risk factor for pulmonary aspiration, carefully developed strategies during the past decades have reduced the risk of aspiration during elective surgery. Several large studies were concerned primarily with...
the incidence of aspiration and its associated mortality during
general anesthesia (19). In a retrospective study of 215,488
general anesthetics for elective and emergency surgery, Warner
et al. (20) found an incidence of pulmonary aspiration of
1 in 3,216 (0.03%) and a mortality rate of 1 in 71,829 pa-
tients (0.0014%); the incidence of aspiration was found to be
times four higher in patients undergoing emergency surgery.
There was no serious morbidity from pulmonary aspiration
in the immediate perioperative period in nearly 120,000 elec-
tive procedures and general anesthetics in American Society
of Anesthesiologists (ASA) physical status I and II patients.
The incidence of pulmonary aspiration and severity of pul-
monary outcomes were highly associated with the presence of
comorbidity (ASA physical status III and higher) and proce-
dures performed emergently. Finally, Warner et al. concluded
that patients with clinically apparent aspiration who do not
develop symptoms within 2 hours of aspiration or com-
pletion of the procedure are unlikely to have respiratory
sequelae.

Olsson et al. in 1986 (19) studied 185,385 patients un-
dergoing general anesthesia and found an aspiration rate of
1 in 2,131 (0.05%). Forty-seven percent of the patients with
reported aspiration developed aspiration pneumonitis, with a
mortality rate of 1 in 45,454 (0.002%) (16). In 1996, Mellin-
Olsson et al. studied 85,394 anesthetics prospectively. They re-
ported 25 cases of aspiration, presenting an overall incidence of
1 in 3,424. All occurred in patients receiving general anesthe-
sia, with an incidence of 1 in 2,106. Of the 25 aspiration cases,
13 occurred during elective procedures with an incidence of 1
in 3,303, and 12 in emergency procedures with an incidence of
1 in 2,632. There were no aspiration events in patients receiving
regional anesthesia nor in those patients who were under IV
sedation and analgesia but breathing spontaneously (21). In a
report on the epidemiology and impact of aspiration pneumo-
nia in patients undergoing surgery in Maryland between 1999
and 2000 (22), the prevalence of aspiration pneumonia was
1 in 809. There were no aspirative events in patients receiving
cuffed endotracheal tubes and the exclusive use of fast-acting
sphincter tone. Iatrogenic factors include the administration
of sedatives and narcotics during labor, which further pro-
longs gastric emptying and also may depress protective air-
way reflexes. Moreover, the lithotomy position and manual
abdominal compression for delivery additionally increase in-
tragastric pressure. The incidence of aspiration in obstetric pa-
tients for cesarean section under general anesthesia was 1 in
1,431 (0.07%) in an Italian study (30). A Scandinavian re-
port noted aspiration in 4 of 3,600 cesarean sections (0.11%)
and in 4 of 36,800 parturients (0.01%), with no fatalities
(31).

“Silent Aspiration” during Anesthesia

During the induction of anesthesia, when protective reflexes are
diminished, the risk of aspiration is greatest. However, even af-
ter having successfully completed induction of anesthesia, pul-
monary aspiration is not uncommon. Owing to the fact that
this kind of aspiration is usually not detected by the anesthe-
siologist, it is called “silent” aspiration (32). Despite the tube
being correctly placed in the trachea, with an appropriately
inflated cuff to “seal” the airways, aspiration may still occur.
Nevertheless, during short-term endotracheal intubation, the
incidence of silent aspiration is relatively low. In older studies,
an incidence of 8% to 25% during anesthesia was reported
(33). In 1970, Blitt et al. detected “silent” aspiration in less
than 1% of 900 studied anesthetized patients (34). These clin-
icians attributed the low incidence of aspiration to their use of
cuffed endotracheal tubes and the exclusive use of fast-acting
intraesophageal induction in contrast to the induction with inhala-
tion anesthetics, which was still popular in those times. More-
ever, they reported that only 1 out of the 900 patients (0.1%)
may have developed pulmonary complications as a possible
consequence of silent aspiration. However, even in this pa-
tient, the pulmonary complication may have been from other 
reasons (34). It is noticable that there is no further, more 
recent study about silent aspiration during anesthesia. This 
fact and the very low incidence of serious consequences of 
aspiration underline that silent aspiration during short-term 
endotracheal intubation, as during anesthesia, is only of minor 
concern.

**Aspiration in the Early Postoperative Period**

There are no specific data about the incidence of aspiration 
in surgical patients in the early postoperative period or in se-
quard aspiration pneumonia. Postoperative nausea and vom-
ting (PONV) is a frequent phenomenon after anesthesia and 
surgery (33) and has been well reviewed in large prospective 
multicenter studies. However, none of these studies revealed 
pulmonary aspiration associated with PONV as a significant 
problem. Nevertheless, as impaired consciousness is a major 
risk factor for pulmonary aspiration in all patients who are 
not fully recovered, the need for close observation is evident 
in the early postoperative period.

