Complications of managing the airway

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The inability to secure the airway, with consequent failure of oxygenation and ventilation, is a life-threatening complication. Failure of oxygenation leads to hypoxia followed by brain damage, cardiovascular dysfunction, and finally death. Time is a very crucial factor in this context. Complications vary widely in severity; while some are dramatic and immediately life-threatening (unrecognized esophageal intubation), others can be severe and long-lasting (nerve injuries) or mild and short-lived (sore throat). To minimize injury to the patient, the anesthesiologist should examine the patient’s airway carefully, identify any potential problems, devise a plan that involves the least risk for injury, and have a back-up plan immediately available. Each anesthesiology department should establish guidelines/algorithms specific to their institution. Unfortunately, a reliable test for detecting all patients at risk does not exist.

Key words: oxygenation; ventilation; intubation; complications.

Difficulty in managing the airway is the most important cause of major anesthesia-related morbidity and mortality. In the closed claims analysis of the American Society of Anesthesiologists (ASA), 6% of all claims concerned airway injury.1 Difficult intubation was a factor in only 39% of airway injury claims; 87% of the airway injuries were temporary, and 8% resulted in death. In 21% of these claims, the standard of care was not performed. The incidence of affected anatomical structures is shown in Table 1. Female gender, elective surgery and outpatient procedures showed a higher proportion of injury, whereas there was no difference regarding ASA status or obesity.
COMPLICATIONS WITH SUPRAGLOTTIC DEVICES

Mask ventilation

The maximum risk of airway problems presents during the ‘cannot intubate, cannot ventilate’ situation.\(^2,3\) Difficult mask ventilation is an underestimated aspect of the difficult airway. The ability to ventilate and oxygenate the patient sufficiently using a mask is essential. Face masks should be completely free of residual cleansing agents, as these can cause serious mucosal, skin or eye injury (conjunctivitis, burning, irritation) and tongue swelling (allergic glossitis).

While applying a mask to a patient’s face, soft tissue damage may occur if the tissue is subjected to excessive pressure. Care must be taken to avoid contact with the eyes to prevent corneal abrasions, retinal artery occlusions, or blindness. Excessive pressure on the mandible may damage the mandibular branch of the facial nerve, resulting in transient facial nerve paralysis. Pressure on the mental nerves has been implicated in causing lower-lip numbness. Oropharyngeal airways must be gently inserted into the mouth to avoid injury (broken teeth or mucosal tears). Improper placement may worsen airway obstruction by forcing the tongue backward. Equal care should be given to the placement of nasopharyngeal airways to avoid epistaxis.

During the course of induction, the lifting pressure applied to the angle of the mandible is sometimes sufficient to subluxate the temporomandibular joint. Patients may experience persistent pain or bruising at these points, and may even have chronic dislocation of the jaw which may cause severe discomfort.

Positive airway pressure can force air into the stomach instead of the trachea. Gastric distention may occur, causing more difficult ventilation and an increased propensity for regurgitation. For these reasons, mask ventilation should not be performed in non-fasted or morbidly obese patients or patients with intestinal obstruction, trendelenberg position, tracheo-esophageal fistula, or massive oropharyngeal bleeding. Cricoid pressure can help reduce the amount of air being forced into the stomach and limit the likelihood of vomiting. Nonetheless, gastric rupture has been reported with face mask ventilation.

Recently, it was shown that independent risk factors for difficulties with mask ventilation include the presence of beard, body mass index \(> 26 \text{ kg/m}^2\), lack of teeth, age \(> 55\) years, and history of snoring.\(^4\) Patients with trauma to the pharyngeal mucosa

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**Table 1. Severity of injury and standard of care.**

<table>
<thead>
<tr>
<th>Site of injury</th>
<th>Severity of injury</th>
<th>Standard of care</th>
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<tr>
<td></td>
<td>Non-death (n (%))</td>
<td>Death (n (%))</td>
</tr>
<tr>
<td>Larynx (n = 87)</td>
<td>86 (99)</td>
<td>1 (1)</td>
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<tr>
<td>Pharynx (n = 51)</td>
<td>46 (90)</td>
<td>5 (10)</td>
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<tr>
<td>Esophagus (n = 48)</td>
<td>39 (81)</td>
<td>9 (19)</td>
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<tr>
<td>Trachea (n = 39)</td>
<td>33 (85)</td>
<td>6 (15)</td>
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<tr>
<td>TMJ (n = 27)</td>
<td>27 (100)</td>
<td>0</td>
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<tr>
<td>Nose (n = 13)</td>
<td>13 (100)</td>
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may be at risk for subcutaneous emphysema. Whenever continuous positive airway pressure is applied to patients with basilar skull fractures, pneumocephalus may occur.

**Laryngeal mask airway**

The laryngeal mask airway (LMA) has been used in millions of patients and is accepted as a safe technique. Muscle relaxation is unnecessary, laryngoscopy is avoided, and hemodynamic changes are minimized during insertion. However, numerous complications are associated with the LMA. The tip of the epiglottis can be folded into the vocal cords during placement, inducing labored breathing, coughing, laryngospasm, and sometimes complete airway obstruction. Excess lubricant can promote coughing or laryngospasm. A known disadvantage of the device is its inability to protect against pulmonary aspiration and regurgitation of gastric contents. The incidence of regurgitation of small amounts of gastric contents was reported to be as high as 25%. However, the overall risk of aspiration and regurgitation using the LMA is in the same low range as for endotracheal intubation when the indications and contraindications of LMA usage are respected.

