There are also no claims for such injury since 2000 in the ASA Closed Claims Project that is designed to detect patterns of injury during anesthesia.[137] It should be stressed that during induction of anesthesia, there are many factors that may increase IOP such as crying, coughing, bucking, or straining particularly during suboptimal intubating conditions. All of these events increase IOP significantly more than succinylcholine. Based on the current evidence, succinylcholine may be used to facilitate endotracheal intubation in open eye injuries, despite its effect on IOP.

An alternative option for those at risk for aspiration is to use higher dose rocuronium (0.9-1.2 mg/kg) and to reverse neuromuscular blockade with sugammadex. Attempts to perform laryngoscopy and intubation before onset of complete neuromuscular blockade may result in straining or coughing that will dramatically increase IOP; therefore a peripheral nerve stimulator should be used to ensure adequate relaxation. This technique leaves the patient at risk for aspiration of gastric contents for a longer period of time (90-120 seconds) than if succinylcholine is used. A smooth emergence from anesthesia can be achieved by the well-timed use of narcotics to prevent strenuous coughing and bucking prior to extubation.

Additional factors implicated in increasing IOP are mask pressure, hypercarbia, hypoxia, and elevated arterial blood pressure. Regional anesthetic techniques with intravenous sedation can also be used in selected cases of open-globe injuries.[138]

Anesthesia-Related Eye Injuries

Eye injuries that occur during anesthesia for nonocular surgery are uncommon. Corneal abrasion is the most common eye injury,[9] and may be due to direct contact from the face mask, surgical drapes, or other foreign objects that come in contact with the eye. General anesthesia predisposes to corneal abrasion because it suppresses corneal reflexes, increases lagophthalmos (incomplete eyelid closure), and decreases tear production and stability.[139] Patients complain of a foreign body sensation—pain that is made worse by blinking, tearing, and photophobia. In some instances, the pain from corneal abrasion is far worse than the pain from the surgical site. Corneal abrasion can be prevented by lubricating the eyes with ophthalmic ointment, taping the eyes during surgery, and vigilantly monitoring patients to ensure that they do not rub their face or eyes during emergence from anesthesia. Treatment of corneal abrasion consists of antibiotic ointment to the affected eye and patching the eye for 48 to 72 hours.

Risk factors for postoperative ophthalmic complications include cardiopulmonary surgery, intraoperative hypotension, massive blood loss, anemia, and patients placed in prone or steep Trendelenburg positions. IOP can increase by an average of 13 mm Hg higher than preanesthesia induction values when a patient is placed in steep Trendelenburg position,[140] and remains significantly elevated while the patient remains in this position.[141] Mechanisms for increased IOP in the Trendelenburg position include (1) raised central venous pressure due to gravitational forces that leads to increased orbital venous pressure and IOP, and (2) pneumoperitoneum causing increased choroidal blood volume which, in turn, increases IOP.[141] Dexmedetomidine has been shown to be effective in lowering IOP[142] and its use has been shown to attenuate the increase in IOP during laparoscopic surgery in steep Trendelenburg position without decreasing ocular perfusion pressure.[143]

A devastating but rare complication of surgery is perioperative visual loss (POVL), which is most often associated with cardiac, spine, and head and neck operations. Causes of POVL are ischemic optic neuropathy (ION), central retinal artery occlusion (CRAO), and cortical vision loss. The pathology of POVL varies with its underlying etiology; ION affects the optic nerve, CRAO occurs at the optic disc in the retina, and cortical blindness results from ischemic or embolic damage to the visual cortex or the optic radiations. Patients usually experience painless visual loss or decreased acuity, an afferent pupillary defect, and no light perception. Prognosis for recovery of vision is poor.

ION is the most commonly reported condition associated with POVL. It can be further subdivided into anterior ischemic optic neuropathy (AION) and posterior ischemic neuropathy (PION). AION is associated with damage to the optic nerve head and is more commonly seen after cardiac surgery. Damage to the rest of the optic nerve results in PION, and it is more commonly reported after spinal surgery.[144] In the ASA POVL Registry, ION was associated with estimated blood loss of greater than 1000 mL and anesthetic duration of more than 6 hours.[145] Although the etiology of perioperative ION is unknown, a possible hypothesis is that prone surgery leads to increased venous pressure and interstitial tissue edema that compromises blood flow to the optic nerve. Prevention involves careful preoperative counseling and screening, considering surgical options that reduce the risk of stroke, and staging long spinal surgeries in high-risk patients. Patient positioning should avoid direct ocular pressure, with the head positioned so that it is higher than the heart to reduce orbital edema. Hypotension and severe anemia should be avoided.[146]

In CRAO, interruption of the arterial supply to the retina most commonly occurs from increased IOP due to external pressure during positioning. Other causes include retrobulbar hemorrhage, occlusive disease of the retinal vasculature, and central retinal vein thrombosis.[146] Therapeutic interventions include lowering IOP with acetazolamide or osmotic diuretic agents,[147] induced hypercarbia, topical hypothermia, locally applied thrombolytic agents, and hyperbaric oxygen therapy.[148]

In an ASA closed claims analysis of eye injuries during ophthalmic surgery associated with anesthesia in 1992, Gild et al. found that patient movement such as bucking or coughing was the most common single mechanism of injury. The majority of patient movement occurred during general anesthesia, and the outcome in all these cases was blindness.[9] The use of a peripheral nerve stimulator to monitor neuromuscular blockade during ophthalmic surgery should ensure that patients do not move during general anesthesia.

Acute glaucoma, manifested as dull periorbital pain, during the early postoperative period may occur due to the administration of mydriatic agents such as atropine, scopolamine, and ephedrine. Management consists of lowering IOP with acetazolamide or an osmotic diuretic and timely referral to an ophthalmologist.[149]

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Complete references available online at expertconsult.com.

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ANIL PATEL

KEY POINTS

- Difficult airways are more frequently encountered in patients undergoing ear, nose, and throat (ENT) surgery, especially for cancer. Reviewing the results of a preoperative computed tomography (CT) scan or an endoscopic airway examination may help identify pathologic features likely to produce airflow obstruction or complicate tracheal intubation.
- Although the tracheas of ENT patients are often intubated using ordinary polyvinyl chloride endotracheal tubes (ETTs), microlaryngeal, laser-safe, and wire-reinforced tubes are frequently employed.
- Endotracheal intubation in an awake patient with a flexible bronchoscope is commonly used when intubation following the induction of general anesthesia would be imprudent.
- Fiberoptic endotracheal intubation is usually well tolerated, is gentle on the airway, and does not require force to obtain glottic exposure.
- When the airway disorder is so extensive that awake endotracheal intubation is impractical, tracheostomy performed using local anesthesia (with or without judicious intravenous sedation) is usually the best option. In extreme loss-of-airway emergencies, a cricothyrotomy may be preferable to a tracheostomy because cricothyrotomy takes much less time to complete.
- In some head and neck cases, such as in patients undergoing parotid surgery, the need for electrical testing of the facial nerve precludes the extended use of neuromuscular blocking drugs.
- In many patients with head and neck disorders, gentle emergence from anesthesia, free of coughing and straining, is vitally important to prevent emergence rebleeding as a result of venous engorgement.
- Bleeding following tonsillectomy usually occurs within the first 6 postoperative hours, but it can also occur several days later.
- Facial trauma can produce unremitting bleeding and the aspiration of teeth, blood, bone, and tissue fragments, as well as cervical spine injury. Airway trauma can result from blunt or penetrating injuries, burns, inhalational injury, and iatrogenic causes. In both situations, initial management is dictated by the degree of respiratory distress or potential airway compromise, the available equipment, and clinical preferences.
- Intubating the trachea of a patient with laryngeal trauma may result in further injury to the airway or even complete airway loss. If intubation is attempted, it is advised to use a fiberoptic bronchoscope with a small ETT. Positive-pressure ventilation may worsen any subcutaneous emphysema. In some cases, a tracheostomy may be the most prudent course.
- Causes of stridor include inhaled foreign bodies, bilateral vocal cord palsy, airway edema, angioedema, epiglottitis, traumatic injury, subglottic stenosis, and other pathologic entities. Regardless, the first issue in the setting of stridor is whether or not endotracheal intubation or a surgical approach to the airway is immediately necessary to rescue the patient from death or injury. Heliox administered with a nonrebreathing facemask or high-flow nasal oxygen can be helpful as a temporizing measure.
- The chosen anesthetic technique for endoscopic procedures varies with patient and lesion particulars, clinical preferences, and the selected surgical tools (laser, rigid bronchoscope). Total intravenous anesthesia is a popular choice for many of these cases.
- Lasers can be used to vaporize otolaryngologic lesions; however, special precautions are needed to prevent accidental thermal injury or an airway fire, a potentially deadly complication that may also occur during tracheotomy surgery. Oxygen must be kept to a minimum when a significant potential for an airway fire exists. Moreover, nitrous oxide should not be used during airway surgery because it supports combustion just as does oxygen.

On October 16, 1846, Dr. William Morton famously used ether delivered by inhalation to provide general anesthesia to Gilbert Abbott and allow surgeon Dr. John Warren to remove a tumor from Abbott's neck.[1,2] From this first public demonstration of ether anesthesia onward, the relationship between anesthesiology and ear, nose, and throat (ENT) surgery has been vital. Indeed, no other branch of surgery has as great a need for a mutual understanding between the surgeon and the anesthesiologist, with joint procedural planning and close cooperation being crucial. For example, many ENT surgical procedures require that the anesthesia provider share the airway with the surgeon; consequently, a good anesthesia provider must be unusually knowledgeable about ENT procedures and the possible effects on the patient.

Anesthesia for ENT surgery encompasses a vast range of procedures varying enormously in complexity, duration, and potential for complications.[3] On any given day, ENT anesthesiologists may be assigned to simple high-volume cases, such as myringotomies and tonsillectomies, or to all-day procedures in patients with cancer. They may also encounter patients with severely distorted airway anatomy, sometimes even causing airway obstruction, as well as procedures involving tracheal, glottic, or subglottic surgery that require sharing of the airway in conjunction with the use of special equipment such as surgical lasers. Nasal procedures usually require airway protection from blood and secretions, as well as gentle emergence from anesthesia. Intraoral ENT procedures, such as tonsillectomies, may employ instruments intended to keep the mouth open but that may also unintentionally obstruct the airway. Extreme lateral rotation of the head may be required for some ear procedures. These are just some of the special perils of providing anesthesia for ENT procedures.

Synopsis of Ear, Nose, and Throat Anatomy

Figs. 70.1 to 70.4 illustrate various aspects of ENT anatomy. The oropharynx extends from the uvula to the hyoid bone. The hypopharynx extends from the hyoid to the cricoid cartilage. The glottis includes both vocal cords, the anterior commissure, and the posterior intraarytenoid area. The subglottis extends 5 mm (anteriorly) to 10 mm (posteriorly) below the apex of the vocal cords (also known as vocal folds). The larynx, essential to respiration and speech, has a clinically important glottic closure reflex mediated through bilateral superior laryngeal nerves. This reflex serves to protect the airway against aspiration. For example, swallowing activates this protective reflex. On occasion this protective reflex can be problematic because when sustained spasm of the glottic muscles (a condition known as laryngospasm) occurs,[4-6] gas exchange cannot take place. Laryngospasm is associated with light anesthesia and is frequently triggered by blood or secretions irritating the vocal cords, as often occurs after septoplasty and rhinoplasty surgery. Because it can make ventilation impossible, laryngospasm may constitute a true anesthetic emergency (see later).

Branches of the right and left vagus nerves innervate the larynx. The right vagus nerve gives rise to the right recurrent laryngeal nerve, whereas the left vagus nerve gives rise to the left recurrent laryngeal nerve. The two recurrent laryngeal nerves provide motor innervation to all the intrinsic muscles of the larynx, except the cricothyroid and inferior pharyngeal constrictor muscles, which are innervated by the branches of the superior laryngeal nerves. The internal laryngeal nerve is the internal branch of the superior laryngeal nerve (see Fig. 70.3). It descends to the thyrohyoid membrane, pierces it along with the superior laryngeal artery, and provides sensory innervation to the larynx down to the vocal cords. Sensory innervation below the vocal cords and to the upper trachea is supplied by the recurrent laryngeal nerves (see Fig. 70.3).

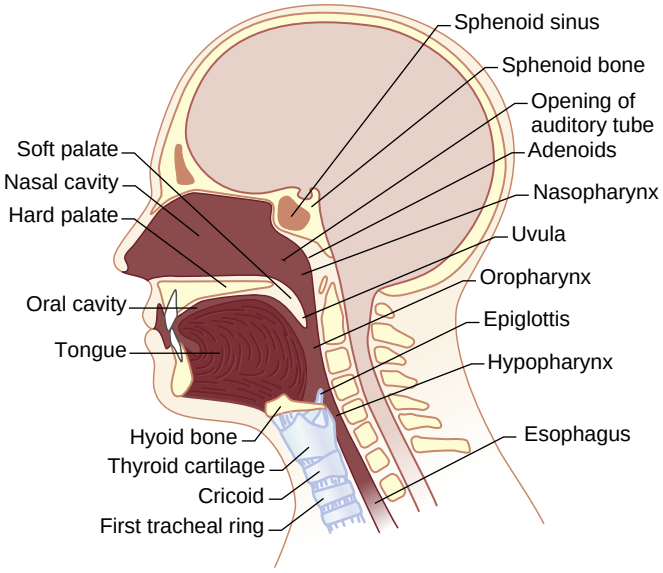

Fig. 70.1 Highlights of otolaryngologic anatomy. Note (1) the anterior position of the trachea relative to the esophagus; (2) the oropharynx, extending from the uvula to the hyoid bone; (3) the hypopharynx extending from the hyoid bone to the cricoid cartilage; (4) the cricoid ring, a structure that is pushed posteriorly during the Sellick maneuver component of rapid-sequence induction, done with the intention of occluding the esophagus to help prevent regurgitation of gastric contents; and (5) the location of the first tracheal ring, important as a surgical landmark because most tracheostomies are performed between the second and third tracheal rings. (From Feldman MA, Patel A. Anesthesia for eye, ear, nose, and throat surgery. In: Miller RD, ed. *Miller's Anesthesia*. 7th ed. Philadelphia: Churchill Livingstone; 2010:2357–2388.)

Injury to the recurrent laryngeal nerves, which supply most of the laryngeal intrinsic muscles, is a feared but often preventable complication in thyroid surgery and a host of other procedures, including tracheal intubation.[7-12] If the damage is unilateral, the patient may present with hoarseness from unilateral loss of vocal cord abduction occurring in conjunction with intact cricothyroid-mediated adduction. This situation causes the affected vocal cord to assume a paramedian position. Bilateral nerve damage can result in dyspnea, stridor, and even full airway obstruction from bilateral vocal cord paramedian positioning. Such patients may require a tracheostomy. Intraoperative neuromonitoring is often used to reduce the chance of injury to the recurrent laryngeal nerves, especially in thyroid surgery.[13-15]

Preoperative Evaluation for Ear, Nose, and Throat Surgery

Although the preoperative evaluation of the surgical patient is discussed in detail in Chapter 31, a few issues are especially pertinent to ENT cases. Many ENT patients, especially

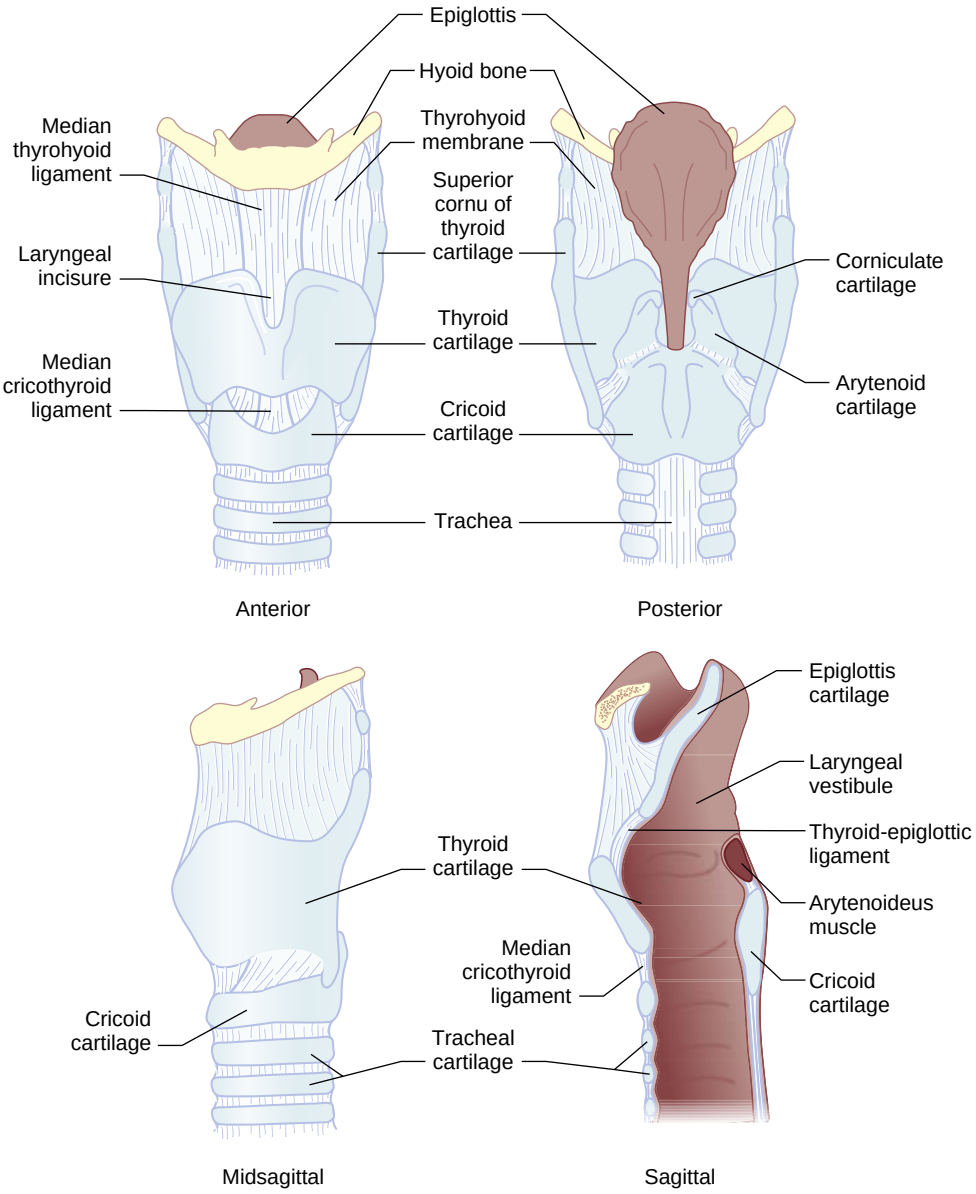

Fig. 70.2 Anterior, posterior, midsagittal, and sagittal views of laryngeal anatomy. Note (1) how the cartilaginous tracheal rings are incomplete posteriorly to allow the trachea to collapse slightly to facilitate the passage of food down the esophagus (and to provide orientation during bronchoscopic procedures!); (2) the superior cornu of the thyroid cartilage, an important landmark in the superior laryngeal nerve block because this is close to where the internal branch of the superior laryngeal nerve penetrates the thyrohyoid membrane; and (3) the median cricothyroid ligament and (not labeled) the twin lateral cricothyroid ligaments, known collectively as the cricothyroid ligament and entered in both emergency cricothyrotomy procedures and with emergency transtracheal jet ventilation. (From Feldman MA, Patel A. Anesthesia for eye, ear, nose, and throat surgery. In: Miller RD, ed. *Miller's Anesthesia*. 7th ed. Philadelphia: Churchill Livingstone; 2010:2357–2388.)

those with malignant head and neck diseases, have histories of prolonged tobacco and alcohol use, whereas many others suffer from obesity or obstructive sleep apnea (OSA). Patients with chronic airway obstruction may develop pulmonary hypertension, sometimes leading to right-sided heart failure (cor pulmonale). A history of hoarseness may signal recurrent laryngeal nerve injury or worse, whereas the presence of stridor is *always* a cause for immediate concern. In cases involving the airway, the anesthesiologist and surgeon frequently review available radiographic and video studies to establish an airway plan collaboratively. A history of head and neck radiation for malignancy treatment frequently makes intubation difficult because the structures may become tough and fibrotic ("like wood"), yet they are predisposed to bleeding with instrumentation. A history of snoring may signal that the patient has undiagnosed sleep apnea and is prone to airway obstruction.

ENT cases frequently involve geriatric patients, many of whom are at a high risk for postoperative delirium and cognitive dysfunction.[16-18] Although many ENT procedures involve infrequent risk, some of the large head and neck operation sare considered to have "intermediate" surgical risk. A preoperative resting 12-lead electrocardiogram (ECG) is recommended for patients with known coronary heart disease, peripheral arterial disease, or cerebrovascular disease who are undergoing such procedures. Additionally, patients with a history of heart failure, diabetes mellitus, or renal failure who are undergoing intermediate-risk operative procedures benefit from an ECG. Preoperative ECG testing is not indicated in asymptomatic persons undergoing infrequent-risk procedures.

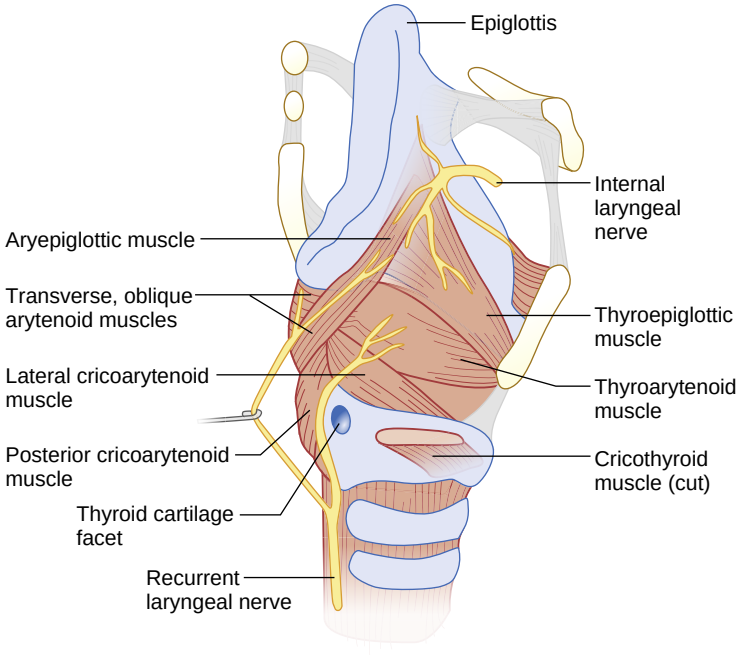

Fig. 70.3 Laryngeal anatomy focusing primarily on the internal laryngeal nerve and the recurrent laryngeal nerve. The two recurrent laryngeal nerves provide motor innervation to all the intrinsic muscles of the larynx, except the cricothyroid and inferior pharyngeal constrictor muscles, which are innervated by the external branches of the two superior laryngeal nerves (external laryngeal nerve). Sensory innervation of the larynx down to the vocal cords is supplied by the internal laryngeal nerve branches of the superior laryngeal nerves (internal laryngeal nerve), these in turn being branches of the vagus. Sensory innervation below the vocal cords and to the upper trachea is supplied by the recurrent laryngeal nerves. (From Schuller DE, Schleuning AJ. *Otolaryngology: Head and Neck Surgery.* 8th ed. St. Louis: Mosby; 1994:252.)

A *preoperative endoscopic airway examination can be performed* in selected patients. This technique uses an ordinary flexible fiberscope usually used for awake endotracheal intubation to conduct a quick transnasal laryngoscopic examination using topical anesthesia. This examination allows the clinician to determine whether a problematic laryngeal disorder exists, such as supraglottic lesions that would not be apparent by ordinary means. The procedure requires minimal time and patient preparation, and it is well tolerated by patients. A review by Rosenblatt provides ample details.[19]

Airway Management in Otolaryngology

Both easy and difficult airways are frequently encountered in ENT anesthesia. The American Society of Anesthesiologists (ASA) Difficult Airway Algorithm (or similar algorithm),[20-28] should ordinarily be a starting point for nearly all aspects of ENT airway management. To a large extent, the specific airway management techniques chosen depend on clinical circumstances, the airway management skills and preferences of the anesthesiologist and surgeon, and the available equipment.