**Pulmonary Aspiration in Critical Care**

Pulmonary aspiration during induction of anesthesia or in an 
emergency case is generally witnessed, and the consequences 
of aspiration may be bronchospasm and hypoxemia, develop 
early. In contrast, aspiration is usually silent in critical care 
patients and frequently chronic without early and clear signs 
of the event. Thus, estimating the incidence of aspiration in 
critical care patients is difficult. Markers like glucose, pepsi, 
radioisotope-labeled feeds, or dye in tracheobronchial secre-
tions have been used to detect aspiration in these patients (36– 
38). With these methods, pulmonary aspiration was detected in 
up to 89% in mechanically ventilated, tube-fed patients (38). 
Other studies, reported in patients with trachostomies, noted 
a positive aspiration rate between 33% (40) and 50% (39). The 
methods mentioned above identified minimal amounts of aspi-
rated material, even if no clinical symptoms could be detected. 
In fact, 87% and 77% of the events, respectively, were classi-
cified as “silent aspiration” (39,40). Even in healthy subjects, tra-
cheal aspiration during sleep is not uncommon (12). However, 
in healthy subjects, immune competence together with efficient 
airway-clearing mechanisms (coughing, mucociliary transport, 
etc.) and the low pathogenicity of the normal oropharyngeal 
flora prevent the development of airway infection. On the other 
hand, if the physiologic defense and clearing mechanisms are 
impaired—as in the critically ill and particularly in sedated, en-
dotracheally intubated patients—pneumonia may follow, even 
if the amount of the aspirated substance is small and the num-
ber of bacteria low. Furthermore, recurrent aspiration of bac-
terially contaminated oropharyngeal secretions is frequent in 
these patients and increases the likelihood of respiratory tract 
infection. This explains the correlation between the duration 
of critical illness—and especially the time of intubation—with 
occurrence of respiratory tract infections. In a large Euro-
pean multicenter study, the incidence of pneumonia in endo-
tracheally intubated patients was 15.8% at day 7 and 23.4% 
at day 14 (41). In critically ill patients, the immunocompro-
mised state and previous antibiotic therapy lead to a shift of 
the oropharyngeal flora from physiologically less virulent bac-
teria to a pathogenic population consisting mostly of Staphy-
lococcus aureus, Gram-negative enteric bacilli, Pseudomonas 
aeruginosa, and Candida species (42). Since aspiration pneu-
monia is one of the most common and relevant results of the 
aspiration of oropharyngeal secretions or gastric contents in 
critically ill patients, its occurrence can be used as a surrogate 
indicator of aspiration. However, the incidence of aspiration 
pneumonia is often submerged within the incidence of VAP. 
VAP incidence, as it is defined, refers only to endotracheally 
intubated, mechanically ventilated patients, and does not in-
clude the aspiration pneumonia of nonintubated patients, such 
as those having suffered a stroke or with swallowing defects 
of other origins. Thus, there is uncertainty as to the exact in-
cidence of aspiration pneumonia. Even the incidence of VAP 
varies between 9% and 70%, depending upon the case mix of 
patients, the setting of the studies, and the criteria used for the 
diagnosis of pneumonia (43).

**Pulmonary Aspiration in Medical Emergencies**

Medical emergency situations are often accompanied by re-
duced consciousness and impaired protective reflexes. Thus, 
tracheobronchial aspiration is common in these cases. Al-
though the exact incidence is uncertain, the overall risk of as-
spiration during emergency intubations is in the range of 20% 
(44). However, this number can be greatly influenced by the 
condition—mainly the level of consciousness—and the situa-
tion during which airway management or airway protection 
measures are performed. Pulmonary aspiration during endo-
tracheal intubation in emergency surgery, even though per-
formed in the operating suite, takes place in 1 of 895 (0.1%) 
cases, which is about four times more frequent than in elec-
tive surgery (20). The risk of aspiration increases with the de-
gree of unconsciousness, as measured by the Glasgow coma 
Scale (45). In prehospital emergency care, aspiration prior to 
airway management occurs in about one third of severely head-
injured patients—those with a Glasgow coma scale score be-
tween 3 and 8 (46,47). Although no specific data have been 
described in the patient with central nervous system (CNS) in-
jury, some authors estimated the incidence of gastric aspiration 
to be up to 30-fold more likely in emergency—as compared to 
scheduled—cases (48). Another study revealed aspiration of 
gastric contents in 50% of the patients who needed to be 
intubated because of respiratory insufficiency in the prehospi-
tal setting, as opposed to 22% in those patients who required 
subsequent tracheal intubation in the emergency department 
(49). Even though different methods have been used to investi-
gate the incidence of pulmonary aspiration in emergency care, 
it seems relatively clear that aspiration in emergencies occurs 
less frequently in a well-prepared setting such as the operating 
suite, with doctors highly skilled in airway management, as 
compared to the difficult situations seen in prehospital emer-
gency care. Furthermore, it can be presumed that endotracheal 
intubation in an emergency situation per se might increase 
the risk of aspiration: if reflexes are not deeply suppressed, 
laryngoscopy stimulates the gag reflex caused by contact of 
the instrument with the pharyngeal wall and can induce vomiting.
Gastric contents will then be aspirated because of disturbed protective reflexes and discoordination of cough reflexes. In many trauma patients, the stomach is acutely distended (50), which further promotes vomiting, regurgitation, and, finally, aspiration. Cardiopulmonary resuscitation also poses a high risk for aspiration. In an autopsy series of unsuccessfully resuscitated patients, nearly half of them had full stomachs, and the overall incidence of pulmonary aspiration was 29% (51). This underlines the high incidence of pulmonary aspiration in emergency patients.

**PATHOPHYSIOLOGY OF PULMONARY ASPERATION**

**Definition**

Aspiration is defined as the misdirection of oropharyngeal or gastric contents into the larynx and lower respiratory tract (52). Aspiration of gastric contents results from either active vomiting or passive regurgitation, both associated with impairment or depression of protective laryngeal and cough reflexes. Aspiration can be composed of materials from the following groups, depending on the nature of the aspirated material (53):

1. Noxious fluids—acid, bile, jejunal secretions, and other chemical substances
2. Solid particles—food, teeth, and other foreign bodies
3. Miscellaneous fluids—blood, water, alcohol, meconium, milk, pus, etc.
4. Microbiologically contaminated secretions

Table 139.2 lists substances that are known to be aspirated.