Laryngospasm and coughing may result from inadequate anesthesia, tip impaction against the glottis, or aspiration. The incidence of sore throat is reported to be 7–12%, an incidence similar to that seen with oral airways. The incidence of failed placement is 1–5%, although this tends to decrease with increasing operator experience. The LMA cuff is permeable to nitrous oxide and carbon dioxide, which results in substantial increases in cuff pressure and volume during prolonged procedures. Increased intra-cuff pressures may increase the incidence of postoperative sore throat or cause transient dysarthria. Edema of the epiglottis, uvula, and posterior pharyngeal wall may at worst lead to airway obstruction. Hypoglossal nerve paralysis, post-obstructive pulmonary edema, tongue cyanosis, transient dysarthria, tension pneumoperitoneum and gastric rupture have also been reported.

To minimize the risk of aspiration and regurgitation, the LMA-Proseal—a laryngeal mask with an esophageal vent—was developed. Cases of gastric insufflation and aspiration have been reported when this device was malpositioned. Branthwaite reported a case of laryngeal perforation leading to mediastinitis and patient death following blind insertion of an endotracheal tube through the intubating laryngeal mask airway (ILMA).

Contraindications for using an LMA include non-fasted patients, morbid obesity, necessity for high inspiratory pressures (>20–25 cmH₂O) in the presence of low pulmonary compliance or chronic obstructive pulmonary disease (COPD), acute abdomen, hiatal hernia, Zenker’s diverticulum, trauma, intoxication, airway problems at the glottic or infraglottic level, and thoracic trauma.

**Esophageal/tracheal combitube**

The Esophageal/Tracheal Combitube (Combitube) is an esophagotracheal double-lumen airway designed for emergency use when standard airway management measures have failed. Disregarding recommendations for use of the proper size of the device (depending on the patient’s height) may cause injury to the esophagus. Contraindications for using a Combitube are intact gag reflexes, ingestion of caustic substances, known esophageal disease, airway problems at the glottic or infraglottic level, and latex allergy.

Obstruction of the upper airway, subcutaneous emphysema, pneumomediastinum and pneumoperitoneum during resuscitation settings, and several cases of esophageal
lacerations or perforation have been reported.\textsuperscript{11–13} The incidence of sore throat with the use of this device is high.

**Other Supraglottic Airway Devices**

There are many other devices available for managing the airway at the supraglottic level: laryngeal tube, ambu laryngeal mask, soft seal laryngeal mask, laryngosed streamlined linear of the pharynx, and perilaryngeal airway. Most clinical problems are similar to those found with the LMA (for example, aspiration) and result from dislodgement, overfilling of cuffs, and insufficient depth of anesthesia.

**COMPLICATIONS WITH INTUBATION**

**Endotracheal intubation**

The main injury associated with use of laryngoscopes is damage to the teeth. Laryngoscopy usually requires deep anesthesia because it causes stimulation of physiological reflexes, and adverse respiratory, cardiovascular and neurological effects are possible (Table 2). Patients with a history of hypertension, pregnancy-induced hypertension and ischemic heart disease are at additional risk. Deep anesthesia, application of topical anesthetics, drug prevention of the sympathoadrenal response using atropine or intravenous lidocaine, as well as minimizing mechanical stimulation, attenuate these adverse effects. Rigid optical instruments such as the Bonfils Retromolar Intubation Fiberscope, the Bullard, Upsher and WuScope laryngoscopes and the rigid bronchoscope have similar complications.

There is a close relationship between \textit{difficult} intubation and \textit{traumatic} intubation. In cases of \textit{difficult} intubation (poor view of the vocal cords), the practitioner tends to

<table>
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<tr>
<th>Table 2. Pathophysiological effects and complications of laryngoscopy and endotracheal intubation.</th>
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<td>1. Cardiovascular system</td>
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<tr>
<td>Dysrhythmia</td>
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<tr>
<td>Hypertension</td>
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<td>Myocardial ischemia and infarction</td>
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<td>2. Respiratory system</td>
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<tr>
<td>Hypoxia</td>
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<tr>
<td>Hypercarbia</td>
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<tr>
<td>Laryngeal spasm</td>
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<tr>
<td>Bronchospasm</td>
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<tr>
<td>3. Central nervous system</td>
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<tr>
<td>Increased intracranial pressure</td>
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<tr>
<td>4. Eye</td>
</tr>
<tr>
<td>Increased intraocular pressure</td>
</tr>
<tr>
<td>5. Miscellaneous</td>
</tr>
<tr>
<td>Toxic and adverse effects of drugs related to laryngoscopy and intubation</td>
</tr>
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</table>

increase the lifting forces of the laryngoscope blade, which may lead to damage of the intraoral tissues and osseous structures. A difficult intubation may thus become a traumatic intubation. Use of increasing force may induce swelling, bleeding or perforation as the intubation becomes more and more difficult and may turn into a 'cannot intubate' and possibly even a 'cannot ventilate' situation. If intubation fails after three attempts, another technique should be used in accordance with the airway management algorithm.14

Lip injuries include lacerations, hematomas, edema, and teeth abrasions. They are usually secondary to inattentive laryngoscopy performed by inexperienced practitioners. These lesions are annoying to the patient, but are usually self-limited.

The incidence of dental injuries associated with anesthesia is greater than 1:4500.15 Maxillary central incisors are at most risk. Fifty percent of dental trauma happens during laryngoscopy, 23% following extubation, 8% during emergence, and 5% in the context of regional anesthesia. Dental trauma is also associated with LMA devices and oropharyngeal airways. Dental injuries are most common in small children, patients with periodontal disease or fixed dental work, and patients in whom intubation is difficult. Pre-existing dental pathology (protrusion of the upper incisors, carious teeth, paradentosis or periodontitis) should be thoroughly explored before the induction of anesthesia, and the patient must be advised of the risk of dental damage. Although tooth guards may possibly obstruct vision, their use may be indicated in certain situations.

In the event that an entire tooth is avulsed, it should be retrieved and saved in a moist gauze or in normal saline. Aspiration of the tooth may induce serious complications requiring bronchoscopy for removal. With a rapid response from an oral surgeon or dentist, an intact tooth can often be reimplanted and saved, but only when performed within 1 hour.