The following general management options exist: (1) general endotracheal anesthesia; (2) general anesthesia using a supraglottic airway (SGA) device (e.g., laryngeal mask airway [LMA]); (3) general anesthesia using an ENT laryngoscope (to expose the airway) in conjunction with jet ventilation; (4) use of intermittent apnea; (5) general anesthesia using the patient's natural airway, with or without adjuncts such as jaw positioning devices or nasopharyngeal airways; and (6) local anesthesia in conjunction with intravenous sedation, with the patient breathing spontaneously. The first option is doubtless the most popular. However, the technique chosen and implemented depends on factors such as the perceived difficulty of intubating the trachea with ordinary methods. Evaluation of the airway in this particular respect is also discussed in Chapter 44.

The airway can become obstructed for many reasons. Examples include the following: aspirated foreign bodies; infections such as epiglottitis, diphtheria, or Ludwig angina; laryngospasm; tumors and hematomas impinging on the airway; trauma to the airway; OSA; tonsillar hypertrophy; and airway edema (e.g., from anaphylaxis, prolonged laryngoscopy, or smoke inhalation or burn injury). In most cases, airway management is determined after a discussion between the anesthesia and surgical teams.

Most patients undergoing ENT surgery have their airway managed by tracheal intubation. Although under ordinary circumstances tracheal intubation is straightforward, patients whose tracheas are expected to be difficult to intubate can be identified and usually managed with techniques such as videolaryngoscopy or fiberoptic intubation. A key decision in such cases is whether the tracheal intubation should be performed with the patient awake or following the induction of general anesthesia. Another important decision is what tools or interventions to employ in the event that difficulty with ventilation or intubation is encountered. In exceptional cases, a tracheostomy using local anesthesia must be performed.

Patients for ENT surgery are often managed using an ordinary polyvinyl chloride (PVC) endotracheal tube (ETT), but microlaryngeal tubes (MLTs), laser tubes, and wire-reinforced tubes are also frequently used. Reinforced tubes

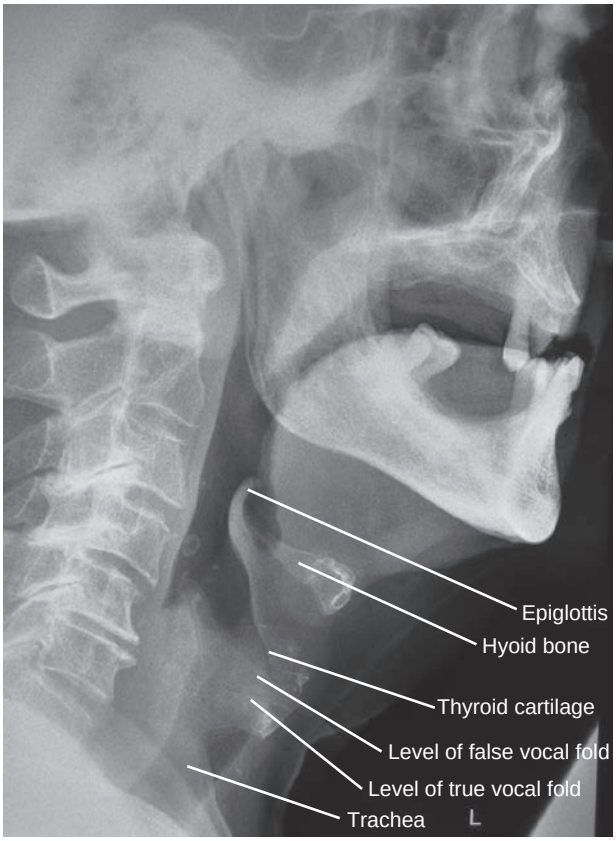

Fig. 70.4 Lateral radiograph demonstrating laryngeal anatomy. Notice (1) the normally wafer-thin epiglottis, which serves as a protective cover to the laryngeal inlet during swallowing and may become much larger and "thumb shaped" when edematous (e.g., as a result of pediatric epiglottitis); (2) the limited amount of prevertebral soft tissue in the oropharyngeal and hypopharyngeal regions; when edematous (e.g., as a result of a retropharyngeal abscess), this tissue may expand anteriorly to obstruct the airway; and (3) the hyoid bone, which aids in tongue movement and swallowing and which, if found fractured on autopsy, is suggestive of foul play by throttling or strangulation. (From Feldman MA, Patel A. Anesthesia for eye, ear, nose, and throat surgery. In Miller RD, ed. *Miller's Anesthesia*. 7th ed. Philadelphia: Churchill Livingstone; 2010:2357–2388.)

have the advantages that they are unlikely to kink and they fit especially well into tracheostomy stomas because of their excellent flexibility. Selection of laser-resistant ETTs should be made based on the material appropriate to the type of laser being used for the procedure. In addition, the tracheal cuff can be filled with saline dyed with methylene blue to allow immediate detection of laser injury to the cuff. Practical considerations in this setting start with the fact that the tube must be adequately secured using tape or other means; some maxillofacial surgeons suture the tube to the side of the mouth or even tie the tube to the teeth with wire. In addition, the ETT cuff pressures ordinarily must be kept less than 25 mm Hg to avoid ischemic damage to the tracheal mucosa. When nitrous oxide is used, cuff pressures gradually increase as nitrous oxide enters the cuff by diffusion. This is of particular concern in surgical procedures of long duration, such as free-flap surgery.

Before attempting tracheal intubation, its difficulty using direct laryngoscopy can often be predicted. The 11-point airway assessment tool included with the 2003 ASA Difficult Airway Algorithm is an excellent source of information and advice.[20] In addition, following the completion of tracheal intubation, the difficulty (if any) encountered should be summarized. The Intubation Difficulty Scale (IDS) introduced by Adnet and associates can be useful.[29-33] IDS is a numeric score indicating overall intubation difficulty based on seven descriptors associated with intubation difficulty: number of supplementary intubation attempts, number of supplementary operators, alternative techniques used, laryngoscopic grade, subjective lifting force, the use of external laryngeal manipulation, and the characteristics of the vocal cords.

Most endotracheal intubations are achieved using traditional Macintosh and Miller laryngoscopes, although several alternative laryngoscopes have been advocated. When the view at laryngoscopy is suboptimal, the use of introducers such as the Eschmann stylet (gum elastic bougie) can sometimes be very helpful.[34-39] It is used as follows: when a poor laryngoscopic view of the glottic structures is obtained, the introducer should be inserted into the patient's mouth and gently advanced through the glottic opening (in the case of a grade II view) or anteriorly under the epiglottis (in the case of a grade III view). Subtle clicks resulting from the introducer passing over the tracheal rings help confirm proper placement of the introducer. With the introducer held steady, one then "railroads" a tracheal tube over the introducer into the glottis.

Video laryngoscopes such as the GlideScope (Verathon, Bothell, WA), the McGrath (Covidien, Mansfield, MA) video laryngoscope, the Storz video laryngoscope (Karl Storz, Tuttlingen, Germany), and the Pentax AWS (Hoya Corporation, Tokyo) have become particularly valuable, especially in patients with an "anterior" larynx or in patients with cervical spine immobilization.[40-50]

As discussed in Chapter 44, awake endotracheal intubation involves ETT insertion in a conscious or lightly sedated patient. It is usually performed because endotracheal intubation during general anesthesia is judged to be too risky. Some concerns may reflect possible difficulties with ventilation or endotracheal intubation or possible aspiration of gastric contents. Although fiberoptic intubation using topical anesthesia is the most common approach to awake endotracheal intubation, other methods include awake blind nasal intubation using an Endotrol (or similar) ETT or the use of a Macintosh, Miller, GlideScope, or other laryngoscope with topical anesthesia. Certain airway blocks can be used in addition to topical anesthesia. These are discussed in Chapter 44.

The use of fiberoptic intubation for the airway management of patients undergoing otolaryngologic surgery is popular because this technique works well in the presence of many kinds of airway disease. Although fiberoptic intubation can often be safely performed during complete general anesthesia,[51] many clinicians opt to perform this technique using topical anesthesia with the patient only lightly sedated (awake fiberoptic intubation), depending on the skill level of the anesthesiologist, the cooperation of the patient, and the severity of the pathologic process. A central consideration behind the choice of "awake" versus "asleep" fiberoptic intubation is the safety margin an awake technique allows: if intubation is not successfully accomplished, the patient's ability to maintain his or her own airway remains intact. In addition, during awake intubation,

airway reflexes are generally maintained sufficiently to guard against pulmonary aspiration, an important point in patients with a high risk of aspiration of gastric contents. Patients who have recently eaten and have undergone trauma are at especially high risk.

Awake endotracheal intubation is not synonymous with fiberoptic intubation. Awake intubation can be accomplished safely using many other airway devices. Other possible options for awake intubation include, but are not limited to, direct laryngoscopy with Macintosh and Miller laryngoscopes, blind nasal intubation, use of a GlideScope or other video laryngoscope, use of a lighted stylet, and so on.

Typically, in intubation of the trachea in an awake patient, the airway is initially anesthetized with gargled and atomized 4% lidocaine. Superior laryngeal and transtracheal blocks are occasionally also employed. In addition, judicious sedation is usually administered. Midazolam, fentanyl, remifentanil, ketamine, propofol, and clonidine have all been used in this setting. More recently, the use of dexmedetomidine, a selective α_2-agonist with sedative, analgesic, amnestic, and antisialagogue properties, has been reported. A key advantage of dexmedetomidine is that it maintains spontaneous respiration with minimal respiratory depression.[52-55] Patients being sedated with dexmedetomidine are generally easy to arouse. However, this advantage, along with that of maintaining spontaneous respiration, may not occur when very large doses are given.

Doyle described the successful use of the GlideScope in four cases of awake endotracheal intubation.[56] The potential advantages are as follows: first, the view is generally excellent. Second, the method is less affected by the presence of secretions or blood as compared with the use of fiberoptic intubation. Third, no special restrictions exist on the type of ETT that can be placed when using the GlideScope, but this is not the case for fiberoptic methods. Fourth, the GlideScope is much more rugged than a fiberoptic bronchoscope and is far less likely to be damaged with use. Advancing the ETT into the trachea over the fiberoptic bronchoscope often fails as a result of ETT impingement on the arytenoid cartilages; this is generally not a problem with the GlideScope.

In the end, however, the use of awake fiberoptic intubation in the setting of the patient with airway disease remains steadfastly popular because it is gentle to the airway, is generally well tolerated, and does not require the application of force to obtain glottic exposure.

Special mention needs to be made of the necessity of being fully prepared for dire ENT airway emergencies because these patients may require immediate surgical intervention. In addition to a conventional difficult airway cart, practitioners may wish to maintain a special ENT airway cart with equipment such as that listed in Box 70.1.[57] In addition to these items and unlisted items favored by individual practitioners, ENT surgeons want ready access to an emergency tracheotomy tray, as well as to some form of suspension laryngoscope or rigid bronchoscope. Special attention to the maintenance and cleaning of fiberoptic bronchoscopes is also important, given that they must always be easily accessible and reliable when needed. In the case of electronic fiberscopes incorporating a video display, it is particularly important to establish that illumination settings and white balancing have been correctly set before use.

BOX 70.1 Possible Items for an Ear, Nose, and Throat Airway Emergencies Cart

- Bag-valve-mask resuscitator (Ambu bag)
- Oropharyngeal and nasopharyngeal airways
- Supraglottic airway collection
- Endotracheal tubes, including microlaryngeal tubes and laser tubes
- Malleable stylets
- Topical anesthesia, with syringes, and atomizers
- Laryngoscope collection with extra bulbs and batteries
- Magill forceps (useful for nasal intubation)
- Boedeker forceps (for use with video laryngoscopes)*
- Airway introducer (gum elastic bougie)
- Tube exchange catheters
- Carbon dioxide detection system
- Video laryngoscope (e.g., GlideScope, McGrath, Pentax-AWS)
- Surgical airway kit (e.g., Melker cricothyrotomy kit)
- Emergency tracheotomy tray
- Fiberoptic bronchoscope

*The Boedeker (curved) intubation forceps is useful for removal of foreign bodies when a video laryngoscope is used.[57]

Airway Disorders in Otolaryngology

Otolaryngologic airway disorders can sometimes present the clinician with tremendous anesthetic and airway challenges. In many such cases, awake endotracheal intubation (e.g., by fiberoptic methods) is the method of choice. When awake intubation is impractical (e.g., overwhelming tumor invasion of the airway, inadequate equipment, limited experience), tracheostomy using local anesthesia (with minimal sedation, or no sedation in extreme cases) is sometimes preferred. In such cases, complete airway obstruction is the outcome most feared; this can occur when anesthetic drugs or neuromuscular blocking drugs decrease the tone of the airway musculature, thereby unfavorably changing the airway architecture.

Many ENT pathologic conditions can make airway management difficult. *Airway infections* can include upper airway abscesses, retropharyngeal abscesses, quinsy, Ludwig angina, and epiglottitis (supraglottitis). *Airway tumors* may be present as oral or tongue malignancies, as glottic, supraglottic, and infraglottic tumors, or as anterior mediastinal masses. *Other pathologic conditions* may also complicate airway management, such as congenital malformations (Pierre-Robin sequence, Goldenhar syndrome), periglottic edema (e.g., following rigid bronchoscopy), recurrent laryngeal nerve injury (e.g., following thyroid surgery), maxillofacial trauma, or OSA. Some of the more important of these conditions are discussed in the following paragraphs.

ANGIOEDEMA

Angioedema (former term: angioneurotic edema) is a rapid form of tissue swelling mediated by anomalous activation of the complement system with release of histamine and other inflammatory mediators.[58] It is usually the result of an allergic reaction. Hereditary angioedema is a variant family that arises from an autosomal dominant genetic mutation. Complete loss of the airway can occur in severe

cases of either form. Just as with anaphylaxis, epinephrine may be lifesaving when the cause of angioedema is allergic, but treatment with epinephrine is not helpful in cases of hereditary angioedema.[59] Intubation of the trachea is often required in affected patients, usually during topical anesthesia with the patient awake or lightly sedated.

ACUTE EPIGLOTTITIS

Epiglottitis, an inflammatory disease of the epiglottis, arytenoids, and aryepiglottic folds, is among the most dreaded of airway-related infections, especially in the pediatric population.[60-64] In the past, victims were usually children 2 to 6 years of age, who were often infected with *Haemophilus influenzae*. Today, a vaccine against *H. influenzae* has reduced the frequency of this tragic affliction. The clinical presentation often includes a sore throat, dysphagia, muffled voice, and fever. Difficulty with swallowing leading to drooling from the mouth may occur. Victims may appear to be systemically ill ("toxic") and assume an open-mouth "tripod" position to ease breathing. Stridor, respiratory distress, and complete airway obstruction may occur. The chief differential diagnosis in children is laryngotracheobronchitis (croup).[65,66]

Examining the child's airway at the bedside may exacerbate the condition, and anything that could bring the child to cry (e.g., needles) should be avoided when possible. A common management approach involves careful inhaled induction of anesthesia using sevoflurane with the child sitting in the anesthesiologist's lap. Then oral intubation of the trachea can be performed using a smaller than usual tracheal tube. The child should receive "deep" anesthesia but should still be breathing spontaneously. Intravenous access and full monitoring should be established as anesthesia is deepened. If at laryngoscopy the airway cannot be identified, one trick is to have someone compress the child's chest, thus generating a small air bubble in the glottis that the person performing the anesthetic can aim for in the trachea. Failure to secure the airway in this manner may necessitate rescue through rigid bronchoscopy, by establishing a surgical airway, or by other means. In the past these children were often then managed by tracheostomy; however, contemporary management usually includes intensive care unit (ICU) admission, throat and blood cultures, conversion to nasotracheal intubation, and intravenous antibiotic therapy.

Epiglottitis can also occur in adults.[67] The first president of the United States, George Washington, is said to have died of it, although being repeatedly phlebotomized (as was the custom of the day) undoubtedly contributed to his demise. Here the situation is less ominous because the adult airway is larger. In cooperative adults, cautious oropharyngeal examination and fiberoptic nasopharyngoscopy help assess the degree of disease. The current consensus is that many adults can be adequately treated in an ICU with inhaled mist, antibiotics, and corticosteroids, and that tracheal intubation is necessary only if symptoms of respiratory distress develop. Should intubation be needed, awake fiberoptic laryngoscopy is probably the best way to secure the airway in cooperative adults, whereas the use of inhaled induction of anesthesia in adults with a compromised airway is now considered to be more perilous than was once thought.

RETROPHARYNGEAL ABSCESS

Retropharyngeal abscess formation may occur from bacterial infection of the retropharyngeal space following dental or tonsillar infections.[68-74] If the condition is untreated, the posterior pharyngeal wall may advance anteriorly into the oropharynx, with resulting dyspnea and airway obstruction. Other clinical findings may include difficulty in swallowing, trismus, and a fluctuant posterior pharyngeal mass. An abscess cavity may be evident on lateral neck radiographs, and anterior displacement of the esophagus and upper pharynx may be present. Airway management may be complicated by trismus or partial airway obstruction. Because abscess rupture can lead to tracheal soiling, contact with the posterior pharyngeal wall during laryngoscopy and intubation should be minimized. Incision and drainage are the mainstays of treatment. Tracheostomy is often, but not always, required.

LUDWIG ANGINA

Ludwig angina is a multispace infection of the floor of the mouth.[75-79] The infection usually starts with infected mandibular molars and spreads to submandibular, sublingual, submental, and buccal spaces. The tongue becomes elevated and displaced posteriorly, which may lead to loss of the airway, especially when the patient is in the supine position. As with retropharyngeal abscess, an additional concern is the potential for abscess rupture into the hypopharynx (with possible lung soiling) either spontaneously or with attempts at laryngoscopy and intubation. Airway management options depend on clinical severity, imaging findings (e.g., computed tomography [CT] or magnetic resonance imaging [MRI] findings), and surgical preferences, but elective tracheostomy before incision and drainage remains a classic, if dated, treatment modality.[79] Most experts advocate fiberoptic intubation when possible. In addition, because Ludwig angina is often associated with trismus, nasal fiberoptic intubation is frequently needed.

AIRWAY TUMORS, POLYPS, AND GRANULOMAS

Airway tumors can be benign or malignant (Figs. 70.5-70.7), but regardless of their pathologic characteristics, airway obstruction is always a potential concern.[80-83] Discussion with the surgical team concerning the size and location of the tumor, along with a review of any video-recorded nasopharyngeal video examinations, will help determine whether awake endotracheal intubation is needed. Polyps may also be found throughout the airway and can lead to partial or complete airway obstruction. Vocal cord polyps, cysts, and granulomas may result from traumatic intubation, vocal cord irritation from ETT movement, or other causes, especially in women.[84-90] Vocal cord cancer can also occur.[91] The potential also exists for exacerbation of asthma in patients with nasal polyps who receive aspirin, ketorolac (Toradol), and other nonsteroidal antiinflammatory drugs (NSAIDs) (the Samter triad).[92,93]

LARYNGEAL PAPILLOMATOSIS

Patients with laryngeal papillomatosis caused by human papillomavirus (HPV) infection may require frequent

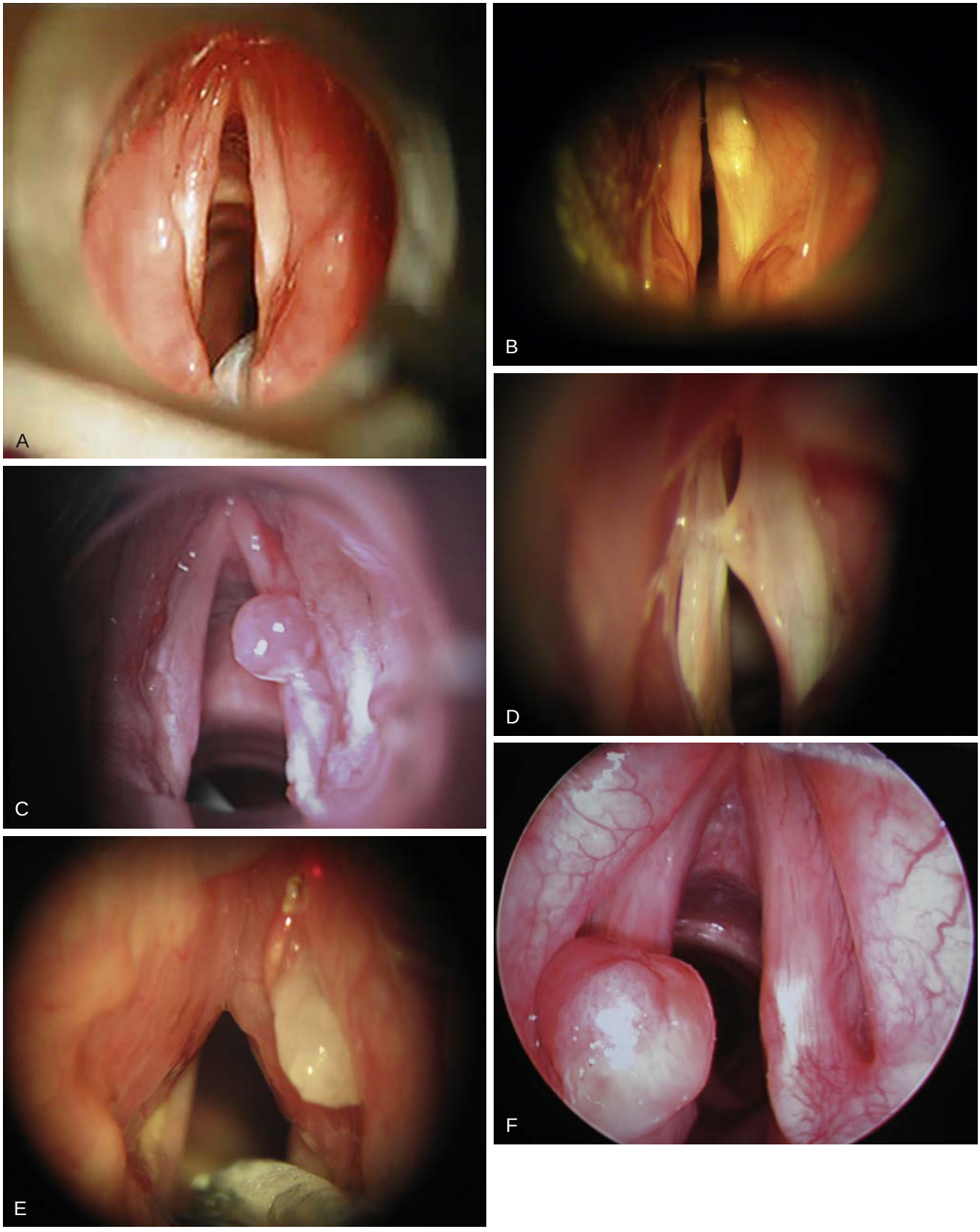

Fig. 70.5 Vocal cord lesions with little or no airway compromise. (A) Normal vocal cord. (B) Minor right vocal cord lesion. (C) Granuloma on the middle right vocal cord. (D) Kissing nodule on the right vocal cord. (E) Anterior webbing of the vocal cord. (F) Intubation granuloma. (From Feldman MA, Patel A. Anesthesia for eye, ear, nose, and throat surgery. In: Miller RD, ed. *Miller's Anesthesia*. 7th ed. Philadelphia: Churchill Livingstone; 2010:2357–2388.)