<table>
<thead>
<tr>
<th>TABLE 139.2</th>
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<tbody>
<tr>
<td><strong>SUBSTANCES KNOWN TO BE ASPERATED</strong></td>
</tr>
<tr>
<td><strong>GASTROINTESTINAL FLUIDS</strong></td>
</tr>
<tr>
<td>Gastric acid</td>
</tr>
<tr>
<td>Bile</td>
</tr>
<tr>
<td>Jejunal secretions</td>
</tr>
<tr>
<td>Fluid enteral nutrition formula</td>
</tr>
<tr>
<td><strong>SOLID PARTICLES</strong></td>
</tr>
<tr>
<td>Food of any kind</td>
</tr>
<tr>
<td>Nuts (peanuts)</td>
</tr>
<tr>
<td>Teeth</td>
</tr>
<tr>
<td>Sand/small stones</td>
</tr>
<tr>
<td><strong>MISCELLANEOUS FLUIDS</strong></td>
</tr>
<tr>
<td>Blood</td>
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<tr>
<td>Alcohol</td>
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<tr>
<td>Hydrocarbons</td>
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<td>Polyethylene glycol</td>
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<tr>
<td>Meconium</td>
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<tr>
<td>Milk</td>
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<tr>
<td><strong>MICROBIOLOGICALLY CONTAMINATED SUBSTANCES</strong></td>
</tr>
<tr>
<td>Oropharyngeal secretions</td>
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<tr>
<td>Pus</td>
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</table>

Aspiration of Gastric Contents and Aspiration Pneumonitis

The major source of aspirated material is the stomach and upper gastrointestinal tract. The content is variable, consisting of gastric acid, food particles, or a mixture of both. In case of small bowel obstruction, the stomach may also contain jejunal secretions and bile. The aspect of solid food will be discussed in a later section.

Gastric acid is very deleterious to lung tissues. Most authors agree that a pH less than 2.5 and a volume of gastric aspirate greater than 0.4 mL/kg body weight—approximately 25 to 50 mL in adults—are required for the development of aspiration pneumonitis (8,8,10). Experimental studies have indicated that the instillation of low pH hydrochloric acid solutions results in a dose-related and pH-dependent acute lung injury (ALI). The severity of the injury is directly related to three variables: (a) the acidity of the instilled fluid, (b) the volume of the instilled fluid, and (c) the toxicity of the fluid (55). Hypotonic fluids cause a more severe lung injury than isotonic fluids; the instilled fluid, and (c) the tonicity of the fluid (55). Hypotonic fluids cause a more severe lung injury than isotonic fluids; the instilled fluid, and (c) the tonicity of the fluid (55). 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Small bowel obstruction often leads to massive (greater than 1 liter) reflux of bile and jejunal secretions into the stomach. This produces an increased gastric pressure with a high risk of regurgitation. Bile has an inflammatory potential comparable to acid (57). Owing to the direct chemical destruction of the lung tissue by aspiration of either gastric acid or bile, this kind of lung damage is termed aspiration pneumonitis.

**Aspiration of Solid Particles**

Aspirate containing large particles accounted for 7.5% of aspiration in Mendelson’s series (6). While two of his five patients who aspirated solid material died of suffocation, most preoperative gastric aspirates do not contain large particles. Solid particles obstruct the airways depending on their size. The bigger they are, the larger is the obstructed lung area behind the foreign body, and the higher the degree of the intrapulmonary right-to-left shunt, resulting in hypoxemia or even suffocation. In the zone around the foreign body, local inflammation will occur with infiltration of mononuclear cells and granulomatous reaction of the lung tissue. If the solid particle is not removed, permanent anastomosis and lung consolidation will develop downstream from the obstruction. Conversely, air trapping and emphyma may develop behind the obstruction (58). Depending on the bacterial content of the aspirate or of the airways behind the obstruction, local pneumonia or even a lung abscess may develop.

Teeth are sometimes accidentally aspirated in craniofacial trauma, and may be detected only by a routine chest radiograph postoperatively or during examination in the emergency room. Foreign body aspiration is a serious problem in children, with the ability to cause critical respiratory insufficiency (59). More than 17,000 children under the age of 14 were admitted to emergency departments in the United States in 2001, resulting in 160 deaths (60). More than 50% foreign body aspirations occur in children aged between 1 and 3 years, less than 10% in children younger than 1 year of age (61), and only occasionally in adults, usually secondary to impaired consciousness. A Medline search revealed that nearly anything that would fit into a pediatric trachea has been detected there. Aspiration of foreign bodies can occur very dramatically, with the ability to cause critical respiratory insufficiency (59). More than 17,000 children under the age of 14 were admitted to emergency departments in the United States in 2001, resulting in 160 deaths (60). More than 50% foreign body aspirations occur in children aged between 1 and 3 years, less than 10% in children younger than 1 year of age (61), and only occasionally in adults, usually secondary to impaired consciousness. A Medline search revealed that nearly anything that would fit into a pediatric trachea has been detected there. Aspiration of foreign bodies can occur very dramatically, with the ability to cause critical respiratory insufficiency (59). However, the oropharynx is heavily contaminated with a variety of microbes, which may cause a problem if aspirated. In healthy individuals, the normal oropharyngeal flora consists mostly of anaerobes and, to a small degree, aerobic bacteria (Staphylococcus and Haemophilus species, among others) (69), which only have a minor infectious potential in the immunocompetent subject. In the presence of an immunocompromised state, the normal flora may be overgrown by pathogens such as Gram-negative rods, S. aureus, and yeasts. Aspirated oropharyngeal secretions contaminated with these pathogenic microbes are usually the source of aspiration pneumonia. However, the development of pneumonia depends on the pathogen's virulence and the quantity aspirated, as well as the patient's defense mechanisms such as mucociliary clearance and cellular and humoral immunocompetence. Repeated aspiration of even small amounts of secretions from above the cuff of the endotracheal tube, as often takes place in mechanically ventilated patients, increases the likelihood of VAP.

**Aspiration of Miscellaneous Fluids**

**Blood.** During craniofacial trauma and, to a lesser extent, during ear-nose-throat surgery and maxillofacial surgery, the aspiration of blood is common. Blood is harmless in terms of its inflammatory property to tissue or mucosal structures. Depending on the volume aspirated, it will cause a certain degree of intrapulmonary right-to-left shunt and hypoxemia. About 400 mL of blood in the alveolar space may be sufficient to cause significant hypoxemia (63). Only a large amount of blood can obstruct the airways sufficiently to cause life-threatening hypoxemia and death through suffocation. Smaller volumes normally can easily be treated with the application of continuous positive airway pressure or positive end-expiratory pressure (PEEP) ventilation (64). Most often, the blood is reabsorbed without further harmful consequences, with the only hazard of aspirated blood being airway obstruction.