Massive tongue swelling, or macroglossia, has been reported in numerous instances in both adult and pediatric patients. Although macroglossia (occasionally of life-threatening proportions) is associated with angiotensin-converting enzyme inhibitors, some cases have occurred while a bite block was in place and when there was substantial neck flexion during endotracheal intubation. Loss of tongue sensation is possible after a compression injury to the lingual nerve during forceful laryngoscopy or after LMA placement with an over-inflated or malpositioned cuff. Reduced sense of taste and cyanosis of the tongue caused by lingual artery compression are additional injuries that may be caused by an oversized, malpositioned, or over-inflated LMA.

Damage to the uvula (edema and necrosis) is usually associated with an endotracheal tube, oro- and nasopharyngeal airways, an LMA, or an alternative supraglottic airway device, or by overzealous use of a suction catheter. Sore throat, odynophagia, painful swallowing, coughing, foreign body sensation and serious life-threatening airway obstruction have been reported.

The incidence of sore throat after intubation is approximately 40% and >65% when blood is noted on the airway instruments.16 The incidence of sore throat following LMA placement is 20–42%, depending on cuff inflation, and 8% with face mask ventilation.17 Fortunately, pain on swallowing usually lasts no more than 24–48 hours. Topical anesthesia, such as lidocaine jelly, applied to the endotracheal tube does not lessen the incidence of this problem and may actually worsen it.

Trauma to the larynx and vocal cords is not uncommon following endotracheal intubation. It depends on the experience and skill of the intubator, as well as the degree of difficulty. In one large study, 6.2% of patients sustained severe lesions, 4.5% developed
a hematoma of the vocal cords, 1% developed a hematoma of the supraglottic region, and 1% sustained lacerations and scars of the vocal cord mucosa. Recovery is generally prompt with conservative therapy, although hoarseness may appear even after a 2-week interval. Granulations usually occur as a complication of long-term intubation but may occur with short-term intubation as well. Injuries of the laryngeal muscles and suspensory ligaments are also possible. Patients with hoarseness should be examined preoperatively by an ENT specialist.

Arytenoid dislocation and subluxation have been reported as rare complications. Mitigating factors include traumatic and difficult intubations, repeated attempts at intubation, and attempted intubation using blind techniques such as light-guided intubation, retrograde intubation, and the use of the McCoy laryngoscope. However, these complications are also found after easy intubations. Early diagnosis and operative repositioning of arytenoid dislocation is necessary, because fibrosation with consecutive malposition and ankylosis may occur after 48 hours.

Numerous investigators have reported vocal cord paralysis after intubation with no other obvious source of injury. Paralysis may be unilateral (hoarseness) or bilateral (respiratory obstruction). The most likely source of injury is an endotracheal tube cuff, malpositioned in the subglottic larynx that presses on the recurrent laryngeal nerve. Permanent voice change after intubation because of external laryngeal nerve trauma occurs in up to 3% of patients undergoing surgery in sites other than the head or neck. However, vocal cord paralysis after intubation is usually temporary. Its incidence may be decreased by avoiding over-inflation of the endotracheal tube cuff and by placing the endotracheal tube at least 15 mm below the vocal cords. Vocal cord paralysis may also have a central origin. Eroded vocal cords may adhere together, eventually forming synechiae. Surgical correction is usually necessary.

Tracheobronchial trauma has various causes. Injury may result from an over-inflated endotracheal tube cuff, inadequate tube size, malpositioned tube tip, laryngoscope, stylet, tube exchanger or related equipment. Predisposing factors include anatomic difficulties, blind or hurried intubation, inadequate positioning, poor visualization, or—most commonly—inexperience on the part of the intubator. Edema after extubation limits the lumen diameter and increases airway resistance. Small children are most susceptible to this problem; almost 4% of children 1–3 years of age develop croup following endotracheal intubation. Tracheal rupture, especially after emergency intubation, has been reported, as well as a bronchial rupture secondary to use of an endotracheal tube exchanger.

Endotracheal tube cuffs inflated to a pressure greater than that of the capillary perfusion may devitalize the tracheal mucosa, leading to ulceration, necrosis, and loss of structural integrity. Ulceration will occur at even lower pressures in hypotensive patients. The need for increasing cuff volumes to maintain a seal is an ominous sign of tracheomalacia. The various nerves in this region of the neck are also at risk. Erosion of the endotracheal tube into the paratracheal nerves may result in dysphonia, hoarseness, and laryngeal incompetence. Tracheomalacia results from erosion confined to the tracheal cartilages. It is imperative that the anesthesiologist inflate the cuff of the endotracheal tube only as much as is necessary to ensure an adequate airway seal. If using nitrous oxide during a lengthy surgical procedure, the pressure in the endotracheal tube cuff should be checked by a cuff pressure control device. The cuff pressure should not exceed 25 cmH₂O.

The incidence of granulomas has been reported to range from 1:800 to 1:20,000. Several months after prolonged endotracheal intubation, tracheal stenosis and fibrosis...
may occur, typically at the site of an inflated cuff, sometimes at the location of the endotracheal tube tip. Dilatation of the stenosis is curative if the stenosis is caught in its early stages. However, surgical correction may be necessary once the tracheal lumen has been reduced to 4–5 mm.

Supraglottic complications induced by long-term intubation may be prevented by early tracheostomy. There is no evidence about the ideal time for tracheostomy in long-term ventilated patients.

Barotrauma, inducing pneumomediastinum or tension pneumothorax, results from high-pressure distention of intrapulmonary structures. High-flow insufflation techniques are most often associated with barotrauma. Such problems are common in microlaryngeal surgery in which jet ventilation is used.