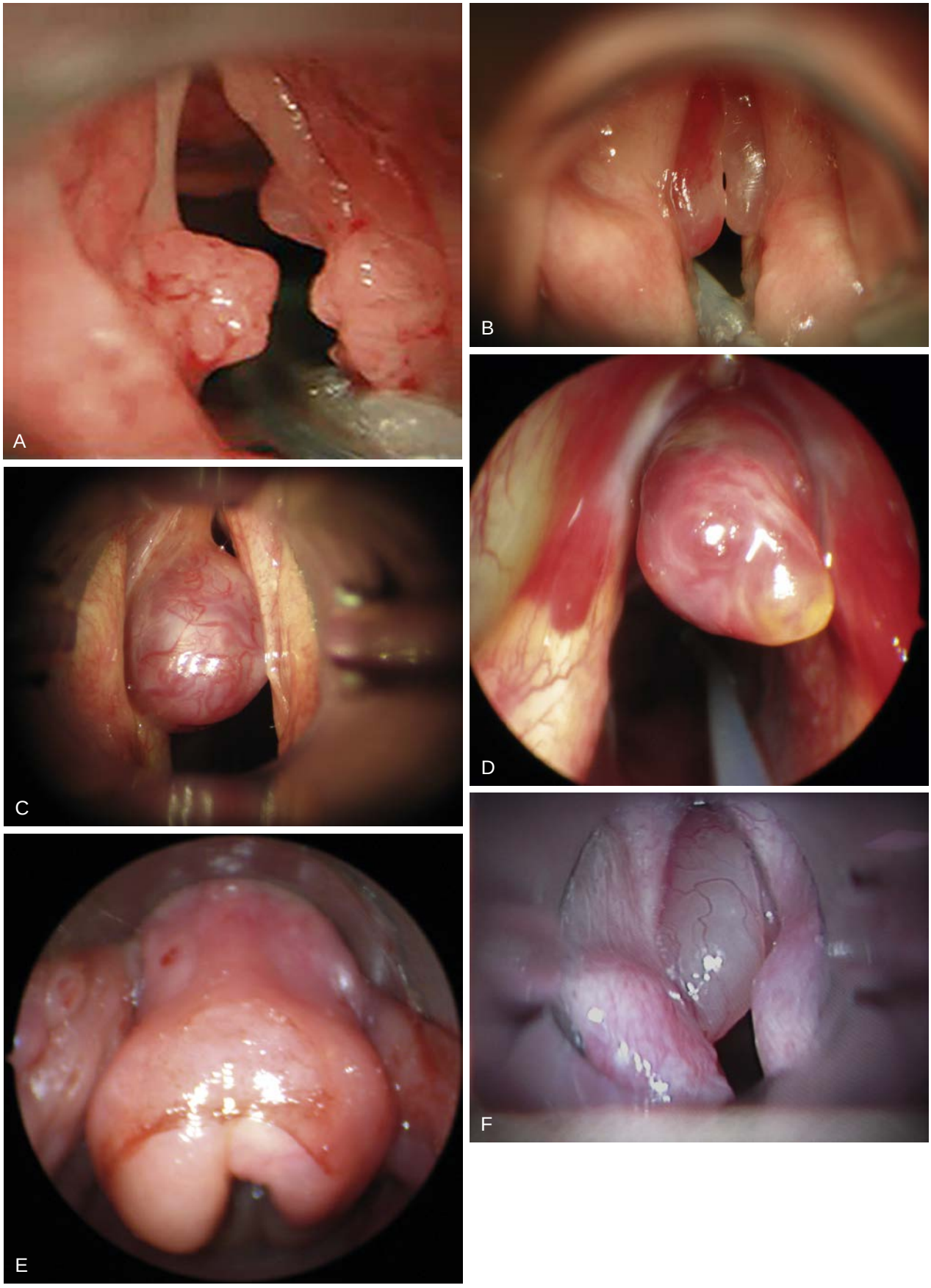

Fig. 70.6 Vocal cord lesions with significant airway compromise. (A) Papilloma of both vocal cords. (B) Bilateral Reinke edema. (C) Left vocal cord polyp. (D) Anterior glottic granuloma. (E) Epiglottic edema. (F) Vocal cord cyst. (From Feldman MA, Patel A. Anesthesia for eye, ear, nose, and throat surgery. In: Miller RD, ed. *Miller's Anesthesia.* 7th ed. Philadelphia: Churchill Livingstone; 2010:2357–2388.)

application of laser treatment for attempted papilloma eradication.[94-99] In some cases the airway may be close to obstruction because of an overgrowth of lesions. During laser treatment, inspired oxygen concentration should be kept to a minimum, with the avoidance of nitrous oxide, to reduce the chance of an airway fire. After treatment, the airway is raw and edematous. Laryngotracheomalacia may occasionally be present, sometimes leading to complete upper airway collapse following extubation of the trachea.

Anesthesia for Panendoscopy

Panendoscopy, sometimes known as triple endoscopy, involves three diagnostic components: laryngoscopy, bronchoscopy, and esophagoscopy. Such procedures and others involving the larynx, pharynx, or trachea often require specialized ENT laryngoscopes, frequently in conjunction with a small-diameter ETT or a tube specifically designed for laser surgery. Panendoscopy is used in patients with head and neck cancer to search for vocal cord lesions, obtain tissue biopsies, monitor for tumor recurrence, and so on. In such cases, one should consider the following specific issues in discussion with the surgical team: what is the anticipated pathologic process, and how is it expected to affect intubation or ventilation? (In some cases the patient's disease may not allow the use of an ETT, so that jet ventilation or a rigid bronchoscope is needed.) What is the plan for airway management, and how does it affect the delivery of anesthesia? How does the presence of coexisting disease

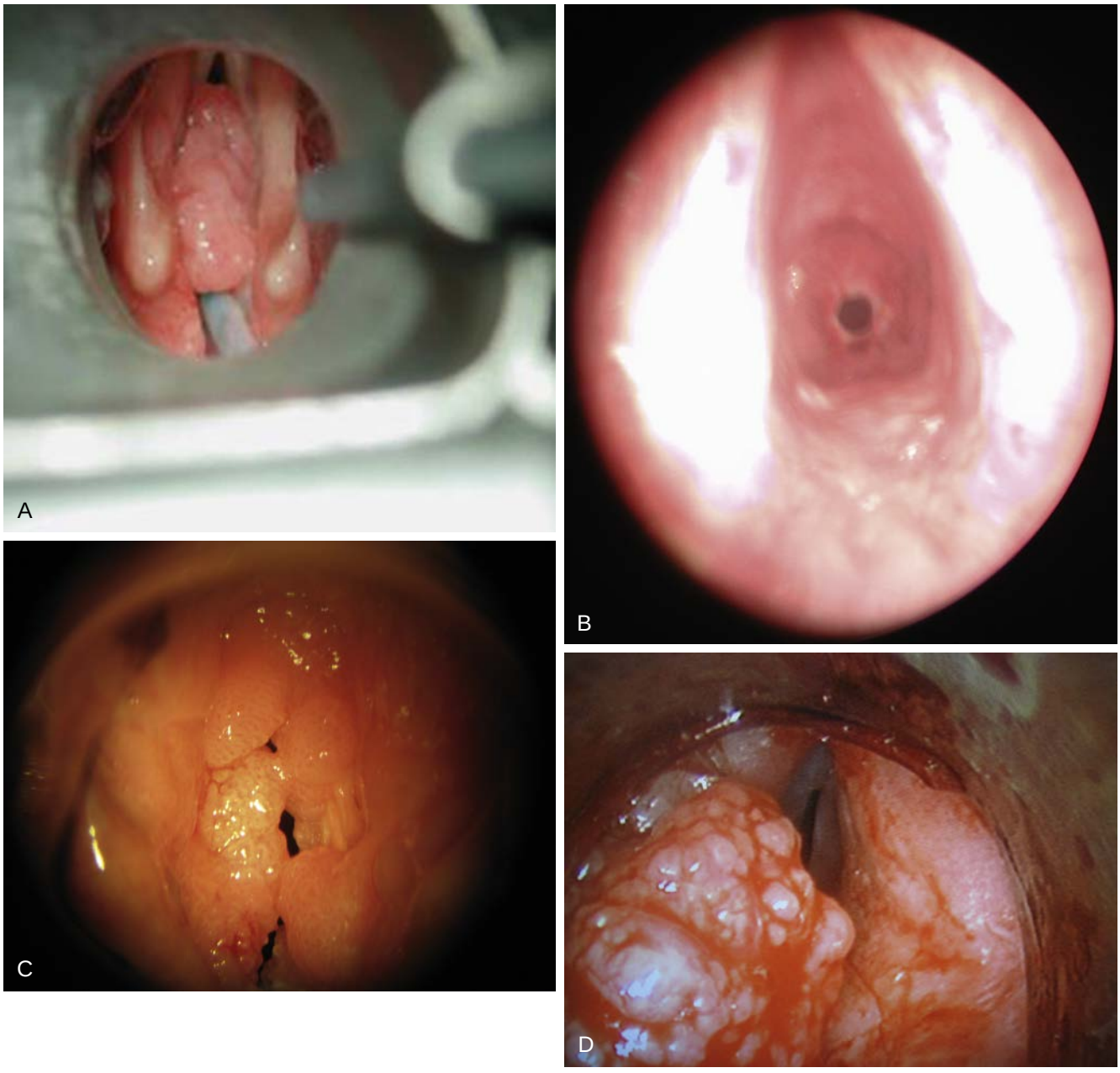

Fig. 70.7 Vocal cord lesions with severe airway compromise. (A) Papilloma of vocal cord. (B) Severe subglottic stenosis (2-mm airway). (C) Bilateral papilloma. (D) Extensive supraglottic carcinoma.

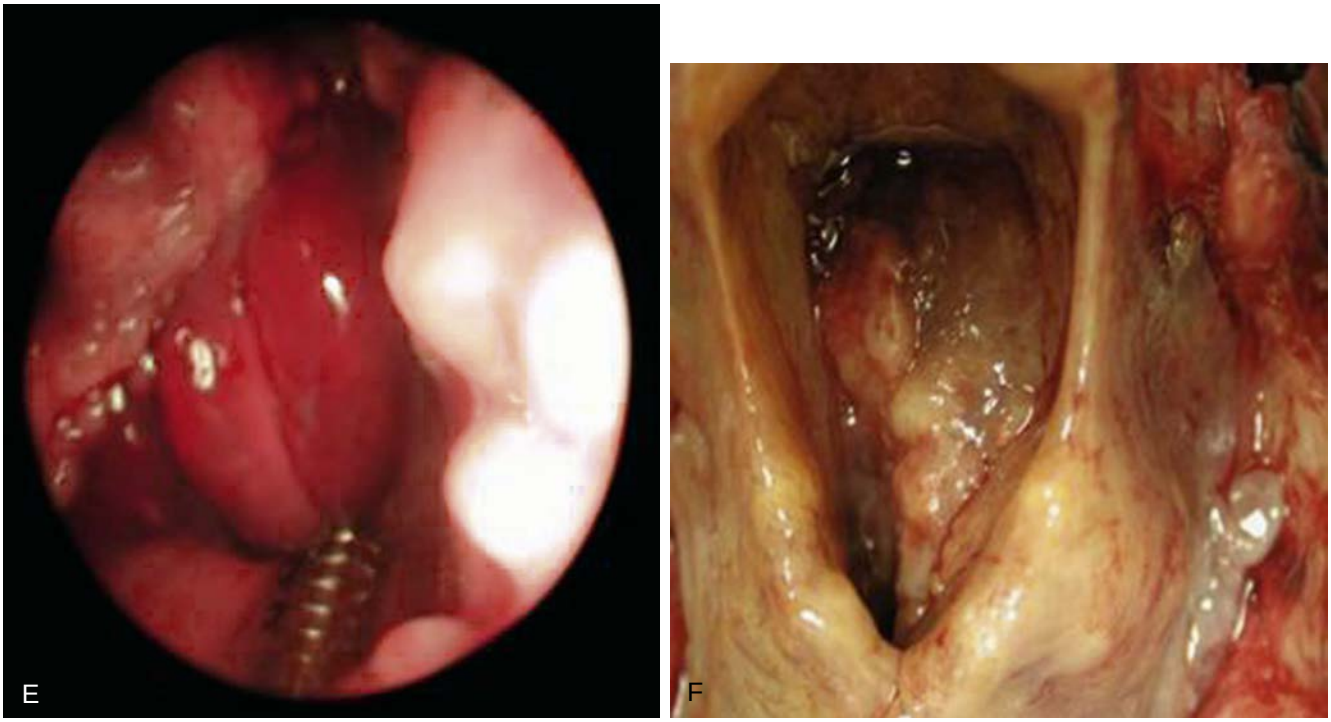

Fig. 70.7, cont'd (E) Acute epiglottitis. (F) Laryngeal carcinoma. (From Feldman MA, Patel A. Anesthesia for eye, ear, nose, and throat surgery. In: Miller RD, ed. *Miller's Anesthesia.* 7th ed. Philadelphia: Churchill Livingstone; 2010:2357–2388.)

(e.g., coronary artery disease, chronic obstructive pulmonary disease, gastroesophageal reflux disease) affect management? What specialized equipment may be needed? (For example, when airway obstruction is present, the surgeon may employ dilatational balloons, lasers, or a microdébrider to open up the airway.)

Five airway options for panendoscopy exist: (1) use of an ETT, typically a narrow-bore MLT that provides the surgeon with a superior glottic view; (2) jet ventilation in conjunction with a rigid ENT laryngoscope, without the use of an ETT; (3) hybrid methods, such as the intermittent use of an SGA or an MLT tube in conjunction with a rigid laryngoscope, jet ventilation, or intermittent apnea; (4) tracheostomy using local anesthesia before inducing general anesthesia; and (5) elective placement of a specially designed transtracheal jet ventilation cannula (e.g., Ravussin jet ventilation catheter before induction[100]). The last two options are only occasionally used for patients with a suspected difficult airway; awake tracheal intubation is the most common approach in patients with a difficult airway. Moreover, when jet ventilation is used, total intravenous anesthesia (TIVA), for example with infusions of propofol and remifentanil, is needed. Finally, when panendoscopy is combined with laser surgery, a laser-safe ETT is often used.[101,102]

Panendoscopy is generally done while the patient is under general anesthesia with the patient's neck flexed and the head extended, usually employing a shoulder roll and a head ring (Jackson position). Typically, an anterior commissure laryngoscope is used and fixed into position by suspension (Fig. 70.8). This technique allows the surgeon's hands to be free and the operating microscope to be used. Other specialized ENT surgical laryngoscopes that are commonly used, often in conjunction with a microscope

Fig. 70.8 Patient undergoing an ear, nose, and throat procedure using a suspended anterior commissure laryngoscope. A jet ventilation attachment is taped to the handle. A fiberoptic bronchoscope with a laser fiber is in use to deliver laser pulses to areas of pathologic tissue. (Image courtesy Dr. Basem Abdelmalak, Cleveland Clinic.)

for laryngeal microsurgery, include the Dedo laryngoscope (Elmed, Addison, IL) and the Universal Modular Glottiscope (Endocraft, Providence, RI). Here, once the laryngoscope is correctly configured ("suspended"), the surgeon brings the operating microscope into the field and uses a variety of microlaryngeal instruments to treat the patient.

A variety of anesthetic techniques can be used for panendoscopy procedures. The most common approach is to perform the procedure while the patient is under general anesthesia with muscle relaxation in conjunction with an MLT-type tracheal tube (Fig. 70.9). This technique is

Fig. 70.9 Regular 7.5-mm inner diameter *(ID)* tracheal tube *(top)* in comparison with a 5.0-mm ID microlaryngeal *(MLT)*–type tracheal tube *(bottom)*. The MLT tube has a narrow lumen that provides the surgeon with improved glottic exposure at the cost of higher ventilation pressures.

familiar to anesthesiologists, provides both airway protection and control of ventilation, allows for reliable capnographic carbon dioxide (CO_2) measurements, and allows for the use of volatile anesthetics without operating room pollution. Disadvantages of the technique include higher than usual ventilation pressures as a consequence of the tube's narrow diameter, somewhat hindered surgical access, and concerns for tube ignition when a laser is in use.

Because a tracheal tube may impair access to some glottic structures, however, some cases are performed using intermittent apnea during general anesthesia and administration of neuromuscular blocking drugs. Disadvantages of this technique include the need for a TIVA technique, the need for repeated intubation-extubation cycles (potentially producing glottic trauma), fragmentation of the surgical work into brief apneic segments, and the repeated interruption of ventilation and oxygenation.

Next, panendoscopy is often performed using supraglottic jet ventilation.[103,104] This technique requires TIVA and entails some special issues because it involves the delivery of high-pressure oxygen pulses (typically 20-50 psi in adults, frequently delivered 1 second on/3 seconds off), usually through an adapter that attaches to the surgical laryngoscope. Additionally, subglottic methods (e.g., using a Hunsaker catheter[105,106]) and transtracheal methods of jet ventilation[107-110] have been described. Each pulse of oxygen entrains room air, thus increasing the gas volume delivered and diluting the oxygen concentration (Venturi effect). Disadvantages of jet ventilation include the need for TIVA, the potential for barotrauma (remember that a pressure of 50 psi is equivalent to 3515 cm H_2O), an inability to measure either end-tidal CO_2 ($ETCO_2$) or tidal volume easily, and the fact that the technique is often suboptimal in obese individuals. Finally, a variant of jet ventilation known as high-frequency jet ventilation is sometimes used in these cases,[111,112] often in conjunction with a special ventilator, an intratracheal catheter, and transcutaneous CO_2 monitoring.

Otolaryngologic Trauma

Although the topic of anesthesia care for the trauma patient is the subject of Chapter 66,[113] a few special points pertaining to patients who have undergone head and neck trauma should be emphasized. First, patients with head and neck trauma may have a concurrent brain injury or injury to the cervical spine. Until cleared of a possible cervical spine injury, patients should be placed in a rigid cervical collar. In addition, although placing the patient's head in the customary "sniffing" position can facilitate laryngoscopy, this technique is contraindicated in patients with a suspected cervical spine injury for fear of exacerbating any injury. Additionally, jaw thrust and chin lift maneuvers can be more difficult when a cervical collar is used or when comminuted mandibular fractures are present.

Second, facial injuries can produce extensive bleeding, as well as the aspiration of blood, bone, cartilage, teeth, and tissue fragments. Third, the airway may be compromised, especially when bilateral mandibular fractures are present. Airway trauma from blunt or penetrating injuries, burns, inhalational injury, or even iatrogenic causes may be present. Immediate airway management options include orotracheal intubation (awake versus rapid-sequence induction), a surgical airway carried out using local anesthesia, or even intubation through an open airway in cases of tracheal transection. Oropharyngeal airways may not be tolerated in patients with an intact gag reflex, and inserting a nasopharyngeal airway may exacerbate bleeding.

Although fiberoptic intubation would seem to offer many advantages in trauma cases, clinical experience suggests otherwise, at least in some cases, because navigating through a distorted airway filled with blood and foamy secretions challenges even the most experienced bronchoscopists. Special concerns exist when the trachea is intubated in a patient with laryngeal trauma because this may result in further injury or even complete airway loss (e.g., in the event of inadvertent ETT placement through a laryngeal fracture into the mediastinum). Clinical findings suggestive of laryngeal trauma include abrasions, discoloration, indentation, bleeding, or pain in the region of the larynx, as well as dyspnea, dysphagia, dysphonia, stridor, hemoptysis, subcutaneous emphysema, and hoarseness. Signs of pneumothorax may also be present, whereas fiberoptic endoscopic examination may reveal edema, the presence of bleeding or hematoma, or abnormal vocal cord function. If endotracheal intubation is attempted in this setting, a fiberoptic bronchoscope with a small-diameter ETT can be used carefully, bearing in mind the foregoing concerns about fiberoptic intubation in the trauma setting. Additionally, positive-pressure ventilation by mask or SGA in this setting may worsen any subcutaneous emphysema. A tracheostomy may be the most prudent course in some cases. Finally, the application of cricoid pressure in blunt laryngeal trauma may result in cricotracheal separation and so is contraindicated. In any event, in both facial trauma and airway trauma, initial management is dictated by the degree of respiratory distress or potential airway compromise, the available equipment, and clinical preferences.

Midfacial fractures deserve special mention. These fractures are defined by the Le Fort classification. A Le Fort I

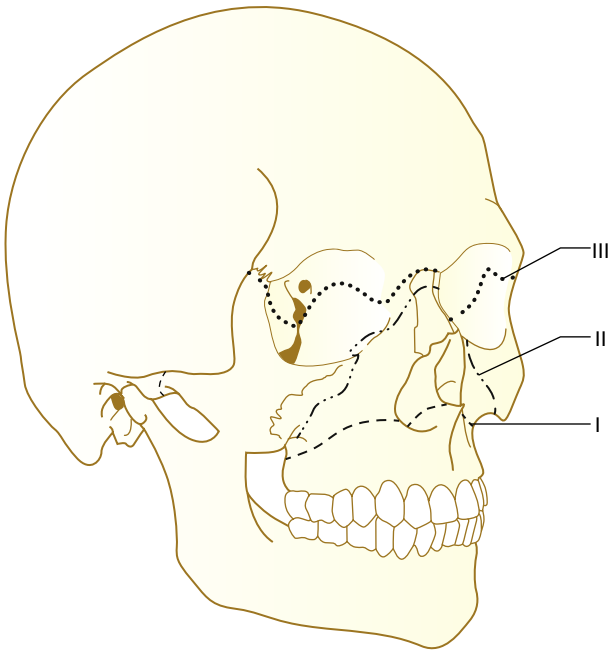

Fig. 70.10 Classification of midfacial fractures. Le Fort I: alveolar fracture. Le Fort II: zygomatic-maxillary complex fracture. Le Fort III: cranial facial dysostosis with separation of the midface from the skull. (From Schuller DE, Schleuning AJ. *Otolaryngology: Head and Neck Surgery.* 8th ed. St. Louis: Mosby; 1994:157.)

fracture is a horizontal fracture that involves the inferior nasal aperture, separating the maxillary alveolus from the rest of the midfacial skeleton. Le Fort II fractures are pyramidal nasomaxillary fractures that break from the upper craniofacial skeleton. Le Fort III fractures, less commonly encountered than the others, involve the separation of the facial skeleton from the skull base. These fractures are illustrated in Figure 70.10.

Nasal Surgery

Nasal surgery can involve external procedures, procedures within the nasal cavity, surgery involving the nasal bones, and nasal sinus surgery. Besides the usual concerns, preoperative assessment should focus on the suitability of topical nasal vasoconstrictor use, the possibility of undiagnosed OSA, and the potential presence of the Samter triad (nasal polyps, asthma, and a sensitivity to aspirin and NSAIDs that may produce deadly bronchospasm). Because postoperative bleeding is a common complication after nasal surgery, patients should not be taking NSAIDs and aspirin for 1 to 2 weeks preoperatively.

Preoperative planning begins by deciding whether the procedure is best performed with local (usually accompanied by intravenous sedation) or general anesthesia. Although local anesthesia may be suitable for simple procedures such as cauterization or straightforward polypectomy or turbinectomy surgery in adults, often general anesthesia is required. When general anesthesia is chosen, a choice must then be made among a simple facemask (as may be appropriate for pediatric myringotomy surgery), an SGA device (e.g., flexible LMA), and a tracheal tube (e.g., an unkinkable wire-reinforced design). This decision should be made jointly with the surgeon. Although the use of an SGA during ENT surgery has its enthusiasts, negative experiences, such as airway obstruction related to device malpositioning, have led many clinicians to prefer a tracheal tube in such cases.

Patients undergoing rhinoplasty are typically young, healthy individuals requiring reconstruction of the external nose for deformity treatment.[114,115] Septoplasty (correction of a deviated septum)[116-118] and surgery to remove nasal polyps[119,120] are often performed to improve nasal airflow and ventilation of the sinuses. Some malignant lesions require excision of the entire nose with follow-up staged reconstruction using a forehead flap. Open nasal fracture reduction procedures are usually performed after the initial swelling has resolved; if the injury is corrected too late, the bones can be difficult to align and can lead to significant surgical bleeding. General endotracheal anesthesia is usually carried out in such cases, often using a midline reinforced ETT taped to the chin. In closed nasal fracture reduction, the surgeon applies forceful pressure to realign the nasal bones, a procedure that usually takes only a few seconds but nevertheless is so intensely painful that the procedure is usually preceded by a single induction dose of propofol, followed by airway support as needed as a nasal cast is applied. However, when the reduction is expected to be bloody or otherwise complicated, the airway is usually protected with an ETT or an SGA device. In many of these procedures, nasal packs, stents, and/or casts are placed; nasal stents offer an advantage over packs in that one can breathe through them.

In many ENT cases, a "throat pack" made of a long piece of saline-soaked gauze is stuffed around the ETT to prevent blood and surgical debris from entering the pharynx and larynx. Typically, a few inches of gauze are kept outside the mouth as a reminder of its presence, because an inadvertently retained pack can lead to catastrophic airway obstruction after extubation.[121] In addition to suctioning, many clinicians follow throat pack removal with pre-extubation laryngoscopy and a neck flexion-extension maneuver to encourage any residual clot (the so-called "coroner's clot") to fall past the soft palate into a position where it can be removed under direct vision.

Gentle awakening in nasal surgery is important because coughing and bucking on emergence frequently produce undesirable bleeding. Techniques that are often helpful include the use of a remifentanil infusion and the application of lidocaine down the ETT with the cuff temporarily deflated while the patient is still under deep anesthesia. Oral and gastric suction before emergence will decrease the incidence of postoperative nausea and vomiting (PONV). When nasal packing is used, patients should be advised before induction of anesthesia that, on emergence, they should breathe through the mouth. On awakening, applying pressure on the nose with a facemask should not be done for fear of ruining the surgeon's handiwork. In addition, all postoperative patients with nasal packs will have obstructed nasal passages unless nasopharyngeal airways are incorporated into the nasal pack, and patients with OSA are in particular need of careful postoperative respiratory monitoring. Finally, postoperative pain in these procedures usually does not require opiates, and the use of oral acetaminophen and an NSAID usually suffices.