**Alcohol.** The pH of alcohol is similar to that of saliva—pH 6 to 7—and its destructive properties on lung tissue have been considered minimal. In an animal study, however, aspirated ethanol has been shown to produce marked pulmonary inflammation and bronchiolitis obliterans (65). How this might be adjudicated in the context of a human aspiration of alcohol is unclear, and only one study concerning ethanol aspiration in the literature underlines the fact that aspiration of ethanol is a rare event.

**Hydrocarbons.** Materials such as gasoline, kerosene, gasoil, furniture polish, and other light oil products are sometimes ingested—mainly accidentally—by children. If vomited or regurgitated, hydrocarbons can be aspirated, resulting in a rapid onset of hypoxemia caused by intrapulmonary shunt (66). The intrapulmonary shunt after aspiration of hydrocarbons results from pulmonary edema and mucosal bleeding (67).

**Polyethylene Glycol.** This material is generally used to clean the bowel prior to endoscopic examinations. Since it is given in relatively large quantities, pulmonary aspiration may occur in at-risk patients, such as children and the elderly (68). Polyethylene glycol induces mucosal inflammation, interstitial edema, and, consequently, hypoxemia.

**Oropharyngeal Secretions.** Oral secretions per se are innocuous to airway mucosa. If aspirated, oropharyngeal secretions are usually small in volume and will not cause significant obstruction of the airways. However, the oropharynx is heavily contaminated with a variety of microbes, which may cause a problem if aspirated. In healthy individuals, the normal oropharyngeal flora consists mostly of anaerobes and, to a small degree, aerobic bacteria (Staphylococcus and Haemophilus species, among others) (69), which only have a minor infectious potential in the immunocompetent subject. In the presence of an immunocompromised state, the normal flora may be overgrown by pathogens such as Gram-negative rods, S. aureus, and yeasts. Aspirated oropharyngeal secretions contaminated with these pathogenic microbes are usually the source of aspiration pneumonia. However, the development of pneumonia depends on the pathogen's virulence and the quantity aspirated, as well as the patient's defense mechanisms such as mucociliary clearance and cellular and humoral immunocompetence. Repeated aspiration of even small amounts of secretions from above the cuff of the endotracheal tube, as often takes place in mechanically ventilated patients, increases the likelihood of VAP.

**Meconium.** The aspiration of meconium (pH 5.5-7) in newborn infants can cause mechanical obstruction, depending on the amount and consistency of the material; it also induces a chemical pneumonitis (70). Meconium aspiration occurs in slightly less than 1% of the newborn infants (71). Of the infants who develop a meconium aspiration syndrome, more than 4% die, accounting for 2% of all perinatal deaths (72). In laboring women with thick meconium staining of the amniotic fluid, amnioinfusion did not reduce the risk of moderate to severe meconium aspiration syndrome, perinatal death, or other...
maternal or neonatal disorders (73). Routine oropharyngeal and nasopharyngeal suctioning during delivery of term newborns through meconium-stained amniotic fluid is a frequent therapy, but it has recently been suggested that this does not prevent the meconium aspiration syndrome (74).

Milk. Milk may be aspirated either directly after ingestion or subsequent to regurgitation or vomiting. The effects of pulmonary aspiration of milk have been studied in animals (75). Vomited milk is usually acidic due to gastric acid admixture. However, instillation of human breast milk into rabbit lung at a pH of 7.0 and 1.8 results in comparable tissue damage and pneumonia (20). Subclinical aspiration can be detected only through additional measures. Several markers have been used to ascertain subclinical aspiration with various success. Such markers include glucose, radiotopote-labeled feeds, or dye (37,78,79). Recently, the presence of pepsin as a sensitive and specific marker of gastric content has been suggested as a useful marker of occult aspiration (80,81).

Aspiration of pus is a very rare event, occurring during surgery for lung abscess or rupture of a peritonsillar abscess. The consequence may be transmission of the infection to other regions of the respiratory tract.

**THERAPY FOR ASPIRATION**

Witnessing the aspiration of gastric secretions into the pharynx should immediately prompt lateral head positioning, assuming integrity of the cervical spine, suctioning, and consideration of endotracheal intubation. The success of treatment may depend on immediate and vigorous measures to relieve airway obstruction. Tracheal suctioning may stimulate cough, bringing up some aspirated material, and thus help confirm a suspected diagnosis. Immediate bronchoscopy is performed only when solid particles, which may obstruct airways, are thought to have been aspirated. Removal of larger material requires rigid bronchoscopy. Bronchoscopic suctioning will not, however, protect the lungs from chemical injury, which essentially occurs immediately. Bronchial lavage may be deleterious, as it may result in surfactant washout and spread noxious aspirated material to uninvolved lung areas. Attempted neutralization of the acid aspirate is of no help, as the acid is rapidly neutralized physiologically.

The major therapeutic approach is to maintain pulmonary function, thus ensuring adequate gas exchange and minimizing further damage to the lungs. In an awake, alert, and cooperative patient, continuous positive airway pressure (CPAP) may be administered by mask, but more often, mechanical ventilation with PEEP in a lung-protective manner must be applied. Recent work also indicates that mechanical ventilation of acid-injured rat lungs with low tidal volumes of 6 mL/kg reduces the severity of lung injury compared to mechanical ventilation with higher tidal volumes of 12 mL/kg (83). These studies confirm the results of the ARDS Network trial in which low tidal volume ventilation decreased mortality in patients with ALI (86). Aerosolized β2 agonists may reduce the severity of lung endothelial injury and augment active ion transport mechanisms, which are responsible for the removal of edema from distal alveoli and airways of the lung (87). Owing to the deleterious increase of pulmonary vascular resistance caused by acid...
injury, the use of selectively acting vasodilators, such as inhaled nitric oxide (iNO), sildenafil, and prostacyclin, may be helpful in improving lung function and cardiac performance.