Laryngoscopy and cuffed supraglottic airway devices may cause periodical or permanent nerve injury. Transient weakness, numbness, or paralysis of the tongue can occur after laryngoscopy, presumably because of pressure on the laryngeal and hypoglossal nerves. Damage of the internal branch of the superior laryngeal nerve during difficult intubation leading to anesthetia of the upper surface of the larynx may occur. Transient palsies may occur when an LMA device is used because it affects the hypoglossal and lingual nerves. The authors personally observed five cases of hyposmia following uncomplicated nasotracheal intubation for head and neck surgery, and one case of anosmia despite the use of preformed, warmed and lubricated nasotracheal tubes. The hyposmias completely recovered in 3–6 months, whereas the anosmia became permanent.

Airway management techniques such as chin lift, jaw thrust and direct laryngoscopy transmit movement to the cervical spine and may induce cervical spine injury. Attempts to hyperextend the necks of patients with ankylosing spondylitis may result in cervical fractures and quadriplegia. Special attention should be given to patients with C1 or C2 fractures because any degree of extension might compromise spinal cord function.

Several conditions—such as Down syndrome, Arnold-Chiari malformation and rheumatoid arthritis—are associated with atlantoaxial instability. Also, elderly patients and those with pathological fragility—such as connective tissue disorders, lytic bone tumors and osteoporosis—should be intubated with caution. Awake fiberoptic intubation should be considered in all cases where time is not crucial.

Corneal abrasions are the most common eye complications that occur during general anesthesia. They are primarily caused by a facemask being placed on an open eye or by the eyelids not being completely closed during anesthesia. Prevention consists of vigilance on the part of the anesthesiologist and application of adhesive tape over the closed eyelids, especially during head and neck surgery. Although these injuries typically heal within 24 hours, they are usually painful and can lead to corneal ulceration. An immediate ophthalmologic consultation is recommended. In the presence of a penetrating eye injury, an increase in intraocular pressure should be avoided by adequate anesthesia.

Temporomandibular joint injury (TMJ) is a rare but serious complication. Rupture of the lateral ligament is possible. TMJ injuries are caused by increasing force during laryngoscopy to optimize the view of the glottis. As a result, limited mouth opening, pain in the joint, lateral deviation of the mandible (in case of unilateral luxation), protrusion of the mandible, and lockjaw may occur. Most of the cases of TMJ injury have not been associated with difficult airway management. In the ASA closed claims database, only 17% of the claims had documented pre-existing TMJ disorders, such as pain.
Nasotracheal intubation

Nasotracheal intubations are potentially hazardous. In the presence of basilar skull fractures or certain facial fractures (such as LeFort II or III fractures) the endotracheal tube may be inadvertently introduced into the cranial vault. A case of an uncomplicated nasotracheal intubation in which asystole occurred after the tube was introduced into the orbit has been reported. Substantial facial trauma and evidence of basilar skull fractures are usually considered to be contraindications for this technique. Nasotracheal tubes may also dissect backward and run behind the posterior pharyngeal wall.

Nasal intubation may cause lacerations of the nasal mucosa, hemorrhage, and epistaxis. Nosebleeds are common but are relatively easy to prevent. It is paramount that the nasal mucosa be vasoconstricted before instrumentation (0.5% phenylephrine). To minimize the chance of nasal injury, a small endotracheal tube that has been lubricated well and presoaked in warm water (to increase its pliability) should be used. Should epistaxis occur, it is recommended that the endotracheal tube cuff be inflated and remain in the nostril to tamponade the bleeding.

Additional complications caused by nasotracheal intubation include dislodgement of nasal polyps or turbinates, adenoidectomy, injury of the nasal septum, and perforation of the priform recess or epiglottic vallecula. In case of injury to the priform recess, damage of the internal branch of the superior laryngeal nerve (which supplies the epiglottis and soft tissue of pharynx and larynx) or superior laryngeal vessels may occur. Delayed complications of nasotracheal intubation are pharyngitis, rhinitis, and synechia between the nasal septum and inferior turbinate bone. Distortion of the nares can lead to the development of ischemia, skin necrosis, or nasal adhesions.

Even in the absence of gross trauma, the mechanical damage to the superficial epithelial layers caused by nasal intubation results in mucociliary slowing and bacteremia. Even short-term intubation has been reported to cause nasal septal and retropharyngeal abscesses. Acute otitis media has been reported to occur in 13% of nasally intubated neonates. Paranasal sinusitis has also been reported, most commonly with nasal intubation for more than 5 days.

Fractures of the frontal part of the skull base with cerebrospinal rhinorrhea, intranasal abscesses or abscesses with intranasal expansion, choanalatresia, hyperplastic tonsils, tendency to uncontrollable nasal bleeding and coagulopathies are contraindications for nasotracheal intubation.

Esophageal intubation

When visualization of the glottis is difficult, the endotracheal tube may inadvertently be introduced into the esophagus. Esophageal intubation is more common with inexperienced practitioners but may also occur in experienced hands. Intubating the esophagus is not disastrous, but failure to detect and correct the condition is. A closed claims analysis of adverse anesthetic events reported that 18% of respiratory-related claims involved esophageal intubation. Preoxygenation can help alleviate this problem by allowing a longer apneic period for endotracheal intubation and by delaying the onset of hypoxemia.

End-tidal \( \text{CO}_2 \) monitoring is essential in confirming endotracheal placement of the endotracheal tube. Capnography should be available wherever intubation is performed. Fiberoptic bronchoscopy is another safe method for confirming the proper position of
an endotracheal tube. All other signs, such as equal bilateral breath sounds, symmetric bilateral chest wall movement, epigastric auscultation and observation of tube condensation, are potentially misleading.

Perforation of the esophagus and retropharyngeal abscess has been reported on several occasions. It is most likely to occur when inexperienced clinicians handle emergency situations, when intubation is difficult, or in the presence of esophageal pathology. Subcutaneous emphysema, pneumothorax, fever, cellulitis, cyanosis, sore throat, mediastinitis, empyema, pericarditis, and death can occur. The mortality rate of mediastinitis is >50%.