In many of these procedures, a topical vasoconstrictor such as phenylephrine, oxymetazoline, or cocaine is used. Although these topical agents are important drugs that reduce bleeding and improve visualization during nasal and endoscopic procedures, they sometimes produce cardiovascular toxicity.[122] The cardiovascular effects of cocaine, usually administered as a 4% (40 mg/mL) topical solution, result from the drug's blocking the reuptake of norepinephrine at sympathetic nerve terminals. Consequently, cocaine would not be a first-choice vasoconstrictor in patients with coronary artery disease or hypertension, or in patients taking monoamine oxidase inhibitors.[123] When cocaine use is appropriate, the dose should not ordinarily exceed 1.5 mg/kg.

Phenylephrine is an α-adrenergic agonist topical vasoconstrictor either used alone or in combination with lidocaine. The initial dose should not exceed 500 μg (<20 μg/kg in children ≤25 kg). Because severe hypertension sometimes results following phenylephrine use, blood pressure monitoring is particularly important. Instances of unacceptable hypertension should be treated with direct vasodilators or α-receptor antagonists; the use of β-adrenergic and calcium channel blockers should be avoided because they may worsen cardiac output and produce pulmonary edema.[124]

Oxymetazoline, a selective α_1-agonist and partial α_2-agonist imidazoline-derivative, is perhaps the most popular topical vasoconstrictor in ENT surgery, primarily because of its excellent safety profile and availability as an over-the-counter product.[125-127] Three sprays of 0.05% solution are administered in each nostril. This drug should be avoided in patients taking monoamine oxidase inhibitors. However, despite its relative safety, complications have been reported.[128,129]

Tonsillectomy and Adenoidectomy

The adenoids are a mass of lymphoid tissue located posterior to the nasal cavity, in the roof of the nasopharynx. If this tissue becomes hyperplasic, nasopharyngeal obstruction and a number of related problems can occur such that the adenoids merit surgical removal (adenoidectomy). When removed, the tonsils are usually taken as well. Other indications for tonsillectomy include tonsillar hyperplasia, recurrent tonsillitis, and malignant disease.[130] An especially important consideration here is that chronic oropharyngeal airway obstruction as a consequence of tonsillar hypertrophy can lead to OSA and its attendant complications (daytime sombulence, cor pulmonale, pulmonary hypertension, right ventricular hypertrophy, cardiomegaly). In addition to the usual, preoperative assessment focuses on findings suggestive of OSA, possible cardiac comorbidities, and a history of recurrent upper respiratory tract infections. The presence of a fever or a productive cough may be grounds for postponement of the surgery or for postoperative care in setting of increased vigilance (e.g., ICU or step-down facility), especially in infants.

Induction of anesthesia in adults usually entails administering intravenous drugs, whereas inhaled inductions are popular with children, followed by placement of an intravenous catheter and administration of glycopyrrolate. Oral RAE (named after the inventors Ring, Adair, and Elwyn) tracheal tubes or wire-reinforced tubes, taped in the midline to the mandible, are often preferred by surgeons and are less likely to kink following retractor placement. When a tonsillar or parapharyngeal abscess is present, the patient may have a compromised airway complicated by trismus and pharyngeal edema. Although awake abscess decompression by needle aspiration before the induction of anesthesia is sometimes done, awake fiberoptic intubation is the usual approach in this setting.

At the end of the surgical procedure, the throat pack, if previously placed, should be removed, the oropharynx should then be suctioned, and an orogastric tube should be used to empty the stomach. Extubation is sometimes performed using deep anesthesia but more commonly is carried out when the patient has intact airway reflexes. Coughing on the tracheal tube on emergence may be attenuated by the administration of lidocaine, either given intravenously or placed down the tracheal tube with the cuff temporarily deflated. Emergence on a light remifentanil infusion can also be beneficial.

Posttonsillectomy hemorrhage is a dreaded surgical emergency, especially in children.[131-133] It usually occurs within the first six postoperative hours, but it can also occur several days later. When possible, the patient should receive appropriate intravenous fluids preoperatively (including blood products when necessary). The presence of hypovolemia may dictate a reduction in induction drug dosage or the use of etomidate. Because the stomach may contain a considerable amount of blood, a *rapid-sequence induction* with cricoid pressure is usually performed with a view to protect the airway from aspiration of gastric contents. Vigorous suctioning is also needed to remove the copious oropharyngeal blood likely to be found during laryngoscopy.

Endoscopic Sinus Surgery

Endoscopic sinus surgery has become a common ENT procedure. Indications are varied and include conditions such as nasal polyposis, recurrent or chronic sinusitis, epistaxis control, tumor excision, orbital decompression (e.g., for Graves ophthalmopathy), foreign body removal, treatment of sinus mucoceles, and more.[134-136]

Proper anesthetic management helps ensure a good outcome. Considerations in such cases include local versus general anesthesia, SGA device versus ETT, and inhaled anesthesia versus TIVA, and preferences of the surgeon and anesthesiologist as well as patient comorbidities are taken into account. The most important goals are a blood-free surgical field, patient immobility, stable cardiorespiratory conditions, and gentle emergence from anesthesia. Controlled hypotension is sometimes used to improve surgical conditions; when this approach is used, intraoperative β-adrenergic blockade is associated with better operating conditions than when vasodilation drugs are administered.

Despite minimal arterial blood pressure differences, propofol-remifentanil intravenous anesthesia may provide better surgical conditions as compared with a traditional balanced technique (e.g., using an isoflurane-opiate technique), possibly because of lower heart rates and cardiac

output.[137] Use of an SGA device is preferred to an ETT because of better surgical conditions and smoother emergence. However, SGA devices are prone to malpositioning and provide less protection from gastric regurgitation as compared with an ETT.[138]

The procedure typically begins with decongestion of the nose and infiltration of 1% lidocaine with 1:100,000 epinephrine, often followed by the bilateral nasal placement of pledgets soaked in 4% cocaine. In most cases, an image-guided surgical system is used; this allows the surgeon to know exactly where he or she is operating by using a preoperative CT scan. This technology allows the surgeon to visualize four different views simultaneously: the coronal, sagittal, and axial CT scan images at the same time as the real-time endoscopic view. This system requires a special headset that may preclude the use of electroencephalographic (bispectral index) monitoring.

Given the close proximity of major blood vessels and nerves, the orbit, and the brain, complications are possible, especially when the surgical landmarks are obscured by blood. Some major complications include orbital hematoma formation, blindness from orbital trauma or damage to the optic nerve, formation of cerebrospinal fluid leak, carotid or ethmoid artery invasion, entry into the cranial cavity, severe hemorrhage, and death.

Finally, not all sinus surgery is endoscopic. For example, although now largely replaced by endoscopic methods, the once common Caldwell-Luc procedure involves fenestration of the anterior wall of the maxillary sinus with surgical drainage of this sinus into the nose through an antrostomy.

Thyroid and Parathyroid Surgery

The usual indications for thyroid surgery include thyroid cancer, symptomatic thyroid goiter, and failed medical management of hyperthyroidism; the surgical procedure is almost always elective.[139] The most common indication for parathyroid surgery is hypercalcemia from hyperparathyroidism secondary to a benign parathyroid adenoma. When the hypercalcemia is severe, preoperative treatment (e.g., fluids, furosemide, bisphosphonates) may be needed.

Hyperthyroid patients should be treated preoperatively to reduce the risk of thyroid storm (thyrotoxicosis). Thyrotoxic patients may experience sinus tachycardia, atrial fibrillation, myocardial ischemia, congestive heart failure, nervousness, tremulousness, insomnia, heat intolerance, weight loss, and other findings.[140,141]

Large goiters may result in deviation of the larynx, tracheal compression leading to considerable airway narrowing, Horner syndrome, or superior vena cava obstruction, especially with retrosternal extension.[142,143] Preoperative airway evaluation by endoscopic examination and by CT is often useful to determine the extent of the disease and the possibility that sternotomy will be needed.

General anesthesia with tracheal intubation and muscle relaxation is usually employed, although many surgeons routinely use a nerve integrity monitor (NIM) ETT for neuromonitoring,[144-146] in which case neuromuscular blocking drugs must be avoided in the postintubation period. Gentle emergence from anesthesia is necessary to avoid coughing on the ETT and the possibility of hematoma formation from venous engorgement. The use of a small-dose remifentanil infusion (0.01-0.05 μg/kg/min) in the extubation period is a popular means to diminish coughing on the ETT. Although deep extubation also reduces the incidence of bucking and straining, many clinicians avoid this technique wherever possible because of airway obstruction.

Possible complications of thyroid and parathyroid surgery include hematoma formation (possibly resulting in airway impairment), vocal cord dysfunction from recurrent laryngeal nerve injury, pneumothorax, and other conditions. In patients with compressive goiters, postthyroidectomy tracheomalacia may occur following goiter excision. In postoperative patients who have undergone parathyroid and total thyroidectomy, serial calcium levels are taken to detect inadvertent hypocalcemia.

Airway Fires

An airway fire is a potentially deadly complication that may occur during tracheotomy surgery, during laser surgery to the airway, and elsewhere. For a fire to occur, the triad of fuel (e.g., ETT, drapes, sponges), oxygen, and an ignition source (e.g., laser or electrocautery) is needed. The ASA published an Operating Room Fires Algorithm (Fig. 70.11),[147] to which the reader is referred. An additional helpful resource is a checklist developed by Dr. B. Abdelmalak (Box 70.2). Prevailing conventional wisdom, at least until recently, holds that cases of airway fire call for immediate removal of the ETT. Although this is a reasonable rule of thumb, it should also be noted that in some patients removal of the ETT would result in irreversible loss of the airway. Clinicians in such a setting face a particularly difficult choice: leave the ETT in place and risk fire-related injury to the patient, or remove the ETT and risk deadly loss of the airway.

Ear Surgery

Ear operations range from simple, brief procedures such as myringotomy and tube placement to much more involved procedures such as skull-based surgery. These procedures are best divided into external ear procedures (e.g., removal of exostoses or foreign bodies), middle ear procedures (e.g., myringotomy, tympanoplasty, stapedectomy), mastoid operations (e.g., mastoidectomy), and inner ear procedures (e.g., cochlear implant placement). In such procedures, and especially with inner ear procedures, patients are particularly prone to PONV.

Although many simple procedures can be performed in well-selected individuals by using local anesthesia and intravenous sedation, more complex procedures, especially those requiring an operating microscope (for which immobility is essential), are usually best accomplished using general anesthesia with the presence of a secure airway. Regardless, in all such cases the anesthesiologist must consider issues such as the appropriate form of airway management, whether nitrous oxide is contraindicated, the possibility that postintubation muscle relaxants should be avoided to permit facial nerve monitoring, and the possible need for antiemetic prophylaxis. Most patients require a tracheal tube; the unkinkable,

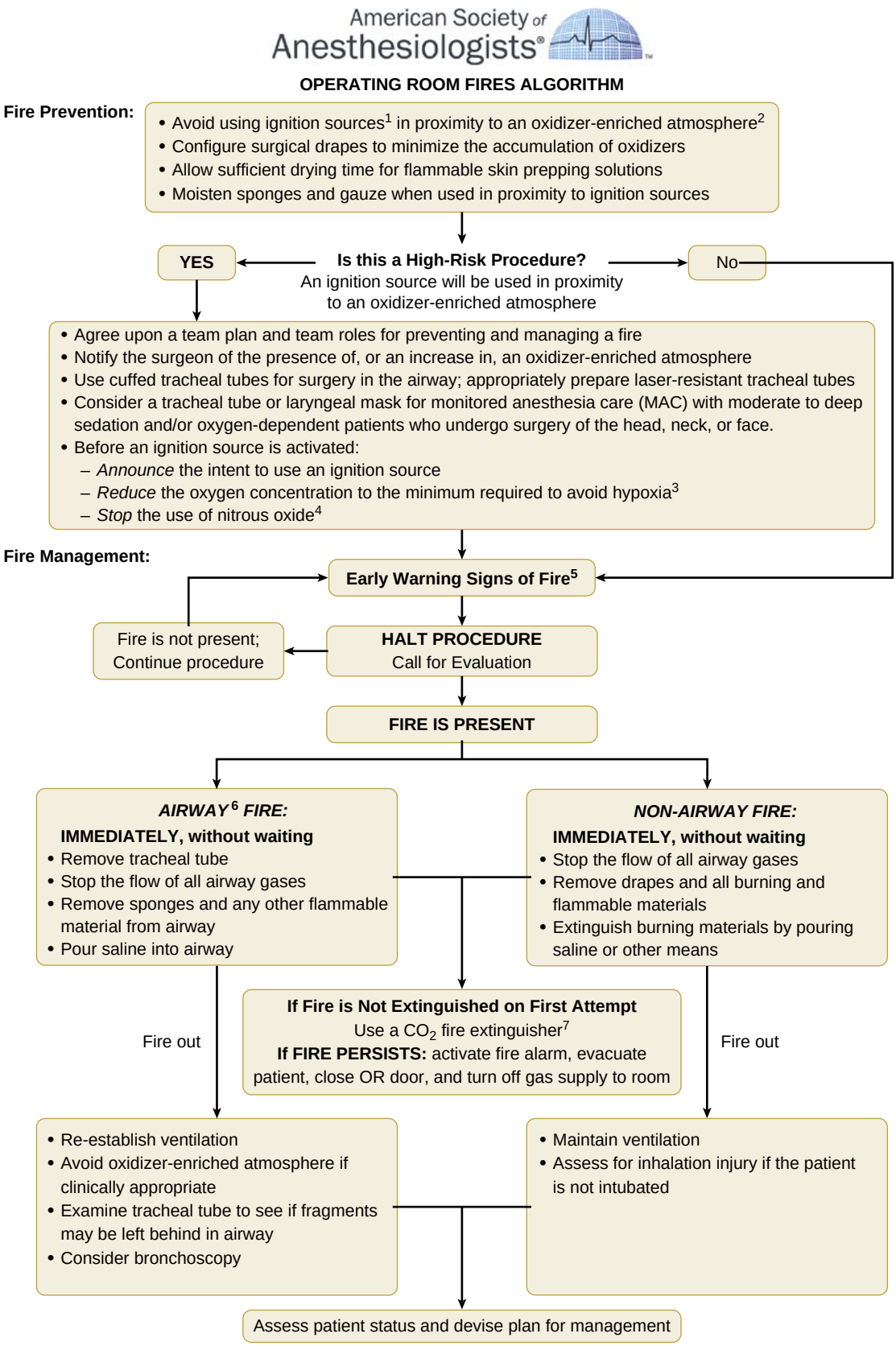

Fig. 70.11 American Society of Anesthesiologists' Operating Room Fires (1) Ignition sources include but are not limited to electrosurgery or electrocautery units and lasers. (2) An oxidizer-enriched atmosphere occurs when there is any increase in oxygen concentration above room air level, and/or the presence of any concentration of nitrous oxide. (3) After minimizing delivered oxygen, wait a period of time (e.g., 1-3 min) before using an ignition source. For oxygen dependent patients, reduce supplemental oxygen delivery to the minimum required to avoid hypoxia. Monitor oxygenation with pulse oximetry, and if feasible, inspired, exhaled, and/or delivered oxygen concentration. (4) After stopping the delivery of nitrous oxide, wait a period of time (e.g., 1-3 min) before using an ignition source. (5) Unexpected flash, flame, smoke or heat, unusual sounds (e.g., a "pop," snap or "foomp") or odors, unexpected movement of drapes, discoloration of drapes or breathing circuit, unexpected patient movement or complaint. (6) In this algorithm, airway fire refers to a fire in the airway or breathing circuit. (7) A CO2 fire extinguisher may be used on the patient if necessary. Algorithm. CO_2, carbon dioxide; *OR,* operating room. (From American Society of Anesthesiologists. Practice advisory for the prevention and management of operating room fires. *Anesthesiology.* 2008;108:786–801. Copyright 2013, the American Society of Anesthesiologists, Inc. Lippincott Williams & Wilkins. Anesthesiology 2013; 118:00-00)

BOX 70.2 Management of Airway Fires

Prevention and Preparedness

1. Keep the O_2 concentration at approximately 30%, or less if possible. Use an O_2/air mixture. Avoid N_2O.
2. Use a "laser-safe" endotracheal tube.
3. Inflate the endotracheal tube cuff with dyed normal saline to provide an early indicator of cuff rupture.
4. Use a pre-prepared 50-mL syringe of saline to extinguish any fire, and flood the surgical field if a fire occurs.
5. Have an extra endotracheal tube available for reintubation in case a fire occurs.
6. Inform the surgical team working on the airway of any situation in which high concentrations of O_2 are being used.

In the Case of an Airway Fire

1. Stop lasering. Stop ventilation. Turn O_2 off (as well as N_2O if it was mistakenly in use).
2. Inform the surgical team, and assign someone to call the control desk for help.
3. Remove the burning endotracheal tube* and drop it in the bucket of water, if available.
4. Put out the fire with your improvised fire extinguisher.
5. The area should be flushed with saline.

When the Fire Is Extinguished

1. Ventilate the patient with 100% O_2 by facemask (or supraglottic airway if appropriate).
2. When the patient is stable, assess the extent of airway damage. Consider using a ventilating rigid bronchoscope; debris and foreign bodies should be removed.
3. Reintubate the patient if significant airway damage is found.
4. When appropriate, arrange for admission to an ICU.
5. Provide supportive therapy, including ventilation and antibiotics, and extubate when appropriate.
6. Tracheotomy may be needed.

ICU, Intensive care unit; *N_2O,* nitrous oxide; *O_2,* oxygen.
Courtesy Dr. B. Abdelmalak, Cleveland Clinic, Cleveland, Ohio.
*Removing the endotracheal tube may be inappropriate in some cases (see text).

wire-reinforced variety is commonly used to avoid airway trouble following head rotation. Alternatively, preformed tracheal tubes (e.g., RAE tubes) are commonly used.

Nitrous oxide is avoided in middle ear procedures because it diffuses from blood to the middle ear, thereby increasing middle ear pressure and potentially distending any carefully placed tympanic membrane grafts. However, many ENT surgeons now use "underlay" grafts, in which increased middle ear pressures can actually help hold the graft in place, as opposed to older "overlay" grafts, in which a high middle ear pressure would dislocate the graft.

Many middle ear operations are performed to ameliorate hearing loss from infection or inflammation. The most frequent of these procedures, myringotomy with tube placement, is most commonly performed in children by using simple sevoflurane mask anesthesia, in conjunction with acetaminophen or (less commonly) fentanyl to treat postoperative pain. The procedure can usually be safely accomplished without establishing intravenous access.[148]

Stapedectomy, typically performed to treat otosclerosis, is usually performed using general anesthesia and may involve the use of surgical lasers (hence a potential need for laser precautions), as well as facial nerve monitoring (hence a potential need for periods with minimal neuromuscular blockade). The use of a volatile anesthetic in combination with a remifentanil infusion helps provide mild hypotension (which reduces blood loss), as well as surgical immobility. Nitrous oxide can theoretically be used early in the procedure, but it must be avoided later on to avoid damaging possible "overlay" grafts to the tympanic membrane. However, most clinicians simply avoid nitrous oxide entirely, to reduce the incidence of PONV. Gentle emergence, often involving a remifentanil infusion, helps avoid coughing or "bucking" with the tracheal tube present, with possible displacement of the bone prosthesis. Not surprisingly, extubation of the trachea during deep anesthesia is sometimes performed. Ossiculoplasty procedures involve similar considerations.

Common inner ear procedures include surgery to the cochlea, endolymphatic sac, and labyrinth. Patients with pathologic processes in the labyrinth and endolymphatic sac, such as patients with Meniere disease, often suffer from vertigo and hearing loss and are especially prone to PONV. In cochlear implant surgery, mastoidectomy is performed to implant the signal coupler while the electrode array is implanted into the cochlea, a procedure often taking over 4 hours. Considerations similar to those for stapedectomy apply, including the potential need for nerve monitoring, the avoidance of PONV, and gentle emergence from anesthesia. Some surgeons also request a degree of hypotension as a means to reduce blood loss.

Untreated chronic otitis media often leads to mastoiditis, tympanic membrane perforation, and damage to the ossicular chain. Additionally, the formation of a cholesteatoma (an invasive growth of keratinizing squamous epithelium) may spread into the mastoid cavity, inner ear, and even the brain to cause additional damage. When antibiotic treatment fails, mastoidectomy (removing infected material, draining subperiosteal abscesses, and reestablishing middle ear ventilation) may be indicated. Because blood loss can be substantial, controlled hypotension is sometimes requested. The nerve identification and gentle emergence issues discussed earlier often apply as well. Nitrous oxide is often avoided, at least in the later stages, because of the tympanoplasty component of the procedure.

Surgical procedures of the outer ear may be used to correct congenital and acquired malformations. Although these patients often present no special challenges, beware of patients whose malformation is part of Goldenhar syndrome or Treacher Collins syndrome because these patients frequently offer airway challenges. General anesthesia is typically employed, and postoperative pain can be substantial when a rib graft is used.

Parotid and Other Salivary Gland Surgery

The salivary glands comprise a pair of parotid glands, two submandibular glands, two principal sublingual glands, and a number of minor salivary glands. As exocrine glands, their function is variously to produce saliva, digestive enzymes (amylase), and lubrication, as well as to provide a bacteriostatic function. Indications for submandibular

gland surgery include tumors, chronic sialadenitis refractory to medical treatment, and removal of impacted stones. The most frequent parotid disease warranting surgery is a benign neoplasm, frequently a pleomorphic adenoma. Superficial parotidectomy (complete or limited) with facial nerve dissection is the most commonly performed procedure for these lesions, although a simpler enucleation procedure is sometimes also performed.[149-151] Identification of the facial nerve and its branches, often employing nerve stimulation methods, is central to the procedure. For this reason, the surgical team usually requests that muscle relaxants be avoided after endotracheal intubation has been achieved.

Besides the usual considerations applying to all surgical patients, preoperative evaluation of patients for salivary gland surgery should consider any previous head and neck surgery and any history of radiation therapy (which can make mask ventilation difficult). The physical examination should look for tumor displacement of the airway, as well as impaired temporomandibular joint (TMJ) mobility and other predictors of airway difficulties. Available head and neck CT scans or MRI studies should be reviewed with the surgical team, with a focus on airway issues.

During these procedures, complete immobility of the patient is important. Consequently, general anesthesia with endotracheal intubation is usually required, although cases of parotid surgery performed using local anesthesia have been reported.[152] Management of the airway with an LMA for parotid surgery has been described; however, the typical 2- to 4-hour duration of the operation and the need for an operative side-up head position lead most anesthesiologists to use a tracheal tube. Sufficient anesthetic depth and patient immobility are usually achieved using relatively large doses of opioid and inhaled anesthetics, with muscle relaxants avoided to allow facial nerve monitoring for both parotid and (less commonly) submandibular surgery. I frequently employ a single, small dose of rocuronium to facilitate endotracheal intubation, followed by sevoflurane anesthesia in conjunction with a remifentanil infusion (e.g., 0.1 μg/kg/min) to provide immobility. Finally, preservation of the facial nerve is of prime importance in these operations; consequently, the surgeon often must identify the facial nerve by using a nerve stimulator. This crucial step is not possible if neuromuscular blockade is present.

Sleep Apnea Surgery

OSA involves repetitive partial or complete upper airway obstruction because of collapse of the pharyngeal airway during sleep.[153-158] This condition typically occurs despite continued movement of the diaphragm and can lead to apneas (with complete obstruction), hypopneas (with partial obstruction), and respiratory effort–related arousals. The last of these can occur without desaturation, whereas hypoxia itself leads to arousal from sleep, with reopening of the airway and the intake of a breath. Severity is related to the number of these respiratory events per hour as determined by polysomnography. Patients in whom conservative treatment (e.g., weight loss, continuous positive airway pressure, bilevel positive airway pressure, oral appliances) fails may benefit from either surgical modification of the upper airway or, rarely, tracheostomy. Commonly performed procedures include uvulopalatopharyngoplasty, uvulopalatal flap surgery, tonsillectomy and adenoidectomy, genioglossus advancement, maxillomandibular advancement, and other procedures. Sometimes these procedures are performed in combination. Possible comorbidities such as obesity, metabolic syndrome, type 2 diabetes, coronary artery disease, or cor pulmonale should be identified. Patients with OSA can be difficult to intubate tracheally or ventilate by mask, and they are especially prone to postoperative hypoxia. In addition, they frequently have conditions such as macroglossia, redundant pharyngeal tissue, lingual tonsil hypertrophy, or an anterior larynx, all of which can make direct laryngoscopy difficult.

Clinical features that increase the likelihood that OSA is present include a body mass index greater than 30 kg/m^2, large neck circumference (>17 inches in men; >16 inches in women), a high Mallampati score (3 or 4), and the presence of features such as a large uvula, macroglossia, retrognathia, tonsillar hypertrophy, or a high arched palate. The airway features that predispose to OSA may also lead to a difficult airway. For example, difficult intubation is encountered five to eight times more often in patients with OSA compared with other patients. Additionally, snoring and OSA are independent risk factors for difficult ventilation by mask.