Meconium aspiration syndrome (MAS) remains a relevant cause for respiratory distress syndrome in premature infants, and is characterized by severe impairment of pulmonary gas exchange, surfactant inactivation, and pronounced inflammatory changes. Surfactant replacement therapy has been established for years as one of the most important therapeutic interventions in the management of premature infants with ARDS (88,89). Owing to the fact that aspiration and ARDS include the loss of pulmonary surfactant function, there is considerable interest in surfactant replacement therapy in adult patients. An international, multicenter, industry-sponsored study showed no improvement in either oxygenation or mortality when replacement surfactant was used in these patients (90). The study had enrolled 498 patients when it was discontinued, after interim analysis revealed a 41% mortality rate in both groups. Clinical experience has shown exogenous surfactant inconsistent as a therapeutic modality for adult patients with ARDS. However, current data do suggest that patients with primary ARDS (e.g., pneumonia, aspiration) may benefit more from surfactant replacement therapy than patients with secondary ARDS (e.g., sepsis, trauma); there has been no large, randomized, clinical trial conclusively showing that exogenous surfactant improves outcome in ARDS (91). The value of surfactant replacement in near-drowning is discussed elsewhere.

Steroids in aspiration syndromes have been shown to be clinically ineffective and, indeed, impede recovery in animal models (92), and likely in humans as well (93-95).

**Antibiotic Therapy**

**Aspiration Pneumonitis**

Although common practice, the prophylactic use of antibiotics in patients with suspected or witnessed aspiration is not recommended (96). Prophylactic antibiotics may increase late mortality by promoting the growth of resistant bacteria (97). However, empiric antibiotic therapy is appropriate for patients who aspirate gastric contents consisting of small bowel secretions or in other conditions associated with high bacterial colonization of the aspirate. Specific antibiotic therapy should be initiated in the setting of a secondary bacterial infection and should also be considered for patients with aspiration pneumonitis that fails to recover within 48 hours after aspiration (23).

**Aspiration Pneumonia**

The antibiotic therapy of aspiration pneumonia depends on the expected causative agent. However, distinctions are made between early- and late-onset pneumonias, which have different epidemiology and pathogenesis, and thus each type requires different strategies for therapy and prevention.

**Early-onset Pneumonia.** Early-onset pneumonia occurs typically in trauma patients and acute illness a few days after admission (98). The mechanism is mostly aspiration of oropharyngeal secretions before or during endotracheal intubation. Thus, the causative microbial organisms of early-onset pneumonia are usually identical with those potentially pathogenic microbes, which can frequently be found in the oropharyngeal flora of healthy subjects, such as methicillin-resistant *Staphylococcus aureus*, *Haemophilus influenzae*, or *Streptococcus pneumoniae*. Since these organisms are also responsible for community-acquired pneumonias, the antibiotic treatment of early-onset pneumonia is not different from that of community-acquired pneumonia.

**Late-onset Pneumonia.** As late-onset pneumonia occurs more than 4 to 7 days after admission (99), the spectrum of the causative organisms is usually nosocomial, often consisting of *Pseudomonas aeruginosa*, among others. The principles of antibiotic therapy of late-onset pneumonia are the same as those of nosocomial pneumonia. Both issues—therapy of community-acquired and nosocomial pneumonia—are discussed separately in Chapter 111.

**Prevention of Aspiration and Its Sequelae**

**Prevention of Aspiration in the Perioperative Period**

The ritualistic preoperative fasting over the past decades has been questioned, given that fasting can cause dehydration, diminishes the energy reserve, and increases patient anxiety. Moreover, the amount of gastric secretions may be increased through hunger and emotional stimuli (100-101).

Many studies have attempted to identify patients at risk before induction of general anesthesia with various fasting durations in various settings. It is generally agreed upon that clear fluid given up to 2 hours before elective surgery does not adversely affect gastric contents in healthy patients (102,103). This knowledge is one of the keystones of the “fast-track surgery” approach (103). One study found gastric volume and pH unchanged in children who had received 6 or 10 mL/kg apple juice 2.5 hours before anesthesia; in addition, they were less thirsty and less irritable than the control children who received no juice (107). However, the preoperative fast should not be lessened for anything other than clear liquids, as aspiration of particulate material (106) or human breast milk are grave, regardless of acidity (73), nor should fasting be abated in obstetric patients or patients awaiting emergency procedures. The current ASA guidelines for preoperative fasting (108) list fasting times for clear liquids, human breast milk, infant formula, nonhuman milk, and a light meal. Depending on the substance ingested, a preoperative fasting time between 2 and 6 hours is considered safe. However, the recommended fasting periods apply to healthy patients awaiting elective surgery; exceptions have been defined for other circumstances (Table 139.3).

**Preoperative Administration of Antacids**

The large retrospective review of 215,488 general anesthetics found no difference between patients who received or did not receive prophylaxis for acid aspiration. This leads to the author’s question, “Should these medications have been used routinely?” (20). The potential value of the preoperative administration of antacids is based on the unproven presumption...
that drug-induced increases in gastric pH will decrease the like-
lihood of severe acid pneumonitis (20). Despite the known abil-
ity of antacids to increase gastric fluid pH, it has not been docu-
mented that prophylactic administration to a high-risk patient
population (e.g., parturients) decreases mortality (109,110).
Furthermore, antacids and other drugs, such as H2 antagonists
or proton pump inhibitors, have no impact on the incidence of
regurgitation and aspiration. The duration of antacid action
highly depends on gastric emptying time, which can be short-
ened by prokinetic drugs like metoclopramide. However, this
effect is blocked by atropine or opioids. Opioids slow gastric
motility and thus prolong the pH-elevating effects of antacids.
The administration of antacids (e,g., to the parturient who has
also received opioids) may result in greatly increased gastric
fluid volume at the time general anesthesia is induced. With
this in mind, it seems more prudent to administer nonparticu-
late (clear) antacids, such as 15 to 30 mL sodium citrate as a
late (clear) antacids, such as 15 to 30 mL sodium citrate as a
slow onset of action, the use of H2 antagonists or proton pump inhibitors does not
provide adequate suppression of acid production, nor does
methoclopramide enhance gastric emptying in these emergency
cases.