**Bronchial intubation**

Bronchial intubation often occurs and is sometimes difficult to identify. Asymmetric chest expansion, unilateral presence of breath sounds (usually on the right side), and arterial blood gas abnormalities are diagnostic features. Bronchial intubation (most commonly right-sided) is more common in infants and children because of the small distance between the carina and the glottis. If bronchial intubation goes undetected, it may lead to atelectasis, hypoxia, and pulmonary edema. Fiberoptic bronchoscopy is the best method for detecting the proper position of the endotracheal tube.

The tip of the endotracheal tube may be moved during flexion or extension of the patient’s head as the patient is positioned for surgery. The tip of the endotracheal tube can move an average of 3.8 cm (up to 6 cm) toward the carina when the neck is moved from full extension to full flexion. When inadvertent bronchial intubation is discovered, the endotracheal tube should be withdrawn and the lungs hyperinflated sufficiently to expand any atelectatic areas.

Bronchial intubation is deliberately achieved in thoracic surgery with double-lumen tubes. Even in the best of hands, tracheobronchial injuries occur during double-lumen intubation. Bronchial rupture is a very serious complication. Using double-lumen tubes that are too large may cause bronchial trauma.

**Maintenance of the endotracheal tube**

Airway obstruction can occur at any time during general anesthesia, particularly in prolonged surgery or in patients with predisposing anatomic abnormalities. Airway obstruction can result from diverse factors, including a sharp bend or kink in the endotracheal tube or a tube that is obstructed with mucus, blood, foreign bodies, or lubricant. Reinforced wire tubes may be used to avoid kinking, and their use is recommended in prolonged procedures, oral surgery or during surgery associated with special positioning of the patient. Nitrous oxide can cause expansion of gas bubbles trapped in the walls of an endotracheal tube, leading to airway obstruction.

The cuff of an endotracheal tube can also cause airway obstruction. An over-inflated cuff may compress the bevel of the endotracheal tube against the tracheal wall, occluding its tip. The cuff may also herniate over the tip of the endotracheal tube. When faced with any of these problems, the best solution is to pass a suction catheter or a fiberoptic bronchoscope down the lumen of the endotracheal tube and attempt to clear it. If the endotracheal tube is totally obstructed, passage of a stylet should be attempted. Total obstruction that cannot be remedied quickly requires removal of the endotracheal tube followed by reintubation. A common and serious complication of endotracheal intubation is disconnection of the endotracheal tube from
the anesthesia circuit. This was identified as the most common critical incident in a study of anesthesia-related human errors and equipment failures. Alarms to signal airway disconnection are included on all modern anesthesia machines.

Leaks in an air delivery circuit can cause hypoventilation and dilution of the inspired gases by entry of room air into the system.

Lasers are frequently used in the operating room to ablate benign and neoplastic tissues in the airway. Laser fire is a very serious complication. The use of special laser guarded or metal tubes is recommended, and all inflammatory materials such as dentures and nasogastric tubes should be removed. One of the most catastrophic events associated with their use is an airway fire, which occurs when the laser ignites the endotracheal tube. The heat and fumes of the burning plastic may cause severe damage to the airway. Treatment consists of immediately disconnecting the circuit from the endotracheal tube and removing the burning tube from the airway. The fire should be extinguished with saline, and the patient should be supported by facemask ventilation. The airway should be evaluated for damage with bronchoscopy. Numerous precautions can reduce the risk of an airway fire. If possible, placement of an endotracheal tube may be avoided (ventilating laryngoscope, jet ventilation system, intermittent apneic ventilation). Endotracheal tubes may be protected by wrapping them in non-combustible tapes; alternatively, red rubber or metal non-combustible endotracheal tubes may be used. Cuff ignition can be minimized by filling the cuff with saline solution instead of air. Nitrous oxide should not be used in laser surgery because it supports combustion. It is recommended that inert gases, such as helium or nitrogen, be used instead of nitrous oxide, and that concentrations of oxygen do not exceed 40%.

**Special techniques**

*Fiberoptic intubation* is one of the most common methods utilized in cases of anticipated difficult intubation. Intubation with a fiberoptic bronchoscope should not be attempted when the pharynx is filled with blood or saliva, when inadequate space exists within the oral cavity, or when time is critical and creating a surgical airway is the priority. Relative contraindications include marked tissue edema, distortion of the oropharyngeal anatomy, blood in the airway, soft tissue traction, or a severe cervical flexion deformity.

Potential complications associated with the fiberoptic bronchoscope include bleeding, epistaxis (especially if a nasal airway is attempted), laryngotracheal trauma, laryngospasm, bronchospasm, and aspiration of blood, saliva, or gastric contents. Another possible hazard is associated with the practice of insufflating oxygen through the suction channel. Subcutaneous emphysema of the pharynx, face, and periorbital regions may occur in case of injury of the pharyngeal mucosa.

The *lighted stylet* may be used to facilitate intubation under both local and general anesthesia. Sore throat, hoarseness, arytenoid subluxation and mucosal damage are possible. Heat damage to the tracheal mucosa in prolonged intubation is a potential risk with inappropriate handling.

**COMPLICATIONS WITH INFRAGLOTTIC PROCEDURES**

Infraglottic airway access is the last step in the ASA airway management algorithm. In cases in which endotracheal intubation is impossible and the patient's condition deteriorates into a 'cannot ventilate, cannot intubate' situation, lifesaving steps must be
immediately undertaken. Despite possible (and severe) complications, there are no contraindications for infraglottic procedures in these critical situations. The most severe complication is failure to establish an airway before brain damage or death results.