General endotracheal anesthesia is preferable for OSA surgery because of the risk of aspiration of blood from the surgical site and the risk of laryngospasm should blood or secretions make contact with the vocal cords.

Postoperative vigilance is paramount. One reason is that patients with OSA have an increase in postoperative obstructive episodes, peaking on postoperative day 3 and returning to preoperative levels after a week. Consequently, patients with OSA who are undergoing airway surgery are not outpatient candidates. Postoperative airway edema is another concern and constitutes another reason that it is wise to minimize respiratory depressants such as opioids and sedatives postoperatively. Dexamethasone is often given to reduce airway edema.

Zenker Diverticulum

Zenker diverticulum, first described in 1874, is a herniation or outpouching of pharyngeal mucosa through the posterior wall of the hypopharynx (often between the oblique and horizontal components of cricopharyngeus).[159,160] Typically seen in the sixth to ninth decades of life and occurring in approximately 1 in 800 upper gastrointestinal barium studies, patients may describe regurgitation of undigested food when supine and food caught in the throat (i.e., in the mucosal pouch), as well as coughing, dysphagia, and halitosis. Confirmation of the clinical diagnosis is usually by barium swallow and/or endoscopy.

Surgery can be either open or endoscopic. In the open (transcervical) approach, the diverticulum is exposed through a lateral neck incision and is then resected (diverticulectomy) or tacked superiorly to the prevertebral fascia (diverticulopexy). Cricopharyngeal myotomy may be added to help prevent recurrence. In the endoscopic approach, no skin incision is required; here the surgical procedure usually involves ablating the common wall between the pouch and the cervical esophagus by using an endoscopic stapler, surgical laser, or other means.

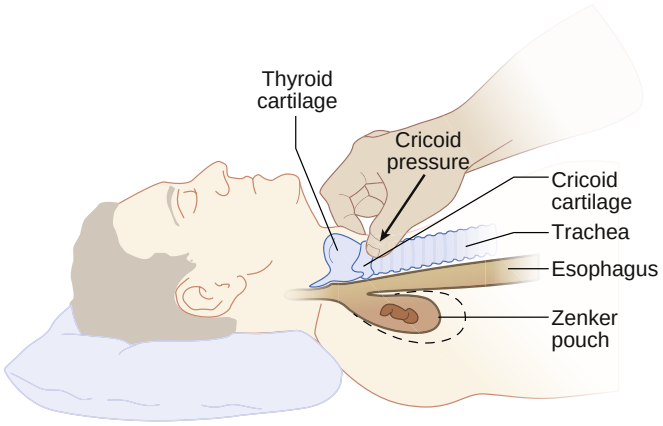

Fig. 70.12 Anatomic relationship of the diverticulum to the cricoid cartilage during application of cricoid pressure. (From Thiagarajah S, Lear E, Keh M. Anesthetic implications of Zenker diverticulum. *Anesth Analg.* 1990;70:109–111.)

Several anesthetic considerations apply. First, patients are frequently older, with applicable comorbidities, such as coronary artery disease. Second, the possibility that food caught in the pouch could end up in the airway is a concern. Additionally, oral medications such as antihypertensives administered the day of surgery may lodge in the pouch and be aspirated. Perhaps preoperative evacuation of the pouch can be performed by applying external pressure before anesthesia, but this is not commonly done because of concerns of causing iatrogenic pulmonary aspiration. More commonly, the patient is positioned with a 30-degree head-up tilt before the induction of anesthesia.

Although awake endotracheal intubation should provide excellent protection against the risk of aspiration of pouch contents, a theoretic concern exists that any coughing during the procedure, either from the use of transtracheal local anesthesia or from the instrumentation, could lead to regurgitation of pouch contents with possible aspiration. A more common technique is the use of rapid-sequence induction of anesthesia, usually with the modification that cricoid pressure is not used, for fear of discharging the pouch contents with the applied pressure. (Application of cricoid pressure is recommended only if the neck of the pouch is below the cricoid cartilage; see Fig. 70.12). Some experts have expressed the concern that using succinylcholine, especially if it is not preceded by a nondepolarizing muscle relaxant, could produce muscle fasciculations that could cause pouch compression. Even after endotracheal intubation, seepage of material around the ETT cuff can occur with surgical manipulation; some clinicians place a moist gauze throat pack to prevent aspiration of this material. Finally, the procedure is occasionally performed using regional anesthesia with deep and superficial cervical plexus blocks.

Care should be taken to avoid perforation of the diverticulum, such as with blind placement of a nasogastric tube or during difficult tracheal intubation. During the surgical procedure, retraction of the carotid sheath may stimulate baroreceptors and initiate arrhythmias, especially bradycardia, whereas significant blood loss and air embolism may occur if major vessels are accidently cut. A smooth awakening from anesthesia that is free from coughing and straining is important to avoid the risks of neck hematoma and the attendant possibility of a compromised airway.

Anesthesia for Surgical Airways: Cricothyrotomy and Tracheostomy

Two general approaches exist to create a surgical airway. In dire emergencies one may perform a cricothyrotomy,[161,162] by entering the airway through the cricothyroid membrane. This is done either by inserting a narrow-bore transtracheal ventilation catheter percutaneously through the cricothyroid membrane and employing emergency high-pressure jet ventilation or by inserting a wider-bore tube of sufficient diameter to allow low-pressure ventilation through a conventional resuscitator bag (e.g., "Ambu" bag). This second approach through the cricothyroid membrane can be achieved by using a vertical scalpel incision, identifying the cricothyroid membrane, cutting through the membrane with a horizontal stab incision, and placing (for example) a 6-mm inner-diameter tracheal tube. Alternately, one can use a commercial kit employing (for example) the Seldinger technique (e.g., Melker cricothyrotomy kit, Cook Medical, Bloomington, Ind.). An educational cricothyrotomy video is available at http://www.cookmedical.com/cc/educationMedia.do?mediaId=1522.

The second approach to achieving a surgical airway is a tracheostomy.[163,164] (Although the terms "tracheotomy" and "tracheostomy" are used interchangeably by clinicians, based on their Greek roots, the former term refers to cutting into the trachea, whereas the latter refers to the opening that has been created.) This approach is best suited for situations that are not high-level emergencies, takes rather longer to complete, and usually involves entering the airway between the second and third tracheal rings following a careful dissection of the neck tissues. Although it is very often performed using general anesthesia in an intubated ICU patient in whom ventilator weaning has failed, it is sometimes performed using local anesthesia, either employing no sedation (this is the usual case in stridulous patients, especially those requiring Heliox) or using a drug such as dexmedetomidine because of its lack of respiratory depression. In any event, the decision to perform a tracheostomy using local anesthesia is made jointly with the surgeon and depends on the extent of airway disease, the experience of the surgical team, and the degree to which the patient is able to tolerate lying supine with his or her head in extension. In some cases, the procedure must be performed with the patient in a semiupright sitting position.

In the case of patients whose tracheas are intubated, at one point in the procedure the anesthesia provider will be asked to withdraw the tracheal tube slowly to permit the airway to be entered without obstruction. Additionally, at this time the airway should be entered using a scalpel and not using cautery, to prevent an airway fire in an oxygen-rich environment.

A number of problems may arise in the postoperative period following a tracheotomy.[165-167] Bleeding, pneumothorax, subcutaneous or mediastinal emphysema, and

hypoventilation or airway obstruction may occur immediately after the procedure, whereas possible late complications include tracheal stenosis, tracheoesophageal fistula formation, tracheomalacia, and even tracheal necrosis. Although posttracheotomy bleeding is usually inconsequential, bleeding into the airway may cause the patient to cough and buck forcefully. In addition, major bleeding from a large artery or vein (often the communicating branch of the superior thyroid artery) may necessitate immediate exploration of the surgical field, whereas bleeding from the innominate artery may occur from erosion by the distal end of the cannula. (One hint that the tracheostomy could be applying pressure to the innominate artery is the finding of pulsations in the tracheotomy cannula after initial insertion. Treatment includes inflating the tube cuff and pulling the tube assembly anteriorly to tamponade the bleeding. An oral tracheal tube should then be inserted for management in the operating room.)

Frequently, tracheotomy tubes must be changed, for instance because of a cuff leak or because of obstruction from the buildup of secretions. A central concern in this instance is that the replaced tube could enter a false passage rather than the trachea. (This in itself is unfavorable, but should the false passage be inadvertently ventilated, the resulting subcutaneous emphysema could eliminate the possibility of easily reestablishing the airway.) This potential problem eventually disappears as the tracheal stoma matures to form a well-defined and self-supporting orifice. However, this rigidity and tissue support are lacking in a fresh tracheostomy, so that following removal of the tracheostomy tube, the tissue may "collapse in" on itself to block the passage. Consequently, certain precautions when dealing with a fresh tracheostomy tube must be borne in mind. First, for the first week or so, tube changes should be performed in the operating room with a full set of tracheotomy instruments (e.g., cricoid hooks) and a means to intubate "from above" as a last resort if the airway is lost. Second, once the tracheotomy site has begun to mature, it is no longer necessary to carry out tube changes in the operating room, but a full set of instruments (especially cricoid hooks) should still be available. Additionally, changing the tube over a tube changer may also be useful, but some clinicians find that it may unnecessarily complicate matters. Third, before any tube change, the patient should breathe 100% oxygen. Finally, a fiberoptic bronchoscope may be potentially useful in confirming tracheal placement of a tracheostomy tube before attempting any positive-pressure ventilation that could lead to subcutaneous emphysema should the tube, in fact, be malpositioned.

Neck Dissection and Laryngectomy

Neck dissection is commonly performed in isolation or during laryngectomy to prevent or treat any local spread of head and neck malignancy.[168,169] The extent of a neck dissection operation is based on the extent to which the neck's six lymph node levels are involved, as well as on the extent to which additional structures (spinal accessory nerve, internal jugular vein, and sternocleidomastoid muscle) are removed. Depending on the degree to which the tumor can be removed and recurrence or spread can be prevented, as well as the extent that phonation and swallowing can be preserved, various surgical options are exercised. Limited disease is sometimes managed by radiation, by laser and microsurgery, or by partial laryngectomy, thus preserving organ function. In total laryngectomy, the larynx is removed in its entirety, with the airway ending in a stoma formed by bringing the cut end of the trachea to the neck surface (with the result that the trachea now becomes independent of the esophagus.) Often a perforation between the trachea and the esophagus (tracheoesophageal puncture) is made to allow eventual placement of a voice prosthesis.[170] In some cases the procedure is supplemented with microvascular free tissue transfer (free flap).

Anesthesia can be induced through a standard intravenous line, followed by large-bore intravenous and arterial lines placed after induction. A central line can usually be avoided, with systolic pressure variation of the arterial line tracing and other clinical findings to guide fluid replacement. Although nerve function monitoring is usually required during the neck dissection phase, neuromuscular blockade is acceptable at the beginning. When neuromuscular blockade is no longer desirable, opioid infusions (e.g., remifentanil) are often used to maintain adequate analgesia in conjunction with an inhaled anesthetic agent. Many clinicians prefer using a balanced technique in preference to deep inhalational anesthesia or TIVA (propofol with or without remifentanil) to avoid the troublesome hypotension. Excessive intravenous crystalloid administration should be avoided to prevent operative site edema.

In total laryngectomy cases, a tracheostomy is customarily performed near the beginning of the procedure by using a wire-reinforced ETT placed into the stoma. (Warning: accidental endobronchial intubation commonly occurs in this setting.) In some cases, the patient is turned 180 degrees from the anesthesia machine; care must be taken to ensure that nothing is disconnected in the process. Extubation in such cases is extraordinarily simple; the ETT should be removed from the stoma when extubation criteria are met. Should reintubation ever become necessary, one merely reintroduces the tracheal tube into the stoma. The patient is then simply brought to the postanesthesia care unit with an oxygen mask placed over the stoma, although when a free flap has been performed, the patient is often brought to the ICU intubated, ventilated, and sedated (depending on the surgeon's preferences and local protocols.)

Maxillary, Mandibular, and Temporomandibular Joint Surgery

Maxillectomy surgery may be limited (e.g., removal of one antral wall, such as in a medial maxillectomy), subtotal (e.g., removal of two walls of the antrum), or total (removal of the total maxilla).[171-173] Orbital exenteration sometimes accompanies the procedure should the intraorbital contents be violated by tumor. Indications for maxillectomy include the following: tumors of the maxillary sinus, palate, and other structures; some intractable fungal infections; and other conditions. The procedure is performed using general anesthesia with tracheal intubation and

invasive monitoring appropriate to the patient's condition and the extent of the surgery. Although massive blood loss is unusual, precautions should be taken because hemorrhage may occur (e.g., with transection of the internal maxillary artery). Hypotensive anesthesia, when appropriate, can help reduce blood loss. Medial maxillectomy procedures conducted endoscopically do not require anything different from ordinary sinus surgery for anesthesia. When electromyography-based cranial nerve monitoring is employed, long-acting paralytic agents should be avoided.

Surgery of the mandible and TMJ may be carried out by maxillofacial surgeons, as well as by otolaryngologists and plastic surgeons.[174-176] Mandibular surgery can range from simple biopsies to all-day radical procedures involving microvascular osteocutaneous flaps. Awake nasal intubation may be required in some cases. Hypotensive anesthesia is often used for orthognathic procedures to minimize blood loss. In some cases the jaw is wired shut, and reintubation, should it be required postoperatively, can be a challenge.

TMJ dysfunction often manifests with pain and decreased mouth opening. Conditions such as osteoarthritis, synovitis, or fibrosis may be responsible. Most TMJ procedures are performed using general nasotracheal anesthesia. As with mandibular surgery, the presence of very limited mouth opening may dictate that the procedure be done with awake nasal intubation.

Ear, Nose, and Throat Laser Surgery

Lasers are commonly used in ENT surgery (Box 70.3 and Table 70.1).[177-180] The most widely used laser in ENT surgery is the CO_2 laser, which allows precise cutting with a particularly fine zone of coagulation that reduces bleeding. Tissue vaporization is particularly efficient with this laser because of the excellent absorption of the produced far-infrared photons (10,600-nm wavelength) by water present in tissue. This laser is used in the removal of laryngeal tumors and lingual tonsillar tissue, in the ablation of hemangiomas, and for the resection of some oropharyngeal malignant tumors.

Another popular laser in ENT surgery is the neodymium: yttrium-aluminum-garnet (Nd:YAG) laser, which emits photons with a wavelength of 1064 nm. These photons are poorly absorbed by water and thus tend to penetrate tissue more deeply than do those from a CO_2 laser. In addition, light from an Nd:YAG laser can be transmitted through flexible quartz fibers that can be used in conjunction with a flexible fiberoptic bronchoscope for use in treating tracheobronchial lesions.

Because surgical lasers involve high amounts of energy, they have the potential for unintended tissue damage, as well as for causing fires. Stray laser beams can ignite surgical drapes. To mitigate these risks, one should place warning signs outside the operating room, provide opaque coverings on any operating room windows, and issue protective goggles. The presence of high oxygen concentrations near the patient's face can facilitate ignition in this region, so delivering supplementary oxygen by facemask or nasal cannula requires special care. American National Standards Institute standard Z136.3 (Safe Use of Lasers in Health Care Facilities) provides additional information on this and related matters.

BOX 70.3 Some Otolaryngologic Clinical Situations in Which Laser Techniques Can Be Useful

Nose

- Turbinate reduction
- Septoplasty
- Removal of nasal obstructions, polyps, synechiae
- Treatment of rhinophyma
- Treatment of keloids and hypertrophic scars

Oropharynx and Pharynx

- Vaporization of papillomas, leukoplakias, and hemangiomas
- Tumor surgery (e.g., partial glossectomy)
- Laser-assisted uvulopalatoplasty
- Tonsillectomy

Larynx

- Removal of vocal cord polyps and granulomas
- Epiglottectomy
- Cordectomy
- Arytenoidectomy

Tracheobronchial Tree

- Treatment of tracheal stenosis
- Removal of nodules, polyps, tumors, and fibromas

Ear

- Surgery of the stapes
- Laser-assisted myringotomy
- Cholesteatoma

From Abdelmalak B, Doyle DJ, eds. *Anesthesia for Otolaryngologic Surgery*. Cambridge, UK: Cambridge University Press; 2012.

TABLE 70.1 A Sampling of Various Kinds of Lasers Available for Clinical Use

Type	Gas or Solid	Wavelength* (nm)	Color	Fiberoptic Transmissible?
Helium/neon	Gas	633	Red	Yes
Argon†	Gas	500	Blue-green	Yes
CO_2	Gas	10,600	Invisible (far infrared)	No
Ruby	Solid	695	Red	Yes
Nd:YAG	Solid	1064	Invisible (near infrared)	Yes
KTP	Solid	532	Green	Yes

KTP, Potassium titanyl phosphate; *Nd:YAG*, neodymium:yttrium-aluminum-garnet.
*Wavelengths are given in nanometers (nm). There are 10^9 nm to a meter.
†The argon laser produces blue-green coherent light at a number of wavelengths but most of the energy is at wavelengths 488 nm and 514 nm.
From Abdelmalak B, Doyle DJ, eds. *Anesthesia for Otolaryngologic Surgery*. Cambridge, UK: Cambridge University Press; 2012.

One special concern is that regular ETTs can ignite from a laser beam. In the past, metallic tapes applied in a spiral manner were sometimes used. Today, however, several special-purpose ETTs are available for this purpose (Table 70.2).

TABLE 70.2 Some Types of Laser Endotracheal Tubes in Clinical Use

Name	Description	Intended Use
Laser-Flex	Airtight stainless steel corrugated spiral with a PVC Murphy eye tip and double cuffs. More information is available at http://www.cardinal.com/us/en/distributedproducts/ASP/43168-145.asp.	CO_2 or KTP lasers
Laser-Shield II	Silicone rubber tube wrapped with aluminum and wrapped over with Teflon. More information at http://assets.medtronic.com/ent/flipbook-us/files/assets/basic-html/index.html#190	CO_2 or KTP lasers
Lasertubus	Soft white rubber, reinforced with corrugated copper foil and an absorbent sponge; double cuffed. More information at http://www.myrusch.com/images/rusch/docs/A20C.pdf	CO_2 or KTP lasers
Sheridan Laser-Trach	Red rubber design with embossed copper foil and outer covering designed to reduce damage to mucosal surfaces and vocal cords. More information at http://www.teleflex.com/en/usa/productAreas/anesthesia/documents/Sheridan-ET-Tube-Guide.pdf	CO_2 or KTP lasers

CO_2, Carbon dioxide; *KTP,* potassium titanyl phosphate; *PVC,* polyvinyl chloride.

From Abdelmalak B, Doyle DJ, eds. *Anesthesia for Otolaryngologic Surgery.* Cambridge, UK: Cambridge University Press; 2012.

The choice of anesthetic technique depends on the clinical circumstances. TIVA techniques for laser ENT surgery are particularly popular and are essential when patients are unintubated and jet ventilation is used. When patients are intubated, a potent inhalational agent such as sevoflurane is often used, although frequently an infusion of remifentanil is used as an anesthetic adjunct in such cases (typical rate: 0.05-0.1 μg/kg/min). (Remifentanil, with its vagomimetic effect, is especially useful to limit the heart rate in the face of intense sympathetic stimulation from the effects of the suspension laryngoscope.) Finally, to reduce the chance of a fire, while lasers are in use nitrous oxide should not be used, and the oxygen concentration should be limited to the lowest concentration necessary to maintain acceptable arterial oxygen saturation levels.

Airway management is often a challenge in laser surgery cases, and the surgeon and anesthesiologist must work together to devise a plan. One issue is whether general anesthesia should be preceded by awake intubation because the presence of airway disease may complicate both ventilation and intubation. Another issue is whether the procedure should be performed using general anesthesia with the patient breathing spontaneously, albeit with assistance, as is sometimes desirable when an anterior mediastinal mass is present. Muscle relaxation is often employed to help ensure an immobile surgical field. With the widespread availability of sugammadex, most clinicians are able to use rocuronium as a relaxant, followed by a "sugammadex rescue" should the airway become unmanageable following relaxant administration. Many clinicians, however, simply intubate the patient awake whenever issues of this kind arise.

In some cases, the entire surgical procedure is done without intubation. The advantages of this approach are a decreased risk of fire (no ETT to ignite) and improved access to airway structures. Disadvantages include the risk of aspiration with an unprotected airway and potential difficulties in ventilating the patient. Typically in such cases, an anterior commissure laryngoscope or similar device is used in conjunction with TIVA and jet ventilation. In other cases, the laryngoscope is used in conjunction with a small-diameter ETT (e.g., MLT size 5.0), and the procedure is performed while the patient has brief periods of apnea in conjunction with intermittent removal of the ETT to allow unimpaired access to the glottic structures.

Laser vaporization of tissue, especially from CO_2 lasers, often results in a plume of smoke that can be hazardous. The use of a smoke evacuator at the surgical site along with protective masks that filter out particulate material is often advised, especially when virus particles are present in the vaporized tissue.

Extubation of the trachea in these cases can be challenging. Some patients benefit from the administration of intravenous dexamethasone to reduce edema. Stridor is sometimes encountered after extubation; although this condition may require reintubation, one can sometimes avoid this by the use of inhaled racemic epinephrine or the use of Heliox, a mixture of helium (typically 70%) and oxygen. Extubation over a tube exchanger can be helpful when the need for reintubation is a concern and is expected to be challenging.

Even when the tracheas of patients are extubated conservatively following laser surgery, airway problems can arise later. In cases of immediate respiratory distress following laser procedures, consider the following possibilities: tissue edema (e.g., after Nd:YAG laser use), residual muscle relaxant or anesthetic effects, airway secretions, pneumothorax, bleeding, and pneumomediastinum.

Phonosurgery

Phonosurgery is surgery conducted to improve a patient's voice.[181-185] In many cases the patient's voice has been damaged as a result of unilateral vocal cord paralysis. One common operation used in this setting is medialization of the paralyzed vocal cord (laryngoplasty) so that the normal vocal cord can make contact with the paralyzed side. This procedure is done using local anesthesia with minimal sedation (e.g., 20 mg propofol administered just before the injection of the local anesthetic) because the patient needs to phonate on request. Continuous intraoperative imaging of the vocal cords, especially during phonation, is carried out to achieve the repair. An infusion of dexmedetomidine is sometimes used.

Head and Neck Flap Reconstructive Surgery

Tissue transfer in the form of pedicle flap or a microvascular free flap is commonly employed to reconstruct defects created following tumor surgery.[186-188] Potential advantages of such flaps include the avoidance of staged procedures,

improved wound healing, superior cosmetic results, and improved tolerance for postoperative radiation therapy. For optimal anesthetic care, anesthesiologists must have a clear understanding of these procedures and their implications for anesthetic management.

A *pedicle flap* is one in which the flap vessels are transferred intact with the rotated flap. If the flap is moved from a distant "donor" site and the flap vessels are reanastomosed to the recipient site vessels, then the tissue is termed a *microvascular free flap.* Examples of myocutaneous pedicled flaps are the pectoralis major flap and the latissimus flap used (for instance) to cover the carotid artery after the point where it is sacrificed and reconstructed using a vein graft. In contrast to pedicle flaps, free flaps provide the surgeon with more options for donor sites. Frequently, separate surgical teams for the donor and recipient sites are employed. Surgery in relation to free flaps can be elective, or it may be performed on an emergency basis to rescue an ischemic flap. Elective procedures tend to be long-duration operations conducted using general anesthesia. An arterial cannula is generally used, although special care must be taken to ensure that the arterial cannula and any additional intravenous catheters are not inadvertently placed at a site where tissue harvesting is planned (e.g., radial forearm flap). Central lines are not usually placed, in part because information about volume status can usually be better achieved using less invasive means such as systolic blood pressure variability. Many of these procedures begin with a tracheostomy and end with the patient being cared for in an ICU while intubated and ventilated. Intraoperative and postoperative flap monitoring is achieved clinically (examination for color, turgor, edema, and capillary refill), as well as by using technical means of blood flow assessment, such as Doppler ultrasound.

Intravenous crystalloids and colloids are administered liberally but cautiously to prevent hypovolemia and hypotension that could lead to ischemic flap failure. Conversely, excessive fluid leads to detrimental edema formation within the flap. The use of vasopressors such as phenylephrine or norepinephrine is generally discouraged during free flap procedures because these drugs may contribute to graft ischemia as a result of vasoconstriction.