Based on the arguments mentioned above, the ASA Task
Force on Preoperative Fasting (108) does not recommend the
routine administration of antacids, gastric acid secretion block-
ners, antemetics, or anticholinergics in patients who have no
apparent increased risk for aspiration. Only nonparticulate
antacids should be used when indicated for selected patients to
decrease gastric acidity during the perioperative period (e.g.,
prior to cesarean section).

Rapid Sequence Induction

Protection against acid aspiration in patients at risk relies
mainly upon rapid sequence induction (RSI). Injection of in-
travenous agents and the simultaneous application of effec-
tive cricoid pressure are followed immediately by tracheal in-
tubation. The Sellick maneuver should be used when regional
anesthesia is not feasible in patients thought to be at high risk
for aspiration. The cricoid pressure is used to produce a col-
lapse of the esophageal lumen and should be maintained until
the endotracheal tube is visualized passing through the vocal
cords, the cuff has been inflated, appropriate breath sounds are
confirmed, mist is noted to be present in the endotracheal
tube, and end-tidal CO2 presence is verified (29). Most anes-
thesiologists prefer an elevated head-up position during RSI.
The rationale for this maneuver is that an intragastric pres-
sure higher than 20 cm H2O is required to overcome the lower
esophageal sphincter. The head-up position exceeding this dis-
tance impedes passive regurgitation, as in the case of muscle
paralysis. In contrast, the head-down, Trendelenburg position
would enable the regurgitated gastric contents to drain out of
the oropharynx passively or be suctioned actively with a suc-
tion system. However, since endotracheal intubation usually is
easier with the patient in an elevated, semirecumbent position,
we would recommend it rather than the head-down position.

Despite taking all precautions, aspiration may still occur re-
gardless of the patient’s position or the applied cricoid pressure.
Moreover, the ability to maintain adequate cricoid pressure for
the necessary length of time and the accuracy in the delivery of
cricoid pressure are uncertain. The application of cricoid pres-
sure is a non-evidence-based, but clinically widespread, method
in aspiration prophylaxis. Although there is little scientific ev-
idence to support the widely held belief that the application of
cricoid pressure reduces the incidence of aspiration during RSI
(114), we recommend its use because of the minimal detrimen-
tal effects of application.

Because of the drawbacks to general anesthesia, many anes-
thesiologists prefer regional anesthesia for cesarean section.
The use of these techniques for cesarean delivery has greatly
increased due to the far lower incidence of aspiration. Accord-
ingly, the incidence of maternal pulmonary aspiration has de-
creased greatly in the past decades—from 43 per 100,000 live
births to 1.7 per 100,000 live births (115). The absolute num-
ber of deaths due to regional anesthesia has been decreased by
80%, down to 1.9 per 1,000,000 regional anesthetics. How-
ever, when general anesthesia is thought necessary for any rea-
son, RSI and insertion of a cuffed endotracheal tube are oblig-
atory.

When general anesthesia is indicated in patients at risk for
pulmonary aspiration, airway management is one of the most
important issues. Failed intubation occurs in the general surgi-
cal population at a rate of 1 in 2,330 (0.04%) (116), and is

<table>
<thead>
<tr>
<th>TABLE 139.3</th>
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<tbody>
<tr>
<td><strong>PRACTICE GUIDELINES FOR PREOPERATIVE FASTING</strong></td>
</tr>
<tr>
<td>Ingested material</td>
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<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Clear liquids^b</td>
</tr>
<tr>
<td>Breast milk</td>
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<tr>
<td>Infant formula</td>
</tr>
<tr>
<td>Nonhuman milk^c</td>
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<tr>
<td>Light meal</td>
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</tbody>
</table>

*These recommendations apply to healthy patients who are
undergoing elective procedures. They are not intended for women in
labor. Following the Guidelines does not guarantee complete gastric
empyting.

^aThe fasting periods noted above apply to all ages.

^bExamples of clear liquids include water, fruit juices without pulp,
carbonated beverages, clear tea, and black coffee.

^cSince nonhuman milk is similar to solids in gastric emptying time, the
amount ingested must be considered when determining an appropriate
fasting period.

^dA light meal typically consists of toast and clear liquids. Meals that
include fried or fatty foods or meat may prolong gastric emptying
time. Both the amount and type of foods ingested must be considered
when determining an appropriate fasting period.

From American Society of Anesthesiologists Task Force on
Preoperative Fasting. Practice guidelines for preoperative fasting and
the use of pharmacologic agents to reduce the risk of pulmonary
aspiration: application to healthy patients undergoing elective
procedures: a report by the American Society of Anesthesiologists Task
approximately eightfold higher in the obstetric population (117). Most airway catastrophes occur when airway difficulty is not recognized before the induction of anesthesia, and the anesthesiologist is not prepared to manage the difficult airway. Thus, meticulous preanesthetic examination is necessary to identify the patient at risk for airway difficulty as well as for aspiration; additionally, every airway should be considered a difficult airway, and backup plans should be in place if needed. The difficult airway is discussed elsewhere (Chapter 38).

Prevention of Aspiration in Critical Care

Several studies have demonstrated that regurgitation and aspiration is increased in tube-fed, critically ill patients lying in the supine position, as compared to the semirecumbent position (118–120). A fourfold higher VAP incidence was found in the supine position (34%) as compared to the semirecumbent group (8%) (120); there was also a significant association with gastric feeding and the occurrence of VAP. However, the risks of enteral feeding have to be balanced against its benefits. Thus, it seems prudent to avoid large gastric volumes rather than abandon gastric feeding per se in critically ill patients (17).