**Translaryngeal airway**

*Retrograde wire intubation* is an excellent technique for securing a difficult airway. The procedure takes some time to perform and should not be considered under emergency circumstances unless the practitioner is extremely experienced in the technique. Bleeding may occur at the site of the tracheal puncture. Cases of severe hemoptysis with resultant hypoxia, cardiopulmonary arrest, dysrhythmias and death following retrograde wire intubation have been reported. Subcutaneous emphysema localized to the area of the transtracheal needle puncture is common. In severe cases pneumomediastinum and pneumothorax may occur.\(^{21}\) Laryngospasm may result from irritation by the retrograde wire unless the vocal cords are anesthetized or relaxed. Other, less common complications include esophageal perforation, tracheal hematoma, laryngeal edema, infection, tracheitis, tracheal fistula, trigeminal nerve injury, and vocal cord damage.\(^{32}\)

In both the *surgical cricothyroidotomy* (using a scalpel) and the *needle cricothyroidotomy* (using a needle-set) procedures, the cricothyroid membrane requires penetration. Acute complications are bleeding (especially during surgical cricothyroidotomy), misplacement of the tube (especially after needle cricothyroidotomy) and barotrauma. Subcutaneous emphysema, pneumothorax, pneumomediastinum and pneumopericardium tube malposition or failure of airway access, wound infection, displaced cartilage fractures and laryngotracheal separation may occur during this technique.

Granulation tissue around the tracheostomy site, subglottic stenosis, massive laryngeal mucosa trauma, endolaryngeal hematoma and laceration, vocal cord paralysis, hoarseness, and thyroid cartilage fracture with dysphasia are direct long-term complications. All emergency translaryngeal airways should be eventually changed to a formal tracheostomy. Subglottic stenosis is a delayed complication, especially in children.

**Transtracheal airway**

*Transtracheal jet ventilation (TTJV)* is accomplished by introducing a small percutaneous catheter into the trachea and insufflating the respiratory tract with high-pressure oxygen over a jet ventilator or a hand jet device. Although this technique may be helpful in critical situations, life-threatening problems are associated with its use.

If the TTJV catheter is displaced from the trachea, subcutaneous emphysema, hypoventilation, pneumomediastinum, pneumothorax, severe abdominal distention, or death may result. Oxygen delivered through a transtracheal catheter must be able to escape the lungs freely or over-distention and pulmonary rupture may occur. In cases of total airway obstruction, the risk for pneumothorax is greatly increased because gas cannot escape from the lungs. Strong consideration should be given to placing a second transtracheal ‘egress’ catheter in these circumstances or simply avoiding this technique altogether. Laryngospasm can also impede the outward flow of oxygen from the trachea. Inadvertent placement of a gas delivery line into the gastrointestinal tract may also result in complications (gastric rupture, esophageal perforations, bleeding, hematoma, and hemoptysis). Damage to the tracheal mucosa may occur in patients who are managed with long-term TTJV, especially if the gas is not humidified.
Although **percutaneous dilatational tracheostomy** (PCDT) is not usually recommended for emergency use, it appears to be suitable for emergency situations in skilled hands. Many different sets are available. Bleeding, subcutaneous and mediastinal emphysema, pneumothorax, airway obstruction, aspiration, infection, accidental extubation and death are early complications. Delayed complications are tracheal stenosis, scars, hoarseness, tracheoesophageal and tracheocutaneous fistulae.

**Minitracheostomy** occasionally results in excess bleeding into the airway, necessitating progression to a full surgical tracheostomy. Air embolism, subcutaneous emphysema, pneumomediastinum and tension pneumothorax may occur.

**Subglottic stenosis** is a complication of long-term intubation. This is much more difficult to repair and frequently results in permanent speech impairment or laryngeal damage. A tracheostomy tube can cause tracheal erosion, particularly into the esophagus (tracheoesophageal fistula) or the brachiocephalic artery. Accidental extubation and dislodgement of the cannula occur occasionally, most commonly in the early postoperative period. Infection, mediastinal sepsis, tracheal stenosis and tracheomalacia are rare late complications.

**RESPONSES TO INTUBATION**

The larynx has the greatest afferent nerve supply of the airway. Airway reflexes require suppression for stress-free airway management, especially for endotracheal intubation. Intensive autonomic responses may occur during placement, maintenance and removal of all airway devices.

**Hemodynamic changes**

Direct laryngoscopy and endotracheal intubation are both stimulating procedures that may cause intense autonomic responses. Tachycardia, hypertension, dysrhythmias, bronchospasm, and bronchorrhea are common; hypotension and bradycardia occur less often. Patients with pre-existing hypertension are at higher risk.

The sympathetically mediated responses to mechanical stimulation of larynx, trachea-carina and bronchi may be blocked by topical or intravenous lidocaine, by giving opioids or short-acting selective \( \alpha_1 \)-blockers before laryngoscopy and intubation. Large hemodynamic responses have to be prevented in patients with coexisting cardiovascular disease. More than 11% of patients with myocardial disease develop some degree of myocardial ischemia during intubation. The key element is to provide an adequate depth of anesthesia with either intravenous or inhalation agents before instrumentation of the airway.

Fiberoptic intubation performed under adequate local anesthesia and conscious sedation is an appropriate technique to prevent major hemodynamic changes during intubation. The lowest cardiovascular responses were registered in patients after insertion of a LMA.

**Laryngospasm and bronchospasm**

Due to reflex responses to stage II of anesthesia, **laryngospasm** can occur during intubation. Laryngospasm involves more than spastic closure of the vocal cords. An infolding of the arytenoids and the aryepiglottic folds occurs; these structures
are subsequently covered by the epiglottis. This explains why a firm jaw thrust can sometimes break the spasm: the hyoid is elevated, thereby stretching the epiglottis and aryepiglottic folds to open the forced closure. Malpositioning due to incorrect insertion techniques, as well as inadequate depth of anesthesia during LMA insertion, may induce laryngospasm. It may also occur during fiberoptic intubation performed in non- or sub-anesthetized laryngeal structures. Positive mask pressure may help; treatment with a short-acting muscle relaxant may be necessary to break the spasm.