Stridor and Heliox

Stridor is noisy inspiration resulting from turbulent gas flow in the upper airway. Stridor should always command clinical attention because it is almost always the result of airway obstruction.[189-194] The first issue of clinical concern in the setting of stridor is whether intubation is immediately necessary. If intubation can be delayed for a period of time, a number of potential options can be considered, depending on the severity of the situation and other clinical details. These options include the following: expectant management with full monitoring, 100% oxygen by facemask, and positioning the head of the bed for optimum conditions (e.g., 45-90 degrees); use of nebulized racemic epinephrine (e.g., 0.5-0.75 mL 2.25% solution in 2.5 mL normal saline) and dexamethasone ([Decadron] 4-8 mg intravenously every 8-12 hours) when airway edema may be the cause of the stridor; and use of Heliox (70% helium, 30% oxygen). Dexamethasone can take several hours to take full effect, and nebulized cocaine in a dose not exceeding 3 mg/kg can be used instead of racemic epinephrine. Finally, whenever possible, immediate attempts should be made to establish the cause of the stridor (e.g., foreign body, vocal cord edema, arytenoid cartilage dislocation, tracheal compression by tumor).

Frequently, stridor occurring after extubation is the result of laryngeal edema, and it may be more problematic in children because of their small airway size. Be aware that as laryngeal edema progresses, diminished stridor may reflect impending total airway obstruction. The specific cause of laryngeal edema can often be established with fiberoptic nasopharyngeal examination, and causes are often classified as supraglottic or subglottic. Supraglottic edema most commonly follows surgical instrumentation, impaired venous drainage, eclampsia or preeclampsia, hematoma formation, or excessive fluid administration. Subglottic edema may result from traumatic intubation attempts, bucking on the ETT, prolonged intubation, tight-fitting tubes, or excessive cuff pressures.

The manner in which Heliox helps relieve airway obstruction is worthy of note. Some airway-obstructing conditions may be thought of as breathing through an orifice, involving flow through a tube whose length is smaller than its radius. Gas flow through an orifice is always somewhat

Fig. 70.13 An E-size tank of Heliox, with an attached nonrebreathing facemask in a plastic bag. In this case, the mixture is 70% helium and 30% oxygen, although other mixtures are available. This gas mixture is usually given using a nonrebreathing facemask with a gas flow of 10 L/min as a temporizing measure in stridulous individuals.

turbulent. Under such conditions, the approximate flow across the orifice varies inversely with the square root of the gas *density*. This is in contrast to laminar flow conditions, in which gas flow varies inversely with gas *viscosity*. Although the viscosity values for helium and oxygen are similar, their densities are very different. For example, the density for air and oxygen at 20°C is 1.293 and 1.429 g/L, respectively. However, the density of helium at that temperature is only 0.178 g/L. Clinically, Heliox is usually administered from an E-size cylinder through a nonrebreathing facemask starting at a flow of 10 L/min (Fig. 70.13). When the usual 30% oxygen concentration is too low, one trick is to titrate in additional oxygen by nasal cannula. In summary, a setup to administer Heliox should be readily available in every ENT operating room suite to assist in the treatment of stridor.

Anesthesia for Face Transplantation

Face transplantation remains a very rare procedure (Fig. 70.14).[195,196] The procedure can be total or partial. The recipient must be able to undergo a very prolonged anesthetic and be free of serious comorbidities. Each procedure is unique with respect to indications, as well as with respect to the nature and the extent of the graft. In the case of the donor, although anesthetic principles similar to conventional organ procurement apply, because of the surgical complexity and time involved, harvesting of the facial graft should ordinarily be performed before harvesting other organs. Although the donor usually has an ETT in place at the time of tissue procurement, a tracheostomy may be performed first to avoid interference with the surgical field. Recipient patients who do not have a tracheostomy may first require awake fiberoptic oral intubation, followed by a tracheostomy. A wire-reinforced ETT is often used. Large-bore catheters are placed to facilitate fluid resuscitation, whereas a central line may be useful to monitor central venous pressure. If a central line is used, however, it must not impinge on the surgical field. Blood and fluid management is no different from that during other long surgical procedures involving microvascular free flaps. As with microvascular surgery, pressors such as phenylephrine or norepinephrine, commonly used to treat hypotension, are discouraged because of the risk of compromising graft

Fig. 70.14 Ms. Connie Culp before (A) and after (B) the two stages of her face transplant at Cleveland Clinic. Stage 1 was carried out in December 2008 (lead surgeon: Dr. Maria Siemionow). (Images courtesy the Cleveland Clinic, Cleveland, Ohio.)

perfusion. Finally, there may be periods when muscle relaxation must be avoided to allow nerve identification using electrical stimulation.

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Complete references available online at expertconsult.com.

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71 Anesthesia for Robotic Surgery

DAN B. ELLIS and MEREDITH A. ALBRECHT

KEY POINTS:

- Robotic surgery has witnessed explosive growth. Currently (2018) more than 3 million procedures have been performed using the da Vinci system worldwide.[1]
- Robotic surgery is not true autonomous surgery but instead the robot is used as mechanical "helping hands" aiding skilled surgeons.
- By creating three-dimensional views, allowing increased movement of laparoscopic instruments within a patient's body, and allowing precise movements, robotic surgery can enhance a surgeon's ability to visualize pathologies and to perform complex procedures.
- Given the size of robotic equipment and the need for specific patient position during procedures, robotic surgery may present unique challenges for anesthesia providers.
- To facilitate surgical exposure, robotic surgery often requires insufflation of a body cavity with carbon dioxide. Insufflation and resorption of carbon dioxide can lead to a variety of physiologic changes.
- Robotic surgery has been successfully used to care for patients receiving urologic, gynecologic, colorectal, hepatobiliary, otolaryngologic, cardiac, and thoracic procedures.

What Is a Robot?

According to Merriam-Webster, a robot is "a machine that resembles a living creature in being capable of moving independently (as by walking or rolling on wheels) and performing complex actions (such as grasping and moving objects)." Developed in the 1980s by the National Aeronautics and Space Administration (NASA), a robot is a remotely controlled device that allows tasks to be performed in spaces removed from human presence. Eventually, robots began to perform tasks aboard NASA spaceships. While the initial concept of robotic science was useful in space exploration, the U.S. government began looking for other applications of the technology.

The US Department of Defense (DOD) began working to apply the robots that were useful in space to the battlefield. Recognizing that an inordinate number of American soldiers died on the battlefield from hemorrhage or untreated surgical wounds, the DOD looked to use these technologies in surgical theaters. With the goal of having a surgeon remotely operate on patients in difficult-to-reach locations, the military invested in developing remotely controlled articulating arms that could perform surgical procedures.

At the same time, the world's first laparoscopic cholecystectomy was performed in France. This procedure forever altered the course of traditional surgery, and the minimally invasive era of surgical procedures began.

Over the next decade, several companies developed a variety of medical robots and rapidly advanced the science. The first such device appeared in the early 1990s, when an instrument was created to pulverize bone and create space for hip prosthesis during orthopedic surgery.

As work progressed on creating devices to perform procedures, work also continued on allowing remote control of devices. In the mid-1990s, voice recognition software was used to control a laparoscope's position and to aid in organ retraction during traditional laparoscopic surgery. This device, called Automated Endoscopic System for Optimal Positioning (AESOP), is still available today (Fig. 71.1). In many ways, this device was the precursor to the smart devices in our homes and on our persons.

Arguably the greatest advancement in robotic surgery occurred in 1991 when a master-slave version of a robot was developed. This device allowed a surgeon to sit apart from his/her patient and remotely control articulating arms. Two similar devices, the da Vinci Robotic Surgical System, and the ZEUS Surgical System, appeared on the market at similar times. The parent company of da Vinci, Intuitive Surgical, acquired the intellectual property rights to the ZEUS system and discontinued the product. As a result, only the da Vinci Robotic Surgical System is available for use today (Fig. 71.2).

Eventually, high-definition, three-dimensional cameras were added to robots, allowing surgeons to explore a patient's anatomy and access traditionally difficult-to-reach surgical sites from a console located next to the operating table. While several robotic companies have developed products, at the moment, only two remain: AESOP and da Vinci.

The da Vinci robot has four components (Figs. 71.2 and 71.3):

1. Surgeon console (Figs. 71.4 to 71.6)
2. EndoWrist instruments (Figs. 71.7 and 71.8)
3. Optical vision cart
4. Patient cart with four movable arms (Fig. 71.9)

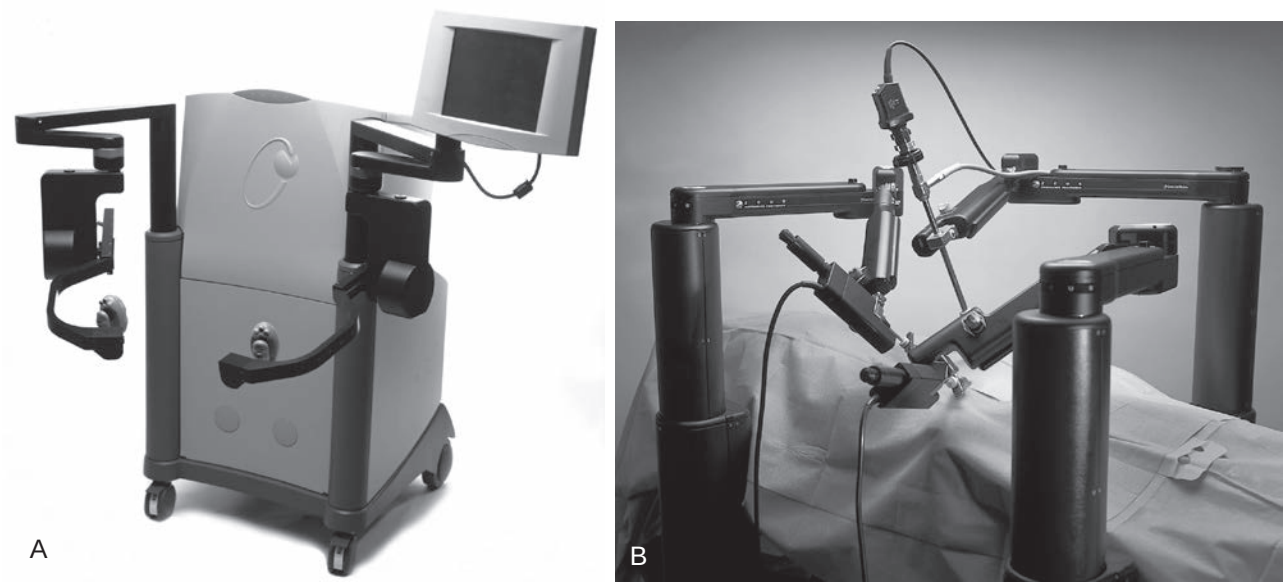

Fig. 71.1 (A) The console of the ZEUS robotic telemanipulation system consists of a video monitor and two instrument handles that translate the surgeon's hand motions into an electric signal that moves the robotic instruments. (B) Two table-mounted Automated Endoscopic System for Optimal Positioning (AESOP) arms hold instruments, and a third arm controls the camera. (Courtesy Computer Motion, Sunnyvale, CA, USA.)

Fig. 71.2 The da Vinci Robotic Surgical System: two surgical consoles, patient-side cart with four mounted surgical arms, and an optical tower. (Courtesy Intuitive Surgical, Sunnyvale, CA, USA.)

The surgeon sits at the surgeon console (see Figs. 71.4 and 71.5) and remotely controls the EndoWrist instruments that are attached to the patient cart. Anesthesia personnel, surgical assistants, and circulating nursing staff may see the procedure in real time via the screen on the optical vision cart (see Fig. 71.2).

During an operation, the surgeon views two high-definition monitors that mimic a binocular or microscope. This two-monitor view creates three-dimensional images. The surgeon's arms rest on the master controls, and his/her fingers manipulate the levers that control EndoWrist articulation. Foot pedals control electrocautery, movement of the robotic camera, and disengagement of robotic instruments. To facilitate collaboration and training, the da Vinci machine will often have two consoles allowing two surgeons to participate in the patient's care.

Why Is the Robot Preferred?

The robot is preferred to open procedures because it allows a minimally invasive approach to surgical pathologies. Less tissue manipulation leads to fewer adhesions and potentially faster recovery from surgery. Fewer wound complications, including infections and incisional hernias, and shorter hospitalizations make robotic surgery attractive when compared to other minimally invasive or open techniques.[2] Further, the robotic approach to surgical procedures allows discrete movements that are helpful in microsurgical dissection and re-attachment of tissues. In comparison with human arms, robotic arms permit seven degrees of free movement. These movements can be categorized into: gross arm movement by the da Vinci robot, fine movements by the articulating arms,

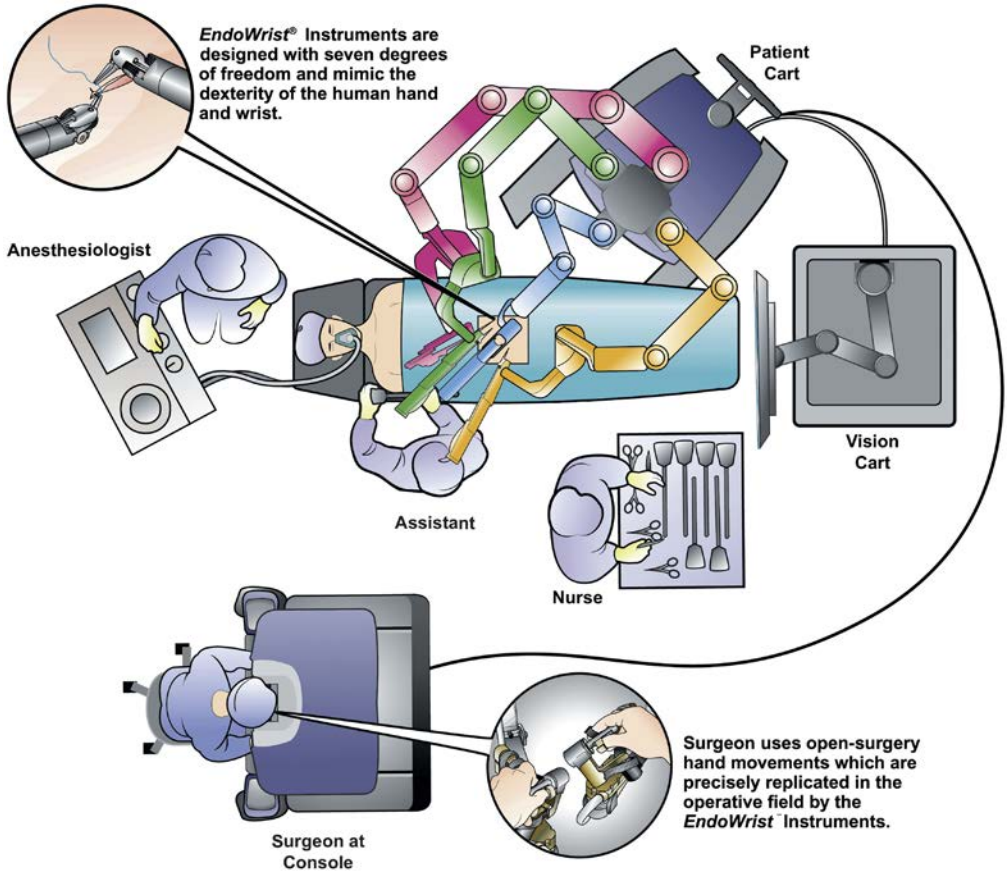

Fig. 71.3 Operating room schematic of the use of a robotic surgical system in general surgery. (Courtesy Intuitive Surgical, Sunnyvale, CA, USA.)

Fig. 71.4 The da Vinci Robotic Surgical System: the surgeon console. (Courtesy Intuitive Surgical, Sunnyvale, CA, USA.)

Fig. 71.5 The da Vinci Robotic Surgical System: stereo viewer that creates a virtual three-dimensional stereoscopic image. (Courtesy Intuitive Surgical, Sunnyvale, CA, USA.)

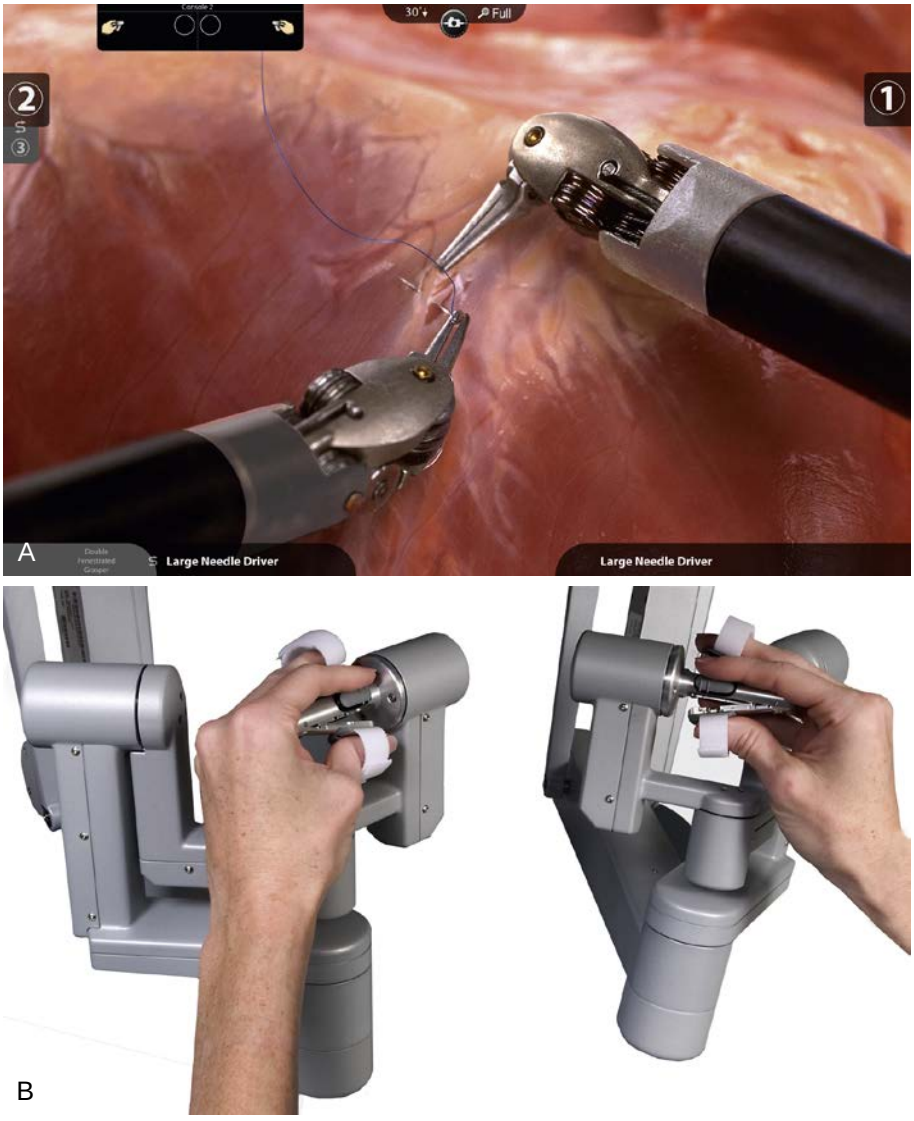

Fig. 71.6 The da Vinci Robotic Surgical System. (A) Virtual three-dimensional stereoscopic image of the surgical field. (B) Master controls that translate the surgeon's hand, wrist, and finger movement into real-time movements of surgical instruments inside the patient. (Courtesy Intuitive Surgical, Sunnyvale, CA, USA.)

and surgical actions performed by the articulating arms (Table 71.1, Figs. 71.7 and 71.8).

These articulating arms are not limited by constraints associated with human wrist joints. Additionally, the robot allows for larger, more coarse movements to be miniaturized in the operating field. For example, moving the controls by 5 mm may move the articulating arms by only 1 mm. This miniaturization permits more fine control. Furthermore, robotic software can reduce or eliminate hand tremors, thereby improving the safety and precision of surgery.

When Is the Robot Used?

The robot is used in hysterectomy, prostatectomy, nephrectomy, cardiac surgery, colectomy, general laparoscopic, thoracoscopic, and transoral otolaryngologic procedures. Although most procedures performed using the da Vinci robot are urologic (prostatectomy) and gynecologic (hysterectomy), a wide range of new applications are being discovered.

Essentially, robotic surgery is helpful whenever microsurgery is necessary and the target organ is difficult to reach. It is especially valuable if its usage converts what is traditionally an open procedure to a minimally invasive procedure.

Future Applications of Robotic Surgery

As imaging modalities and artificial intelligence are applied to robotic surgery, the field will evolve. It is probable that nonrigid, flexible articulating arms of progressively smaller size will ultimately replace the current, rigid articulating arms. "Snake-like" articulating arms will facilitate fewer and smaller incisions to be made in a patient and allow less invasive, perhaps even scar-free, surgery to be performed. Finally, as artificial intelligence evolves, it is possible that semi-autonomous robotic surgery will develop with computer algorithms guiding surgical instruments.

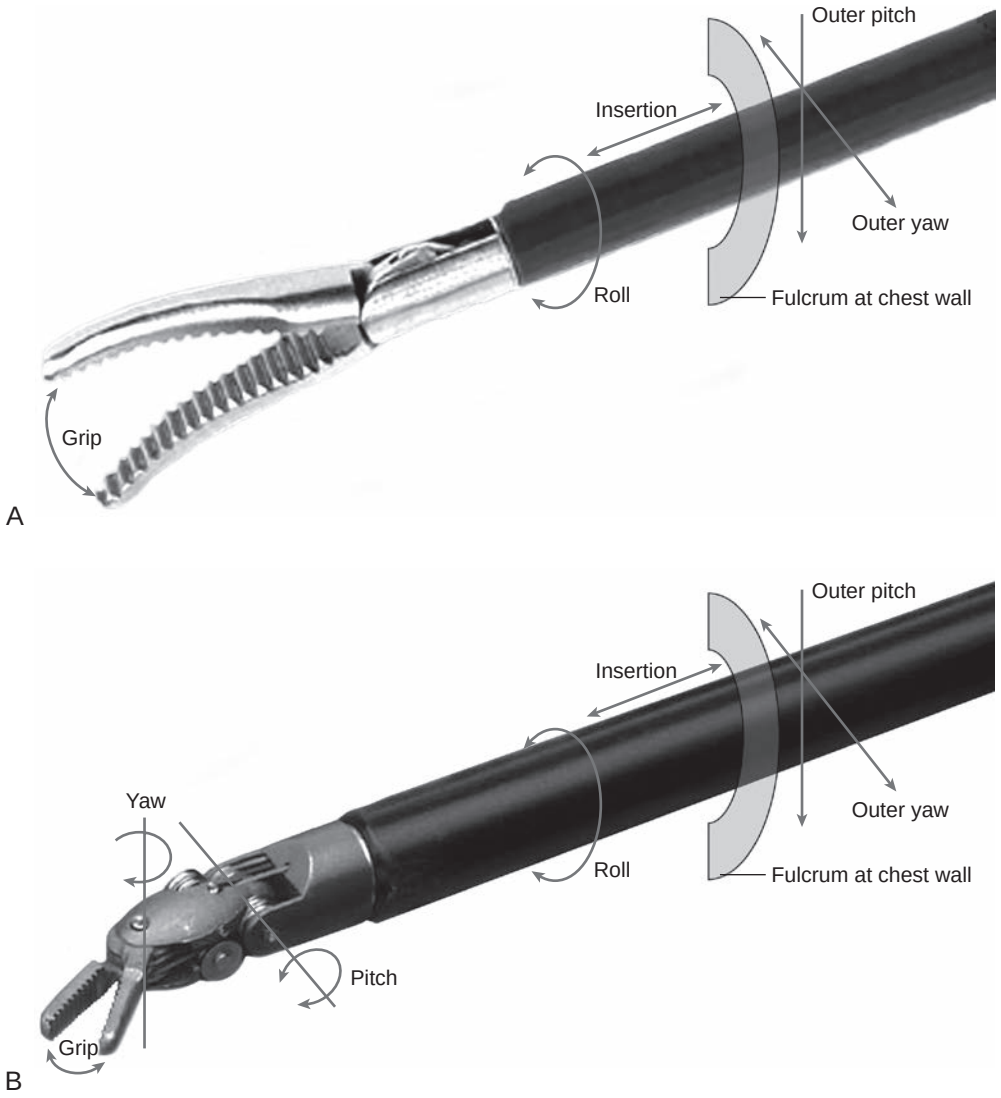

Fig. 71.7 Degrees of freedom (DOF) in motion. (A) Conventional laparoscopic instruments have only four DOF and grip. Insertion (i.e., movement in the *z*-axis), roll, and movement along the *x*- and *y*-axes outside the body relative to a fulcrum point constitute the four DOF. (B) Depiction of the EndoWrist instrument with two added intracorporeal joints, producing seven DOF.