Theoretically, a cuff sealing the endotracheal tube against the tracheal wall will prevent aspiration of even the smallest amounts of oropharyngeal secretions, so-called microaspiration. Low-volume, high-pressure cuffs increase the risk of tracheal mucosal damage and, thus, are not appropriate for long-term endotracheal intubation. Instead, endotracheal tubes with high-volume, low-pressure cuffs are preferred if long-term intubation is expected. However, an endotracheal tube with a high-volume, low-pressure cuff does not prevent microaspiration from the subglottic area (121). Leakage of subglottic secretions occurs down longitudinal channels created by folds within the inflated cuff wall. The reason for these folds is that the cuff must be larger than the cross-section of the trachea so it can adjoin to the tracheal wall. Over the past several years, attempts have been made to improve the fit of the cuff in the tracheal wall by changing the shape and material of the cuff (122). Although some laboratory studies have demonstrated decreased leakage using improved cuff configurations, the problem of VAP is still not clinically solved with this approach.

Since pooled, bacterially contaminated secretions above the cuff are the reservoir for microaspiration, drainage of these secretions should reduce the incidence of aspiration and, consequently, the risk for VAP. However, conventional oropharyngeal suctioning techniques are usually not able to access this subglottic area, which is below the vocal cords and above the cuff of the tube. The removal of secretions from the subglottic area, which is below the vocal cords and above the cuff are the reservoir for microaspiration, drainage of these secretions should reduce the incidence of aspiration and, consequently, the risk for VAP. However, conventional oropharyngeal suctioning techniques are usually not able to access this subglottic area, which is below the vocal cords and above the cuff of the tube. The removal of secretions from the subglottic area, which is below the vocal cords and above the cuff of the tube (123). This extra dorsal lumen is connected to an evacuation system, and the subglottic region is either drained intermittently or continuously with a gentle negative pressure—about 30 mm Hg suction. In four randomized controlled trials, which included more than 800 patients, the use of subglottic suction tubes was compared to conventional endotracheal tubes in critically ill patients (124–127). Only two of the four trials revealed a significant reduction of VAP in the subglottic suction group. There was no decrease in either mortality, length of stay, or duration of mechanical ventilation by the method tested (128). Moreover, in a recent animal study, it was shown that continuous subglottic suctioning may even be deleterious to the tracheal mucosa, while only marginally lowering the bacterial colonization of the lung (129). A recently published study revealed that the use of continuous subglottic suctioning did not modify the level of oropharyngeal and tracheal colonization in long-term ventilated critically ill patients. Two of five patients who had received subglottic suctioning developed laryngeal edema immediately after extubation, and required reintubation (130). A recent meta-analysis (131) studied the effects of subglottic drainage by evaluating the four studies mentioned above (124–127) and a fifth study (132). Subglottic suctioning in patients expected to require more than 72 hours of mechanical ventilation resulted in a significant reduction of the incidence of early-onset pneumonia (that occurring 5–7 days after endotracheal intubation). Furthermore, the duration of mechanical ventilation was shortened by 2 days, and the length of stay in the ICU was shortened by 3 days in these patients. These results suggest that subglottic suctioning might play a role in patients expected to be ventilated for prolonged periods, and only by reducing the incidence of early-onset pneumonia. However, the method (i.e., the specially designed tube) is expensive and may damage the tracheal mucosa. This risk must be weighed against the expected reduction of the incidence of VAP.

Prevention of Aspiration Pneumonia

Pneumonia depends on lung contamination with pathogenic microorganisms as well as their virulence (i.e., their ability to overcome the host defense and localization). Thus, another approach to avoid aspiration pneumonia is to prevent the consequences of microaspiration in endotracheally intubated patients rather than by microaspiration itself. The aspiration of small amounts of oropharyngeal secretions would be harmless for the lung if the sputum was sterile or only contaminated with nonpathogenic microbes. However, several factors—mainly the immunosuppression caused by severe illness, as well as antibiotic therapy itself, etc.—disturb the physiologic microbial balance, causing a shift in the microbiology of the oropharynx. Within a few days, the low-pathogenic and physiologic oropharyngeal microflora changes into a high-pathogenic abnormal flora, consisting mainly of Gram-negative bacilli (133). Therefore, the oropharynx of critically ill patients, and particularly the pooled secretions in the subglottic region, is heavily contaminated with pathogenic and physiologic oropharyngeal microflora changes into a high-pathogenic abnormal flora, consisting mainly of Gram-negative bacilli (133). Therefore, the oropharynx of critically ill patients, and particularly the pooled secretions in the subglottic region, is heavily contaminated with pathogenic microorganisms. Aspiration of oropharyngeal secretions contaminated with these pathogenic microbes is usually the source of aspiration pneumonia (134–136). Therefore, any approach to reduce the bacterial burden of the aspirated oropharyngeal secretions, as well as the virulence of the abnormal microbial flora, might reduce the morbidity of microaspiration and decrease VAP. Topically administered antibiotics at the contamination site (i.e., the oropharynx and the airway) eradicate the microorganisms, or at least reduce their number and, thus, impede the development of aspiration pneumonia. However, there is a considerable controversy about such prophylactic administration of antimicrobial agents given that it enhances the risk of developing resistant bacterial strains. During the last decades, two approaches have been used in mechanically ventilated, critical care patients. One method is the nebulization of antibiotics into the airways via the endotracheal
tube to reduce the colonization of bacteria in the bronchial tract (137–139). The other approach is the decontamination of the oropharynx as well as the gastrointestinal tract. Usually nonabsorbable antibiotics are used in both methods to allow the application of supra-high local antibiotic concentrations at the target site (i.e., the airways or the oropharynx and gastrointestinal tract) without unwanted systemic toxic side effects. The use of supra-high local antibiotic concentrations may prevent or, at least, impede the development of antibiotic resistance.

Most often, aminoglycosides have been used for nebulization. Besides their use in the critically ill, there is substantial experience in patients suffering from mucoviscidosis and cystic fibrosis with the application of nebulized aminoglycosides. Although some data on the use of nebulized antibiotics in mechanically ventilated patients are promising, a final conclusion cannot be made because the studies vary in their methodology and are inadequately powered. Moreover, application of nebulized antibiotics is only effective in preventing pneumonia, and seems not to benefit patients with active pneumonia, particularly when compared to the use of potent systemic antibiotics (140). Mortality was not decreased by the use of nebulized antibiotics in mechanically ventilated patients. Three recently published reviews extensively discuss this topic (137–139).