Tracheal irritation from the endotracheal tube can cause bronchospasm that is sufficiently severe to prevent air movement throughout the lungs. The incidence of intraoperative bronchospasm is almost 9% with endotracheal intubation, 0.13% with an LMA, but close to 0% with mask ventilation. Poor correlation is seen with age, sex, duration or severity of reactive airway disease, or duration of anesthesia. Factors that may contribute to bronchospasm include inhaled stimulants, release of allergic mediators, viral infections, exercise, or pharmacologic factors (including $\alpha$-blockers, prostaglandin inhibitors, and anticholinesterases). Bronchospasm may also occur during fiberoptic intubation.

The spasm can be treated with inhalation of epinephrine or isoproterenol or an $\alpha_2$-agonist (such as albuterol, metaproterenol, or terbutaline) or by deepening the level of a volatile anesthetic.

**Coughing and bucking**

Two additional adverse responses to intubation are coughing and bucking. Such responses are potentially hazardous in cases of increased intracranial pressure, intracranial vascular anomalies, open-globe injuries, ophthalmologic surgery, or in cases in which increased intra-abdominal pressure could rupture an abdominal incision.

Coughing and bucking occur less frequently with the LMA; however, in the presence of lubricant globules on the anterior surface of the cuff, light anesthesia or malpositioning, these adverse reactions may be observed. The incidence of coughing, gagging and retching has been reported as 0.8% using an LMA with a fentanyl-propofol-O$_2$-N$_2$O-isoflurane technique.

**Vomiting, regurgitation and aspiration**

The overall incidence of aspiration during general anesthesia varies and has been reported as 1/2131 (in Sweden) to 1/14 150 (in France), and 1/3216 in the USA, with an associated mortality of 1/71 829 in the USA. A meta-analysis of publications concerning the LMA (547 publications) suggested that the overall incidence of pulmonary aspiration was approximately 2/10 000. An endotracheal tube and a Combitube are most effective in preventing pulmonary aspiration. To reduce the risk of pulmonary aspiration, some new designs of airway management devices were developed: the ProSeal-LMA and the Laryngeal Tube Suction™.

In any patient considered to have a full stomach, the likelihood of vomiting in response to irritation of the airway is increased, and aspiration of stomach contents is a constant concern. Aspiration leads to coughing, laryngospasm and bronchospasm, assuming that protective reflexes are intact. In consequence of these reactions, hypertonia, bradycardia, asystole and hypoxia may occur. The magnitude of the pulmonary reactions depends on the type and quantity of the aspirated material.
The Sellick maneuver, or cricoid pressure, has removed much of the fear of emergency intubation. Cricoid pressure is effective in raising the pressure in the upper esophageal sphincter, thus preventing aspiration.

**Intraocular and intracranial pressure**

With thiopental, etomidate and halothane anesthesia, an increase in intraocular pressure was observed during laryngoscopy as well as LMA insertion, but not with TIVA or remifentanil and sevoflurane. Decreases in intraocular pressures were observed under endotracheal intubation during general anesthesia with propofol and sevoflurane, both combined with remifentanil. Intraocular pressure may also increase during extubation.

Insertion of an LMA does not increase intraocular pressure in children after sevoflurane induction. Sufentanil is also effective in preventing an intraocular pressure increase caused by rapid-sequence induction with succinylcholine. It is extremely important that an increase in intraocular pressure should be avoided in patients with penetrating eye injury.

Intracranial pressure markedly and transiently rises during laryngoscopy and endotracheal intubation. Patients with head injury are at higher risk from this increase as it reduces cerebral perfusion and thus may increase secondary brain damage. Deep anesthesia during induction can prevent these adverse effects.

**Latex allergy**

Almost 17% of overall anaphylaxis in surgical procedures are related to latex anaphylaxis. To prevent anaphylaxis in patients during anesthesia and surgery, the patient’s history has to be carefully evaluated preoperatively. There is currently no therapy for latex allergy, and avoidance of latex-containing products is mandatory for predisposed individuals. Latex allergy is present in 8% of the general population in the USA, with a prevalence of 30% in health-care workers. There is an increased incidence of type I and type IV latex sensitivity in the general population. The prevalence of latex sensitivity among anesthesiologists is approximately 12.5% and of allergy 2.4%.

Patients with spina bifida, rubber industry workers, atopic patients, patients with a multiple surgery history and with certain exotic food allergies are most at risk. Contamination with latex in anesthesia is possible through direct contact by face mask, endotracheal and gastric tubes, gloves, syringes, electrodes; through inhalation from contaminated circuits and room air; and through the parenteral path with latex-containing intravenous administration sets.

Considerations for anesthesiologists handling patients with latex allergy are available at the ASA’s website [http://www.asahq.org/publicationsAndServices/latexallergy.pdf]. In a pediatric study, Nakamura et al found that a high percentage of children with home mechanical ventilation have undiagnosed latex allergy.

**COMPLICATIONS WITH EXTUBATION**

Primary and secondary responses to extubation are possible. The primary effects include local and systemic responses. The same responses that follow intubation may be observed at extubation. During intubation the patient is more protected by
anesthesia induction than during extubation, therefore the cardiovascular responses may be even more exaggerated. The most serious complication after extubation is the occurrence of acute airway obstruction. Decrease in consciousness, central respiratory depression, decrease in muscle tone, and tongue obstruction may lead to inspiratory or expiratory stridor, dyspnea, cyanosis, tachycardia, hypertension, agitation and sweating.

**Hemodynamic changes**

Hemodynamic changes, including a 20% increase in heart rate and blood pressure, occur in most patients at the time of extubation. Patients with cardiac disease, pregnancy-induced hypertension and increased intracranial pressure may be at particular risk for life-threatening ischemic myocardial episodes. Management consists of deep extubation or pharmacologic therapy.