ROBOTICALLY ASSISTED INTUBATION

There have been reports of successful robotic intubations. The Kepler Intubation System (KIS), developed by Thomas Hemmerling, has been shown to intubate mannequins successfully by an operator who has either a direct or indirect view of the patient. KIS is a low-cost system consisting of a joystick, a robot arm, the Pentax videolaryngoscope, and a software control. The intubations occurred within 40 to 60 seconds with a 100% success rate on the first attempt. This system also allowed for semiautomated (a computer system replayed prior operator driven movement sequences) intubations that occurred in less than 45 seconds and had a 100% success rate.[3] The system has also been used on 12 patients and was successful with a first-pass intubation in 11 of the 12 patients (1 was unable to be completed due to fogging of the equipment). The intubations were done in approximately 93 seconds.[4,5] It remains to be seen if a robot intubation system will have widespread use. However, it may have applications in settings where it would be difficult to transport a trained anesthesia provider to the location, such as deep space exploration.

ROBOTIC SURGERY PHYSIOLOGY

Robotic surgery causes a number of physiologic changes. Positioning, insufflation with carbon dioxide (CO_2) to allow visualization of the surgical field, and physiologic changes associated with increasing intracompartmental pressure (i.e., abdominal, thoracic, or oral) are all seen with robotic surgery. Therefore, it is imperative that anesthesia providers are aware of these perturbations so that appropriate compensatory plans may be created.

Insufflation With CO_2

Except for otolaryngological procedures, inert gas must be insufflated into a patient's body to visualize the surgical field. CO_2 is the inert gas of choice because it has a high diffusion coefficient and the risk of a gas emboli is minimized since CO_2 is easily excreted from the body through the respiratory

Fig. 71.8 The EndoWrist instrument of the da Vinci Robotic Surgical System mimics the natural kinematics of the surgeon's hand and wrist. This design allows more degrees of freedom. (Courtesy Intuitive Surgical, Sunnyvale, CA, USA.)

Fig. 71.9 The da Vinci Robotic Surgical System: patient-side cart. (Courtesy Intuitive Surgical, Sunnyvale, CA, USA.)

TABLE 71.1 Seven Degrees of Free Movement Permitted by Robotic Arms

Gross Arm Movements	Wrist Movements	Surgical Actions
In and out	Yaw (side-to-side and left-right)	Grasp or cut
Up and down	Pitch (up and down)	
Side-to-side	Rotation and roll	

system.[6] As CO_2 is insufflated into the abdomen, surgeons exercise caution to keep intraabdominal pressures below 20 cm of water. By minimizing intraperitoneal pressure, the vagal stimulation from elevated intraabdominal pressure is minimized. However, if the patient has a particularly pronounced resting vagal tone or a significant vagal response to peritoneal insufflation, pharmacologic intervention by the anesthesia provider or reduction of pneumoperitoneum may be necessary.

Insufflating the surgical site with CO_2 also may lead to sudden increases in CO_2 in the blood stream because it is absorbed from lymphatic and venous plexi.[7] As a result, increasing minute ventilation is necessary to maintain normocarbia and to keep the patient in homeostasis.

Another potential untoward effect of CO_2 insufflation is gas embolism.[7] Although rare, a gas embolus may have catastrophic effects on the cardiopulmonary system if the embolus becomes lodged in the pulmonary system. Additionally, if a patient has an atrioseptal or ventriculoseptal defect, he or she may develop a gas embolus in the cerebrovasculature with potentially devastating complications.

A more common and less devastating complication of gas insufflation and increased intraperitoneal pressure is atelectasis. This is exacerbated by the effects of insufflation on diaphragmatic excursion.[8] CO_2 insufflation may lead to pneumomediastinum or subcutaneous emphysema (incidence of 0.43%-2.3%). Although this finding typically has no clinical consequences, it may be associated with prolonged CO_2 excretion postoperatively causing hypercarbia and acidosis. Also, there have been reported cases of pneumothorax caused by extension of insufflated gas through diaphragmatic congenital channels into pleural cavities (incidence of 0.03%). An increased incidence is associated with an increased number and size of trocars, longer surgical time, higher gas flow rate, intensified gas pressure, loose trocars, and difficult trocar placement. Due to a number of factors, such as lack of external visualization and haptic feedback during robotic surgery, there is an increased incidence of gas extravasation.[9]

Pulmonary Vasoconstriction

Pulmonary vasoconstriction results from insufflation due to:

1. CO_2 absorption, and
2. physical compression of the lungs.

CO_2 absorption results in hypercarbia and acidosis. The pulmonary system's response to hypercarbia is vasoconstriction, in order to preserve gas exchange by preferentially shunting blood away from less ventilated portions of the lungs. Therefore, carbon dioxide insufflation has a vasoconstricting effect on the pulmonary vasculature.

In addition, during robotic surgery, pneumoperitoneum results in compression atelectasis as the intrathoracic pressure competes with elevated intraperitoneal pressures resulting in lung tissue compression. This process is worsened by Trendelenburg positioning. Nasogastric or orogastric tubes may facilitate gastric decompression and help reduce, albeit not eliminate, increased intraabdominal pressures. As functional residual capacity decreases, patients may experience increased lung collapse and atelectasis. This phenomenon combined with the vasoconstriction due

to the CO_2 insufflation increases the ventilation/perfusion mismatch. This mismatch results in decreased oxygenation.

Atelectasis also leads to hypoxic pulmonary vasoconstriction (HPV). HPV is a compensatory mechanism that allows the body to preferentially divert blood from oxygen-poor regions of the lungs to oxygen-rich regions. and improves gas exchange by shunting blood to areas of the lung that are ventilating normally.[7] This effect appears to be caused by mitochondrial sensors inspiring voltage-gated calcium channels to increase the cytosolic calcium, thereby leading to vasoconstriction.

Insufflating the peritoneum also decreases respiratory compliance and elevates airway pressures. This process makes ventilation increasingly difficult and worsens the aforementioned hypercarbia.[10] To improve ventilation it has been recommended to switch mode from volume control ventilation to pressure control ventilation (PCV). However it has been shown in a randomized trial of patients for robot-assisted laparoscopic radical prostatectomy that aside from lower peak airway pressures and improved compliance in the PCV mode, there was no benefit in other parameters, such as: central venous pressure, mean pulmonary arterial pressure, pulmonary capillary wedge pressure, cardiac index, arterial oxygen pressure, mean airway pressure, physiological dead space, and intrapulmonary shunt fraction.[11]

Elevated CO_2 levels also shift the oxyhemoglobin dissociation curve to the right via the Haldane effect. This shift in the dissociation curve helps deliver oxygen to the tissues and results in slightly less ischemia than would be expected.[12-14] A potential explanation for this phenomenon is that carbon dioxide inspires the Haldane effect and HPV.

Cerebral Vascular Effects

Increased absorbed CO_2 from insufflation also leads to cerebrovascular dilation. Although CO_2 leads to blood being preferentially shunted away from the pulmonary vasculature, CO_2 in the cerebral circulation leads to cerebral vascular dilation. Anesthesiologists must be mindful of the potential increase in intracranial pressure (ICP) that may arise from elevated CO_2 levels.[15,16] Additionally, a number of robotic procedures require steep Trendelenburg positioning to allow surgical visualization of pelvic structures, which also results in increased ICP. Anesthesiologists must be cognizant of possible increased ICP especially in cases where patients need a ventriculoperitoneal shunt due to baseline increases in ICP.

Systemic Effects of Hypercapnia

Hypercapnia will lead to a respiratory acidosis as CO_2 is combined with water and is metabolized into bicarbonate and hydrogen ions. Since bicarbonate does not effectively buffer the acidosis induced from hypercarbia, a respiratory acidosis occurs.[17,18]

Hypercapnia will augment anesthetic effects. Acute hypercapnia will also result in depressed consciousness when $PaCO_2$ exceeds 80 mm Hg.[19] Increased CO_2 also decreases myocyte contractility and can potentially increase the myocardial susceptibility to arrhythmias.[20]

Patient Positioning. Patient positioning during robotic surgery can present a challenge. By definition, robotic surgery requires remote operation of laparoscopic equipment and surgical instrumentation. Therefore much of the normal feedback between surgeon and patient is altered, as surgeons are removed from their patients and replaced by bulky steel instrumentation. Therefore, patients are at much higher risk of iatrogenic injury than their nonrobotic peers. Also, this separation from the patient, and working from the inside of the surgeon console, makes communication between the operating room team and the surgeon difficult.

To minimize nerve injuries, careful attention must be paid to patient positioning. Given the size of the robot, a patient's arms are tucked at his or her sides and are often inaccessible during an operation. Once a robot has docked, access to the patient is hampered. Therefore, if an anesthesia provider is considering additional intravenous/arterial access, consider placing these lines after induction of the anesthesia and prior to docking of the robot. A best practice is to place at least two intravenous catheters in addition to an extra noninvasive blood pressure cuff with an extra connector and hose prior to docking of the robot. This allows more flexibility with intraoperative monitoring of the patient, even during periods of very minimal access.

Further, the type of surgical procedure creates unique positioning considerations. If surgeons are operating on pelvic organs, patients require steep Trendelenburg positioning. Alternatively, if patients are receiving abdominal wall surgery, then the supine positioning is often required.

If a patient is to be placed in steep Trendelenburg position, then the best practice is to tuck a patient's arms at his or her sides to minimize brachial plexopathy from hyperextension of the arms. In addition to minimizing the risk of brachial plexus injury, a patient's arms may be tucked at his or her sides to also allow the robot access to the patient. Foam padding and silicone pads are employed to protect vulnerable nerves. If the patient's arms are not tucked at his or her sides, then care must be paid to making sure brachial plexus injuries do not occur from hyperextension of the arms. Additional padding may be necessary to protect a patient's face, head, and neck from robotic arm movements, and vigilance by an anesthesia team is mandatory.

Given the need for patient immobility during a procedure, continuous neuromuscular blockade is paramount as patient movement resulting from intense surgical stimulation in the setting of inadequate anesthesia or insufficient neuromuscular blockade may lead to significant patient injury. To allow for titratable paralysis during robotic cases, many clinicians infuse neuromuscular blocking agents. As a result, continual monitoring of neuromuscular blockade is imperative. Many anesthesia providers place *multiple* intravenous lines so that boluses of medications and fluids may be given through one line while infusions of vasoactive or neuromuscular blocking agents may be given through another.

Please note that the robot arms and the patient's operating room table may not move together. Therefore, once the robot is docked and the robot arms are inside the patient, it is paramount to avoid dyssynchronous movement of the operating room table to avoid tearing injuries of tissue inside the patient.

Physiologic Changes Associated With Patient Positioning

CARDIOVASCULAR EFFECTS

Robotic urologic and gynecologic procedures require steep Trendelenburg positioning to facilitate surgical exposure. When patients are in a steep "head-down" position, blood is funneled from the lower extremities to the right atrium, thereby increasing pre-load. Studies demonstrate a variety of conclusions with respect to the effect of Trendelenburg position on cardiac index and output.[21-24] Patient comorbidities, anesthetized state, and preoperative medications may potentially alter the cardiac output changes induced by Trendelenburg positioning. In general, healthier patients with a robust cardiovascular systems are better able to adjust for hemodynamic changes and tend to have unaltered cardiac output. Also, increases in cardiac output are typically seen only when patients are euvolemic.[25,26]

INTRAOCULAR EFFECTS

Intraocular pressure increases with progressively steeper Trendelenburg positioning. Additionally, longer procedures tend to correlate with greater increases in intraocular pressure.[28-30] If patients suffer from intraocular pathology, that pathology may be exacerbated by longer surgeries and steep Trendelenburg positioning.

URINARY OUTPUT

Urinary output significantly decreases with pneumoperitoneum.[31] However, the decreased urinary output caused by pneumoperitoneum does not appear to negatively impact renal function over time. The decrease in urine output during insufflation does make fluid management more challenging.

After steep Trendelenburg, injuries seen more frequently with robotic surgeries than normal laparoscopic surgeries include urinary retention, infections of the urinary tract, and subcutaneous emphysema.[27]

Types of Robotic Surgery

A large variety of surgeries may be performed using a robot. The most common include urologic procedures such as prostatectomies, cystectomies, and nephrectomies. Also, common gynecologic procedures are hysterectomies, myomectomies, and oophorectomies. Hepatobiliary procedures, colectomies, cholecystectomies, and hernia repairs are also frequently performed.

UROLOGIC PROCEDURES

The first commonly performed robotic urologic procedure occurred in the 1980s with the development of the Unimate Puma robot by Unimation.[32] The Unimate Puma was a machine with six-axes of movement that allowed rapid transurethral resection of prostatic tissue (TURP). This increased efficiency and decreased operative time led to less absorption of irrigation fluid, which resulted in less risk of TURP syndrome.[26,33] As interest in robotic applications to urologic surgery grew, clinicians sought new applications for robotic surgery, including robotic prostatectomies, nephrectomies, and cystectomies, which were being performed by urologists.

Robotic-Assisted Retropubic Prostatectomies

Arguably the most commonly performed robotic urologic procedure is the robotic-assisted retropubic prostatectomy (RAPR). When compared to traditional open prostatectomies or laparoscopic prostatectomies, RAPR appears to have decreased transfusion rates, facilitated faster recovery of urinary continence, and decreased erectile dysfunction. Additionally, RAPR appears to be easier to learn than traditional laparoscopic prostatectomy techniques.

In many ways, the anesthetic plan for a RAPR is like the anesthetic plan for laparoscopic prostatectomy. A standard intravenous induction followed by tracheal intubation is required. Most clinicians advocate for two intravenous lines, as the patient's arms will be tucked at his sides after he is placed in the lithotomy position. A blood bank sample is necessary, as trocars may unexpectedly invade large blood vessels. Neuromuscular blockade is also of extreme importance, as movement by the patient while the robot is docked may lead to significant and serious complications.

As described above, most anesthesia providers recommend placing a second noninvasive blood pressure cuff with a connector and hose on the patient's other arm, in case of difficulty with blood pressure measurement intraoperatively.

To facilitate surgical exposure of deep pelvic organs, patients are often placed in steep Trendelenburg position. As described above, insufflation of the abdomen with steep Trendelenburg positioning leads to an increase in intracranial and intraocular pressures. Since the positioning can result in physical objects hitting the patient's face, it is important to have facial and ocular shields to prevent harm during the case. Several case reports of postoperative blindness and visual field defects have been reported.[34,35] Gastric contents may drain via gravity onto the eyes and potentially cause ocular damage. Therefore, many clinicians advocate decompressing the stomach with an orogastric tube. Although the exact mechanism of ocular damage is not completely understood, decompressing the stomach may help minimize the risk of a trocar advancing into the stomach in addition to protecting the patient's eyes. Increased ICP can lead to strokes or hemorrhages in vulnerable populations.

Fluid management is also very important during robot prostatectomies and requires a delicate balance. Too much fluid given prior to the reattachment of the bladder and the urethra is associated with an increased risk of postoperative anastomotic leak.[36] Since the head is the dependent structure during the case, too much fluid is also associated with glottic and periocular edema. However, using fluid management that is too restrictive can be associated with acute tubular necrosis and the possible risk of a compartment syndrome due to hypotension in the legs. The risk of compartment syndrome is probably less than 0.5% and is associated with longer cases, obesity, and poor positioning.[37]

Robotic-Assisted Radical Cystectomy

Cystectomies are traditionally a difficult operation, as fluid shifts, fluid management, and patient comorbidities present unique challenges. Perioperative management of these patients is sufficiently challenging that nearly 1 out of every 4 patients are readmitted to the hospital following radical cystectomy.[38,39] Unfortunately, readmitted patients often remain in the hospital for roughly a week.[39,40]

Since 2003, robotic-assisted radical cystectomies have been performed in operating rooms around the world.[41] While a number of randomized controlled trials exist, there is a heterogeneity in the data, and diverse conclusions have been drawn based on the patients' long-term results.[42-45] Overall, robotic-assisted radical cystectomy appears to have lower blood loss when compared to open cystectomies. However, this decreased blood loss appears to come at the cost of increased operative times. Of note, there does not appear to be a difference in length of hospital stay[46] or 2-week readmission rates.[47]

Anesthetic considerations for patients receiving robotic-assisted radical cystectomy mirror the considerations for patients receiving robotic-assisted radical prostatectomy. Steep Trendelenburg, increased ICP, and increased ocular pressure are possible. Additionally, the need for CO_2 insufflation is required for visualization.[48]

Robotic-Assisted Nephrectomy

During the past 10 years, radical nephrectomy has been performed to treat renal cancers and is often viewed as the standard of care for patients with T1 and T2 kidney tumors. This surgery, which may result in a cancer-free state, has been performed using an open or laparoscopic technique. In addition, over the last decade, surgeons have begun turning to robotic assistance to perform these surgeries.[49]

Robotic-assisted surgery, when compared to traditional laparoscopic surgery, may allow enhanced visualization of the surgical field and increased degrees of articulation of the surgical arms. Additionally, several meta-analyses demonstrate similar or slightly improved perioperative outcomes when laparoscopic procedures are compared to robotic procedures.[50,51]

Despite many literature reviews and meta-analyses that compare laparoscopic and robotic surgery, there are very few prospective studies comparing perioperative complications and surgical costs. However, there are documented increases in costs and operative times associated with robotic nephrectomies compared to a traditional laparoscopic approach.[49]

GYNECOLOGIC SURGERY

Since 1999, robotic surgery has been used in gynecologic procedures. Robotic procedures were initially used to perform fallopian tubal re-attachment following permanent sterilization, and are currently being used with hysterectomy, salpingo-oopherectomy, vesicovaginal fistula repair, sacrocolpexy, and ovarian cystectomy.[52]

Robotic-Assisted Hysterectomy

After the first gynecological robot-assisted surgery, robotic assistance was quickly applied to hysterectomies, the second most common surgical procedure performed in the United States.[53]

However, despite the large number of patients receiving robotic hysterectomies, it is unclear whether robotics is superior to traditional laparoscopic approaches.[54]

Robotic surgery for endometrial cancer resection does appear to require more surgical operating time, particularly as surgical teams work to become more comfortable with the procedure[55]; proficiency performing the surgery, as approximated by surgical time, appears to improve after 20 to 30 cases.[56] There has been increased concern about the utilization of the robot during endometrial cancer resection surgery since the outcomes appear similar to laparoscopic hysterectomy, but the cost and operative times are greater.[53,57] The American College of Obstetricians and Gynecologists (ACOG) continues to recommend vaginal hysterectomy as the preferred approach for benign disease, where feasible, due to its lower complication rate and faster recovery time. ACOG states that robotic surgery needs to be better studied to discover if a particular subgroup of patients would be best served by this approach.[53]

Providers have begun performing robotic procedures on morbidly obese patients given the physical surgical demands associated with traditional laparoscopy and the greatly increased morbidity associated with an open abdominal approach. In general, the perioperative outcomes appear to be similar.[58,59] However, the positioning of morbidly obese patients into steep Trendelenburg position can be very challenging. Steep Trendelenburg positioning combined with the pneumoperitoneum necessary to facilitate surgical exposure can create cardiovascular and ventilation challenges. While it is possible that this subgroup of patients (body mass index [BMI] > 40), who would otherwise require an open abdominal approach, could benefit from minimally invasive robot surgery, these cases involve a great number of anesthetic challenges.

Other Gynecological Surgeries

Due to the rather steep learning curve for sacrocolpopexy, robot assistance is believed to facilitate this technically difficult procedure. Randomized, controlled trials have shown similar outcomes with robotic versus laparoscopic surgeries. However, the robotic cases can have increased operative time, postoperative pain, and cost.[53] Myomectomies with robot assistance may allow for more minimally invasive surgeries that would otherwise occur due to fibroid location and high patient BMI.

Robot-assisted surgery for gynecological malignancies has been poorly studied with only retrospective comparisons available. Robot assistance was preferred versus an open approach due to decreased cost, length of stay, and complications. A recent meta-analysis focusing on endometrial cancer concluded that robot versus laparoscopy had a similar duration of surgery but shorter hospital stay, less blood loss, fewer conversions to laparotomy, and overall complications, but a higher cost.[60]

ACOG does not recommend the use of the robot for short-duration and low-complexity surgeries such as tubal ligation, simple ovarian cystectomy, ectopic pregnancy, or bilateral salpingo-oophorectomy.[53]

General Surgery

Colectomy. In 1997, general surgeons in Belgium applied robotic techniques to their patients when the first robotic-assisted laparoscopic cholecystectomy was performed.[52]

However, despite many peer-reviewed studies, a recent meta-analysis did not find significant differences between laparoscopic and robotic colectomy surgeries. This lack of difference is perhaps in large part because of the low number of patients in these studies. Additionally, significant heterogeneity existed in the studies, which might have obscured any results.[61]

In a quality improvement analysis, robotic colectomies were associated with statistically significant increases in operative costs when compared to traditional laparoscopic techniques and longer operative times.[62] However, this economic argument may be tempered by a potentially decreased length of stay, as evidenced by a retrospective review of a National Surgical Quality Improvement Program database of 17,000 colectomies.[24]

Cholecystectomy. Another application of robotic surgery is in robotic-assisted cholecystectomy. In this procedure, a single incision is performed, and robotic arms are introduced into the patient's body. This approach is a contrast to the traditional laparoscopic cholecystectomy that requires multiple incisions.[63]

Patients are gravitating towards single-port robotic cholecystectomy procedures for decreased surgical scarring. The daVinci robot has been successfully used in Europe since 2011 before being brought to the United States.[64] Traditional thinking viewed robotic-assisted cholecystectomy as excessively expensive and not warranting a shift away from laparoscopic cholecystectomy,[65] as a recent meta-analysis showed increased operative times for robotic versus laparoscopic cholecystectomy. However, much of this time occurs in the pre-incision phase of the operation.[63]

Additionally, robotic-assisted cholecystectomy is associated with a significantly higher risk of incisional hernia[64] as the incisional hernia rate is approximated to be between 7% and 20%.[66,67] This increased hernia rate may require additional operations and therefore will increase overall healthcare costs.

Hepatobiliary. The liver's unique location deep in the abdominal cavity and its abundant blood supply has slowed surgeons from aggressively adopting and implementing laparoscopic techniques.[68]

Hepatic surgery was first successfully described in 1954 by Claude Couinaud.[69] Since the initial description, laparoscopic approaches to liver surgery have become more common. Additionally, there does not appear to be a difference in tumor recurrence, tumor spread, or survival for patients who receive laparoscopic hepatectomies.[70] Furthermore, minimally invasive techniques appear to be correlated with decreased blood loss when compared to open procedures.[71]

However, the need for greater articulation of surgical instruments, increased mobility of laparoscopic arms, and enhanced surgical visualization has limited wider adoption of laparoscopic surgery, particularly when compared to open procedures.[72] To address these limitations, hepatobiliary surgeons have begun looking to the da Vinci robot. Experienced surgeons usually do not have difficulty transitioning from the traditional laparoscopic approach to robotic surgery.[73] Additionally, robotic surgery allows three-dimensional imaging of a surgical site.[74]

While robotic surgeries are associated with increased intraoperative costs, overall costs of these robotic procedures may be decreased as they generally are associated with shorter lengths of stay compared to open procedures.[75] Thus, robotic surgery in the management of patients requiring hepatobiliary surgery remains an evolving field.

Otolaryngology

There are over half a million cases of head-and-neck cancers in the world.[76]

As otolaryngologists modernize their approach to both benign and malignant pathologies, they have looked to robotic-assisted approaches to replace larger and more invasive neck dissections that were needed to remove oral cancers.

TONSILLECTOMY

Tonsillectomies are one of the most commonly performed procedures in the United States. Although the practice of routinely removing tonsils in childhood has been replaced by more conservative medical management, tonsillectomies are still performed for refractory tonsillitis. As a result, patient demographics are shifting, and patients are presenting later in life with comorbidities not often seen in childhood. Surgeons are looking to innovate and find modern approaches to removing tonsils and adenoid tissues. The robotic articulating arms allow a more minimally invasive approach to resecting the tissue.[77-79]

HEAD AND NECK DISSECTION

Robotic surgery was first applied to oral and maxillofacial surgery in 1994 by Kavanagh,[80] and has rapidly expanded. Now, robotic surgery incorporates the resection of lesions from the base of the tongue, pharynx, piriform sinus, and nasopharynx.[81] Adoption of this technology has even spread to encompass transaxillary thyroid and parathyroid resection as well as uvulopalatopharyngoplasty.[82]

Even though robotic technologies have existed for quite some time, head and neck surgeons in the United States did not immediately adopt them. In fact, for many years, robotic procedures were not approved by the U.S. Food and Drug Administration (FDA). However, in 2009, the transoral approach to oropharyngeal cancers was approved by the FDA.[83,84] While this approach has not been commonly adopted, European studies have shown promise.[85]

CARDIAC (SEE ALSO CHAPTER 54 ANESTHESIA FOR CARDIAC SURGICAL PROCEDURES)

Robotic surgery has been performed in cardiac operating rooms for quite a few years. In 1997, internal mammary artery harvesting was first performed using an endoscope by Nataf et al.[86] The following year, Loulmet and colleagues[87] reported the first completely endoscopic coronary artery bypass surgery. Cardiothoracic applications of robotic-assisted surgery have expanded to include atrial septal defect closures,[88-90] mitral valve repairs,[91] patent

ductus arteriosus ligations,[92] totally endoscopic coronary artery bypass grafting,[93,94] minimally invasive atrial fibrillation surgery,[95,96] and left ventricular pacemaker lead placement.[97] Although minimally invasive surgery may eventually make surgical sternotomy obsolete, surgeons still must be prepared to convert to an open sternotomy if the need arises.