Another approach to reduce the bacterial colonization of the respiratory tract is the decontamination of the patient’s internal bacterial sources (i.e., the gut, the stomach, and the oropharynx). However, while total decontamination of the oropharyngeal cavity and the gastrointestinal tract is not possible, selective decontamination of the oropharynx and the digestive tract is reasonably achievable (141). The concept of SDD is the elimination of potentially pathogenic micro-organisms as possible, leaving the relatively harmless and even protective anaerobic microflora unchanged (143). SDD has been studied in various critically ill patients (141). The concept of SDD is the elimination of the main pathogenic bacilli (especially Gram-negative bacteria and S. aureus) as well as yeasts by oral and enteral application of a combination of nonabsorbable antibiotics and antifungics (142). These microbes are very often involved in major infections in critically ill patients, whereas they play virtually no role in the physiologic intestinal ecosystem. SDD, as a means of infection prophylaxis, should suppress/eliminate as many potentially pathogenic micro-organisms as possible, leaving the relatively harmless and even protective anaerobic microflora unchanged (143). SDD has been studied in various critically ill patient populations, and several meta-analyses have been published (144,146,145). To date, randomized controlled trials have only demonstrated a significant decrease of VAP and mortality in trauma and liver transplant patients (146–149).

SSD requires meticulous microbial surveillance to monitor the effects of the applied agents (i.e., the successful selective decontamination), as well as the possible emergence of antibiotic resistance. Owing to the risk–benefit controversy, the use of SDD is not commonplace in the United States, and it is routinely used only in selected centers in Europe (149).

PEARLS

1. The major risk factor for aspiration is a reduced level of consciousness. General anesthesia is a risk factor, particularly in emergency cases. Furthermore, any situation that leads to increased gastric pressure or increased gastric content may amplify the incidence of regurgitation and vomiting and, consequently, the risk of pulmonary aspiration.

2. Critically ill patients with ventilatory insufficiency are at particular risk of pulmonary aspiration. Even in patients whose airway is protected by a cuffed endotracheal tube, microaspiration is common, because the cuff configuration does not provide a complete sealing of the trachea.

3. In general anesthesia, the overall incidence of pulmonary aspiration is approximately 1 in 3,000. The pregnant patient is at higher risk for aspiration of gastric contents (about 1 in 900 to 1 in 1,400) for a variety of reasons, including mechanical, hormonal, and iatrogenic factors.

4. Silent aspiration during short-term endotracheal intubation, such as during anesthesia, is only of minor concern.

5. Silent aspiration in long-term intubated and mechanically ventilated patients is common and has been detected in up to 90% of patients. Since aspiration is the main cause of pneumonia in critically ill patients, this issue is of major concern.

6. In emergency medicine, aspiration is a common event due to a reduced consciousness and the impaired protective reflexes of emergency patients. The less prepared,prehospital setting further increases the risk of aspiration.

7. It is important to distinguish between aspiration pneumonia and aspiration pneumonia. Aspiration pneumoni-tis is caused by chemically injurious agents (e.g., acid). Such agents destroy the lung tissue directly (e.g., by chemical burn). In contrast, aspiration pneumonia occurs as a result of microaspiration of bacterially contaminated, subglottic secretions in critically ill patients who are usually endotracheally intubated and mechanically ventilated.

8. The pulmonary consequence of aspiration depends on the nature of the aspirated material and the state of the injured lung. In general:
   a) Acid-related aspiration causes pneumonitis, a chemical injury to the lung parenchyma.
   b) Aspiration of solid particles leads to acute airway obstruction or reflex airway closure with arterial hypoxemia, depending on the size of the particles and the obstructed lung area proximal to the obstruction.
   c) Aspiration of blood is harmless in most circumstances.
   d) Microaspiration of subglottic secretions is the major cause of ventilator-associated pneumonia. The harm of macroaspiration depends on the virulence and the amount of bacteria contaminating the oropharyngeal secretions.

9. Bronchoscopy, most effective rigid, should only be used to remove solid particles from the airway. Bronchoscopy does not improve the course and outcome of patients who aspirated only liquid gastric contents.

10. Bronchial lavage after aspiration of gastric acid is rather deleterious, because it may spread the aspirate to previously unaffected lung areas and can wash out surfactant.

11. Steroids in the treatment of aspiration pneumonias have not been shown to be clinically ineffective. The administration of corticosteroids is controversial and most likely does not yield benefit or improvement of long-term outcome after aspiration. Application of β2 sympathomimetics improves bronchospastic symptoms and may improve the removal of airway edema.

12. The cornerstones of the treatment of the harmful consequences of pulmonary aspiration are symptomatic measures, such as oxygen application, mechanical ventilation with PEEP, and antibiotic therapy only in case of pneumonia.
13. Prevention of macroaspiration during general anesthesia include the following principles:

a) Identification of the patient at risk
b) Skilled and well-prepared personnel (staff anesthesiologist and specialized nurse)
c) Relief of gastric pressure in case of increased contents (i.e., ileus)
d) Maintaining lower esophageal sphincter competence (e.g., removal of the nasogastric tube before induction of anesthesia)
e) In the obstetric patient, alkalization of gastric acid prior to induction of anesthesia
f) Rapid sequence induction including application of cricoid pressure

References


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**SEVERE ASTHMA—DIFFERENT PHENOTYPES**

It is imperative to use a recognized common definition of severe asthma and to distinguish other terms and definitions that are usually mixed in this definition or used as synonyms. This is because of the complexity of asthma as a disease, which is mostly a collection of different phenotypes, rather than a single, specific disease with a unifying pathogenic mechanism [1]. Various clinical definitions have been proposed through national and international guidelines, working groups, and workshops, which incorporate symptoms, lung function, exacerbations, and, in many cases, specific use of high-dose corticosteroids (2–5). In the original European Network description, patients with severe asthma were defined as those who were difficult to control after evaluation and treatment by an asthma specialist for a year or more (4,6).

The NAEPP (National Asthma Educational and Prevention Program) (3) and GINA (Global Initiative for Asthma...