**Laryngospasm**

Laryngospasm, a protective reflex mediated by the vagus nerve, is the most frequent cause of postextubation airway obstruction. It may be provoked by movement of the cervical spine, pain, vocal cord irritation by secretions, or sudden stimulation while the patient is still in a light plane of anesthesia. In a large study in 136,929 patients, the incidence of laryngospasm was 50/1000 in children with bronchial asthma and airway infection and 25/1000 in children in the age group of 1–3 months when endotracheal intubation had been performed.

The optimal course for dealing with laryngospasm is to avoid it. It is imperative that no saliva, blood, or gastric contents touch the glottis while the patient is lightly anesthetized. In cases in which laryngospasm is anticipated, the patient may undergo a deep extubation. A patient undergoing deep extubation should be placed in the lateral position with the head down to keep the vocal cords clear of secretions during emergence. Because suctioning of the oropharynx does not adequately remove secretions around the vocal cords, it is best to extubate patients during a positive-pressure breath. This is the procedure of choice in children too. In a recent study, children could be safely extubated in deep anesthesia from 1.5 minimum effective alveolar anesthetic concentration of either sevoflurane or desflurane.

In a survey of United States anesthesiologists deep extubation is performed by 64% of the interviewed practitioners. The study of Koga et al has shown that the rate of airway obstruction in patients extubated during deep anesthesia (17/20) was not higher than in patients extubated after regaining consciousness (18/20).

**Laryngeal edema**

Laryngeal edema is an important cause of postextubation obstruction, especially in neonates and infants. Supraglottic edema most commonly results from surgical manipulation, positioning, hematoma formation, overaggressive fluid management, impaired venous drainage, or coexisting conditions (such as pre-eclampsia or angioneurotic edema). Retroarytenoidal edema typically results from local trauma or irritation. Subglottic edema occurs most often in children, particularly neonates and infants. Factors associated with the development of subglottic edema include traumatic intubation, intubation lasting longer than 1 hour, bucking on the endotracheal tube, changes in head position, or tight-fitting endotracheal tubes. Laryngeal edema usually
presents as stridor within 30–60 minutes after extubation, although it may start as late as 6 hour postextubation. Regardless of the cause of laryngeal edema, management depends on the severity of the condition. Therapy consists of humidified oxygen, racemic epinephrine, head-up positioning, and occasionally reintubation with a smaller endotracheal tube. The practice of administering parenteral steroids with the goal of preventing or reducing edema is controversial.

**Bronchospasm**

In patients at risk for bronchospasm the timing of extubation is of equal concern. These patients may be extubated either during deep anesthesia (if this approach can be used safely) or when they are fully awake and the own airway reflexes are present. Although the degree of spasm in this condition may be severe, it is usually self-limited and short-lived.

**Negative-pressure pulmonary edema**

When airway obstruction occurs after extubation, such as in case of laryngospasm, negative-pressure pulmonary edema may occur in the spontaneously breathing patient. As a result of inspiratory effort against the closed glottis, these patients generate negative intrapleural pressure > 100 cmH₂O. Increases in left ventricular preload and afterload, altered pulmonary vascular resistance, increased adrenergic state, right ventricle dilatation, intraventricular septum shift to the left, left ventricular diastolic dysfunction, increased left heart loading conditions, enhanced microvascular intramural hydrostatic pressure, negative pleural pressure, and transmission to the lung interstitium may result in a marked increase in transmural pressure, fluid filtration into the lung and development of pulmonary edema.

The condition is seen within minutes after extubation. Management involves removing the obstruction, supporting the patient with oxygen, monitoring the patient closely, and reducing the afterload. Reintubation is rarely necessary; most cases resolve spontaneously without further complications.

**Aspiration**

Pulmonary aspiration of gastric contents is a constant threat for any patient who has a full stomach or is at risk for postoperative vomiting. Laryngeal function is altered for at least 4 hour after tracheal extubation. Depression of coughing reflexes, along with the presence of residual anesthetic agents, places almost all recently extubated patients at risk. Aspiration is probably more prevalent than is currently thought. Most cases are so minor that they do not affect the patient’s postoperative course. Reducing gastric contents by suctioning through a gastric tube and extubation with the patient placed in the lateral position with a head-down tilt is the safest protection against aspiration.

**Airway compression**

External compression of the airway after extubation may lead to obstruction. A rapidly expanding hematoma in close proximity to the airway is a very dangerous situation. This may occur after certain surgeries, such as carotid endarterectomy, and must be quickly diagnosed and treated before total airway obstruction occurs. Immediate surgical
re-exploration is indicated, although the airway concerns in these patients should be approached with extreme caution.

External compression of the neck, such as chronic compression of a goiter, may also result from tracheomalacia. Management includes reintubation, surgical tracheal support (stenting), or tracheostomy below the level of obstruction.

**Difficult extubation and accidental extubation**

Possible causes of difficult removal of the endotracheal tube are failure to deflate the cuff, use of an oversized tube, adhesion of the tube to the tracheal wall, or transfixation of the tube by an inadvertent suture to a nearby organ or a screw in the oro-maxillofacial surgery. Possible sequelae of these complications include airway leak, aspiration, tube obstruction, and trauma from attempts at forceful extubation. In most cases the problem arises from an inability to deflate the cuff, commonly as a result of failure in the cuff-deflating mechanism. Should this problem occur, the cuff should be punctured with a transtracheal needle. Forceful removal of an endotracheal tube with the cuff inflated may result in damage to the vocal cords and arytenoid dislocation.

Accidental extubation during anesthesia may occur with disposable tonsillectomy instruments and change of the patient's head position. Most accidental extubations were reported from intensive care unit patients. Complications after accidental extubation may include hypoxia, hypercarbic respiratory failure, aspiration, retention of pulmonary secretion, arrhythmia and tachycardia. Reintubation may be very difficult, especially after a difficult intubation. The use of the combitube or the LMA may be very useful in this critical situation.

**REFERENCES**