Anesthesiologists must be familiar with cardiac and thoracic anesthesia when performing robotic-assisted cardiac procedures. The ability to perform one-lung ventilation and manage the associated physiologic changes are mandatory proficiencies, and the ventilation strategy is like that typically used during thoracic surgery. Poor pulmonary function test results or pulmonary hypertension may be contraindications to robotically assisted cardiac surgery since prolonged one-lung ventilation may not be tolerated. Additionally, many anesthesiologists turn to transesophageal echocardiography (TEE) to monitor cardiac physiology under anesthesia.

To allow surgical exposure for robotic cardiac surgery, several cannulae must be placed before cardiopulmonary bypass may be initiated. Femoral vessels are usually accessed. However, as iatrogenic dissection of the femoral arteries may occur, some hospitals require preoperative imaging to evaluate for atherosclerotic disease. Other centers use TEE to guide venous cannulation of the right atrium/inferior vena cava junction or superior vena cava (Fig. 71.10). These cannulae are often flushed with 5000 units of heparin, or infused with a heparin drip to maintain patency.

In addition to the cannulae required for cardiopulmonary bypass, an additional cannula is advanced into the pulmonary artery to vent the heart and to allow surgical visualization. Again, TEE can be helpful with placement of these venting cannulae.

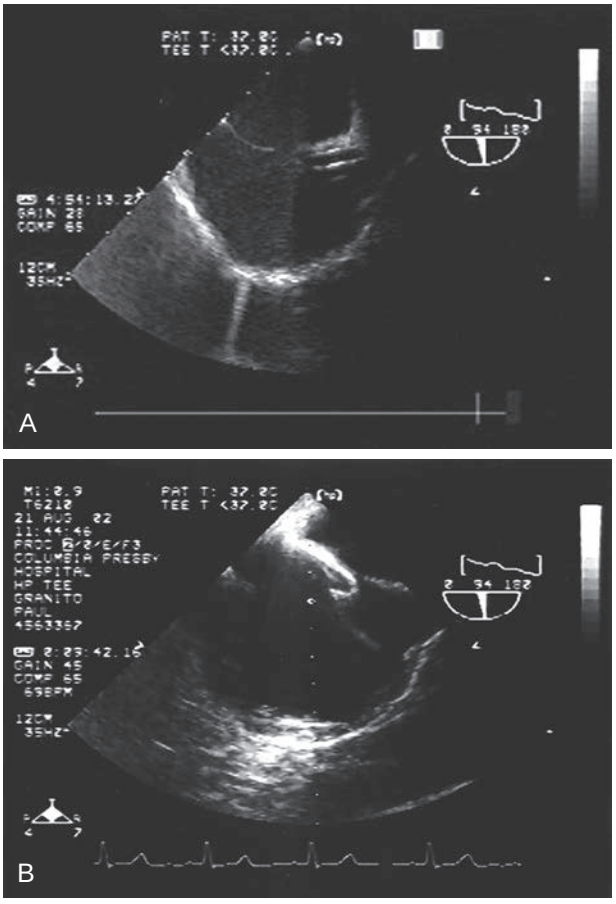

Fig. 71.10 (A) Ultrasound image of the superior vena cava cannula. (B) Ultrasound image, bicaval view, depicting the inferior vena cava containing a J guide wire. Both views are helpful in correctly placing cardiopulmonary bypass venous cannulae.

Mitral Valve Replacement

In 1997, two different reports of robotic-assisted mitral valve replacement appeared in the literature. In November 2002, the FDA approved the use of robot-assisted surgery for this procedure. For the robotic mitral valve procedure to be successful, a patient must be anesthetized, and single-lung ventilation must be initiated. Patients are then positioned with their right shoulder elevated by 30 degrees while their pelvis remains supine. Keeping the pelvis in the supine position allows the femoral vessels to be more easily accessed.

After positioning, trocars are introduced into the fourth or fifth intercostal space by the surgical team and exposure is achieved before the robot is docked. It is imperative that the anesthesia team keeps the patient completely paralyzed from this point forward until the robot is undocked to minimize iatrogenic injury.

Cardiopulmonary bypass is subsequently initiated using femoral cannulae, and cardioplegia is introduced into the coronary vasculature. The ascending aorta is subsequently cross-clamped, and the mitral valve is replaced. Following replacement, the valve's function is evaluated using TEE.

The procedure concludes with the aortic cross-clamp removed, and the patient is weaned from cardiopulmonary bypass. The patient's double-lumen endotracheal tube is ultimately exchanged for a single-lumen endotracheal tube if the patient is to be intubated postoperatively. There are several reasons why a particular patient may not be a candidate for robotic mitral value surgery (Box 71.1).

BOX 71.1 Exclusion Criteria for Robotically Assisted Mitral Valve Repairs

- Severely calcified mitral annulus
- Severe pulmonary hypertension
- Ischemic heart disease
- Surgery requiring multiple valve repairs
- Previous surgery to right hemithorax
- Severe aortic and peripheral atherosclerosis

Coronary Artery Bypass Grafting

Robotic-assisted coronary artery bypass graft surgery is a safe and effective procedure, which is gaining in popularity.[94] Potential exclusion criteria for robotic coronary artery bypass grafting are listed in Box 71.2.[96]

For coronary artery bypass graft procedures, patients are prepared and monitored for anesthesia in a manner similar to mitral valve surgery. Cardiac function and cannulae

BOX 71.2 Exclusion Criteria for Robotically Assisted Endoscopic Coronary Artery Bypass Grafting

- Contraindications to one-lung ventilation
- Ejection fraction <30% or decompensated heart failure (NYHA class III or IV)
- Moderate to severe aortic and mitral valve disease
- MI in preceding 30 days or MI requiring emergent CABG or postinfarction angina
- Calcified or intramyocardial LAD artery or diffuse LAD artery disease
- Large heart within left chest
- Morbid obesity (BMI > 35 kg/m^2)
- Severe peripheral vascular disease
- Severe noncardiac health issues
- Previous thoracic surgery, pleural adhesions, or radiation therapy of mediastinum or thorax

BMI, Body mass index; *CABG*, coronary artery bypass graft; *LAD*, left anterior descending; *MI*, myocardial infarction; *NYHA*, New York Heart Association.

placement are verified using TEE. In addition, anesthesiologists may consider pulmonary artery catheters when appropriate.

To harvest the internal mammary artery for the bypass grafts, single-lung ventilation is initiated using a double-lumen tube or a standard endotracheal tube with a bronchial blocker. Once single-lung ventilation commences, the patient is placed in a modified right lateral decubitus position, a 30-degree tilt to the right from the supine position. External defibrillation and pacing pads are then applied to the left posterior chest and anterolateral right chest. To improve surgical exposure to the left internal mammary artery, the left arm is raised. Conversely, to allow better exposure to the right internal mammary artery, the right arm is subsequently raised (Fig. 71.11). Very minimal CO_2 insufflation (usually 5-10 mm Hg) is needed to displace the mediastinal fat pad and allow surgical exposure. When single-lung ventilation is initiated and the left hemithorax is insufflated with CO_2, bilateral arteries are often able to be visualized.[98] When cardiopulmonary bypass is anticipated, the left femoral artery is cannulated with a 17- or 21-Fr remote access perfusion catheter (Fig. 71.12) with an aortic occlusion balloon. The remote access perfusion catheter

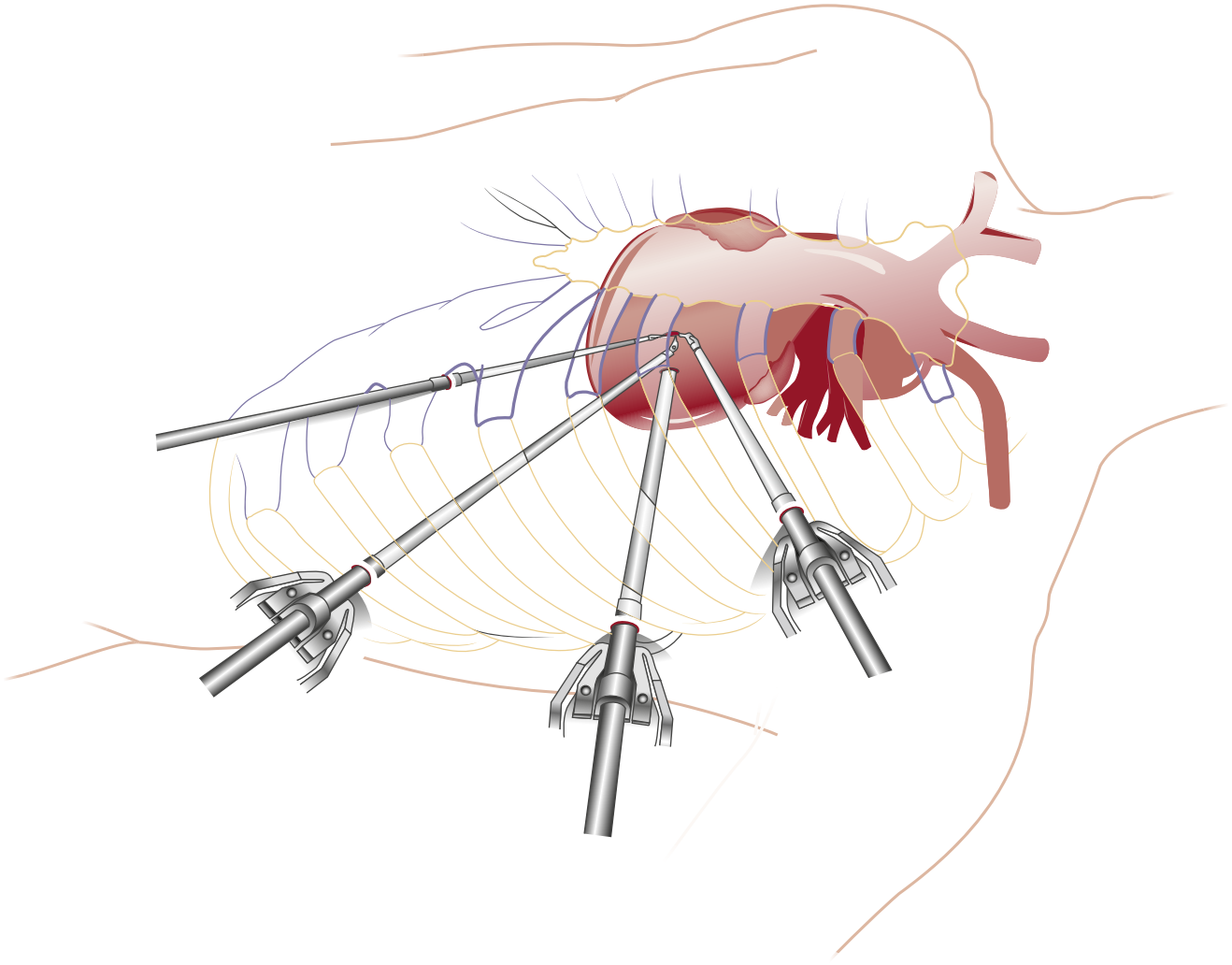

Fig. 71.11 Incision ports for coronary artery bypass grafting. Trocars are placed in the third, sixth, and eighth intercostal spaces. Similar port positions are used for bilateral internal mammary artery dissection.

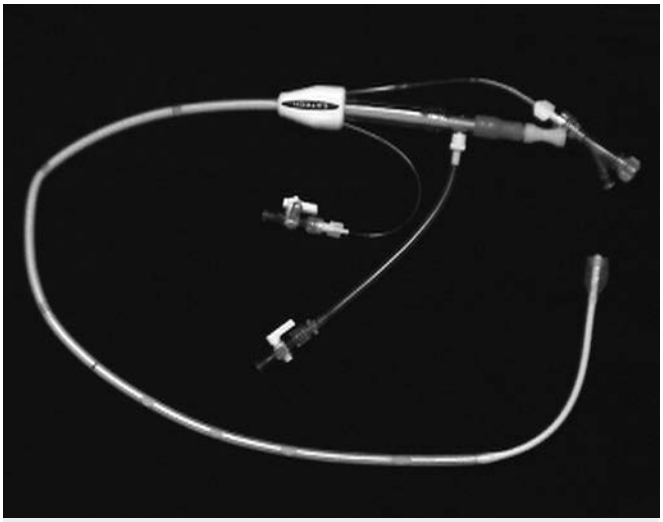

Fig. 71.12 Remote Access Perfusion (Estech Systems, Plano, TX, USA) catheter. The endovascular catheter has a cylindrical balloon for endovascular aortic clamping. The catheter provides anterograde perfusion of the aortic arch at a rate of 5 L/min.

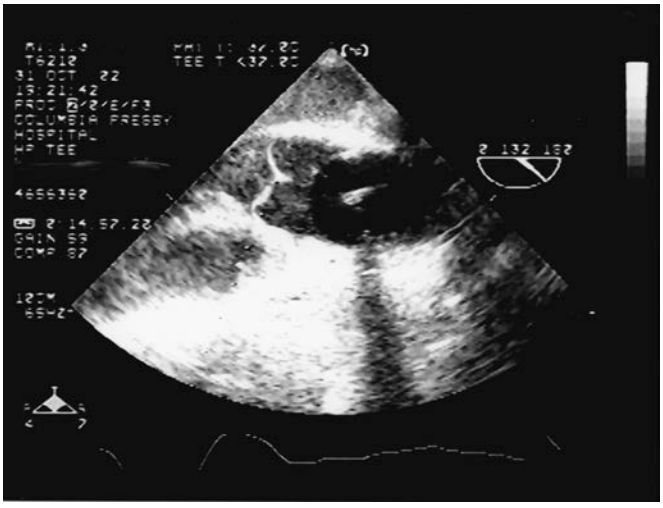

Fig. 71.13 Ultrasound image of Remote Access Perfusion (Estech Systems, Plano, TX, USA) catheter balloon in situ. Transesophageal echocardiography allows the anesthesiologist to keep track of the migration of the catheter balloon. The balloon should be positioned in the ascending aorta 2 to 4 cm distal to the aortic valve. Right radial pressure catheter signal damping can detect balloon malposition when occlusion of the innominate artery occurs.

allows anterograde flow of 4 or 5 L/min. The aortic cannula is subsequently positioned in the ascending aorta, roughly 2 cm above the aortic valve, using TEE (Fig. 71.13). The endovascular balloon is inflated with a volume equal to the diameter (in milliliters) of the sino-tubular junction of the aorta. A balloon pressure greater than 300 mm Hg usually provides complete occlusion of the aorta.[99] Residual flow around the balloon can be seen and monitored with color flow on TEE. The use of bilateral radial arterial lines is useful in detecting the migration of the occlusion balloon toward the innominate artery. Proximal migration of the balloon can be seen most easily with TEE, preventing balloon herniation through the aortic valve.

Single-lung ventilation is then initiated, and the right lung is collapsed. By insufflating the right hemithorax with CO_2, three 1-cm ports may be placed at the third, fourth, and fifth intercostal spaces on the anterior axillary line (see Fig. 71.11). The patient's pericardium is then dissected to expose the heart. Arrhythmias in the early postoperative period are common. Antiarrhythmics, such as amiodarone and β-adrenergic blockers, can be helpful.[100-102]

ROBOTIC-ASSISTED THORACOSCOPIC SURGERY (SEE ALSO CHAPTER 53 ANESTHESIA FOR THORACIC SURGERY)

Video-assisted thoracoscopic surgery (VATS) is a commonly performed procedure for cancerous tumor resection (wedge resections and lobectomies), esophagectomy, hiatal hernia, and lung volume reduction.[103-107] VATS is preferred to open procedures when possible to reduce length of stay, blood loss, pain, and morbidity as long as clinical outcomes are equivalent. However, as it is difficult to do complex surgeries (e.g., a pneumonectomy or a thymectomy) using minimally invasive techniques such as VATS, the hope is that a robotic approach (robotic-assisted thoracoscopic surgery [RATS]) will allow the application of minimally invasive techniques to these more complex surgeries and generate some of the same benefits as open procedures. While several centers are exploring RATS lobectomies, segmentecomies, and mediastinal mass resections, RATS pneumonectomies have been reported at only a couple of pioneering centers.[108] Robotic-assisted surgery usually increases the operative time and cost compared to its laparoscopic alternative.[109]

Robotic-assisted thoracoscopic surgery presents with similar challenges to robotic-assisted cardiac surgeries. Accommodating a more rigid chest wall and moving heart, lungs, and mediastinum can be challenging. In addition, initiating and maintaining prolonged one-lung ventilation and hemodynamic instability associated with CO_2 insufflation of the hemithorax presents unique concerns. Despite these challenges, the robot has been specifically used for thymectomies, mediastinal mass resections, fundoplications, esophageal surgery, and pulmonary lobectomies.[110-112]

Patient positioning is particularly important to expose largely inaccessible areas, as mediastinal structures are heavy, mobile, and change position in response to gravity (see Chapter 53). Supine or slight lateral decubitus position (raising one side 15-30 degrees) is most ideal for anterior mediastinum pathology. This position requires the elevated arm to be at the patient's side as far back as possible to allow the robot to dock successfully. However, hyperabduction of the elevated arm can cause a brachial plexus injury.[111] A full lateral decubitus position (90 degrees) may be optimal for hilar masses and lobectomies. Alternately, a prone or slightly modified prone position can create better exposure for posterior mediastinal masses.[113]

Since the patient will generally be rotated 90 degrees to allow the robot to dock, it is important to achieve lung isolation prior to rotation. Also, the anesthesia circuit,

intravenous line, and arterial line tubing may require extensions. It is suggested that the circuit and lines be combined into one bundle to move them out of the way of surgical personnel and monitoring devices. It is also recommended to have two large-bore intravenous lines since the arms will be difficult to access once the robot is docked. The patient undergoing RATS should generally have an arterial line placed prior to the robot being docked to allow for close monitoring of blood pressure and $PaCO_2$. Intraoperative confirmation of lung isolation will be difficult, so a plan of how to access the airway with a fiberoptic bronchoscope should be established prior to initiating the robotic portion of the case. It is important to note that a failure of lung isolation will result in an inability to complete the surgery via RATS.[110]

CO_2 insufflation helps achieve adequate surgical exposure by mobilizing the mediastinum and simultaneously compressing the lung away from the operative site. Unfortunately, CO_2 insufflation can lead to hemodynamic instability and difficultly with hypercapnia during one-lung ventilation. It can also cause venous gas embolism, decreased venous return, and cardiac collapse if right heart failure develops.

The anesthesiologist must also be ready for potential conversion to open thoracotomy due to bleeding or an inability to obtain adequate surgical exposure.[111] In a recent meta-analysis, the incidence of conversion from RATS to open thoracotomy during pulmonary resections was 0% to 19%.[114,115] The learning curve for new surgeons is also quite steep during the first 20 cases. An increase in operative issues must be anticipated for surgeons learning to use the robot.[114,115]

Another possible pitfall of RATS is that damage to the pleura may allow CO_2 insufflation to spread to the ventilated lung causing difficult ventilation and possibly causing a tension pneumothorax or severe subcutaneous emphysema—both of which can produce hemodynamic compromise.[114]

Studies comparing outcome data from VATS versus RATS in more common procedures are increasing. As might be expected for any complex procedure, outcomes for RATS lobectomies are better at high-volume centers.[116] As shown in other surgical disciplines, longer duration RATS lobectomies have similar outcomes to VATS lobectomies. However, robotic surgery does have increased costs in comparison to laparoscopic alternatives.[117,118] In an investigation of open versus VATS versus RATS treatment of early-stage thymomas, the robotic approach was associated with a reduced length of stay and had a similar complication profile to VATS.[119] In the case of esophagectomies, RATS—while having a longer surgical duration than a minimally invasive approach—has a similar outcome profile.[120]

As robotic instead of open approaches are starting to be used on more complex surgeries, we expect to see an improvement in patient outcomes and possibly a reduction in costs.[108,121]

Summary

Anesthesia for robotic surgery is an exciting and dynamic field. As surgeons and patients look for new innovations and technologically rich approaches to healthcare, it is reasonable to expect that more operations will be performed using robotic techniques. However, there is a real need to investigate the outcomes and costs of a robotic approach versus a more traditional approach. More data are needed to identify the type of cases and patient populations that will improve patient outcomes and reduce costs via robotic surgery. Recognizing the unique physiologic changes and positioning challenges that accompany robotic surgeries will allow anesthesiologists to best care for their patients.

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72 Ambulatory (Outpatient) Anesthesia

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KEY POINTS

- The use of ambulatory surgery continues to increase, mostly as a result of less invasive surgical techniques, improved patient selection and preparation, and an expansion of office-based practice.
- Few absolute contraindications exist to ambulatory surgery. Patients should not be excluded on the basis of arbitrary limits, such as age, body mass index, or American Society of Anesthesiologists physical status classification system.
- Effective preoperative assessment is required to evaluate and prepare patients and is essential for the delivery of safe, high-quality, and efficient ambulatory surgical care.
- Many anesthetics and techniques can be used for ambulatory surgery. Of prime importance, provider experience and careful attention to detail are required to deliver high-quality rapid recovery with minimal side effects.
- Spinal anesthesia may extend the range of patients and procedures suitable for ambulatory surgery, but it requires the use of small doses of bupivacaine combined with opioids or short-acting local anesthetics to avoid prolonged recovery.
- Sedative techniques can facilitate a wide variety of procedures performed in the hospital, office, or remote settings. However, sedation is no safer than general anesthesia and requires the same standards of personnel, monitoring, and perioperative care as for patients undergoing general or regional anesthesia.
- Multimodal analgesia, using combinations of local or regional anesthesia, acetaminophen, and nonsteroidal antiinflammatory drugs, provides effective relief of pain. The reduced need for opioids decreases the incidence and intensity of adverse effects.
- Antiemetic prophylaxis should be based on individual patient risk. Multimodal regimens are required for patients and procedures known to be associated with increased risk for perioperative nausea and vomiting.
- Patients should be discharged with written instructions concerning aftercare, return to normal activities, follow-up evaluation, and a contact telephone number. This advice must include early warning signs and the appropriate action to take.
- Ambulatory surgery remains very popular with patients with infrequent rates of adverse events and complications.

Introduction

Ambulatory surgery has its origins in Glasgow, Scotland, where, between 1898 and 1908, James Henderson Nicoll performed almost 9000 ambulatory surgical procedures on children, nearly half of whom were younger than 3 years of age.[1] Contrary to the prevailing philosophy, which advocated prolonged bed rest after surgery, Nicoll encouraged early mobilization and home follow-up by a visiting nurse to reduce high cross-infection rates and overcome bed shortages and financial constraints. A few years later, Ralph Milton Waters opened his Downtown Anesthesia Clinic in Sioux City, Iowa, allowing adult patients to return home within a few hours of difficult dental extractions, abscess drainage, or reduction of minor fractures.[2] Further progress was slow until the dangers of prolonged bed rest and the economic advantages of shorter stays began to be recognized toward the middle of the twentieth century. The first hospital-based ambulatory surgical units were opened in Grand Rapids, Michigan, in 1951, and in Los Angeles, California, in 1952, and somewhat later at London's Hammersmith Hospital in the United Kingdom in 1969.[3] At the same time, the first freestanding ambulatory surgery center opened in Phoenix, Arizona,[4] rapidly followed by many others across North America in the 1970s and 1980s.

The development of ambulatory anesthesia as a recognized subspecialty was enhanced by the formation of the Society for Ambulatory Anesthesia (SAMBA) in 1984[5] and the British Association of Day Surgery in 1989. These and nine other national societies came together in 1995 to form the International Association for Ambulatory Surgery (IAAS), an umbrella organization dedicated to the worldwide promotion of ambulatory surgery.

Ambulatory surgery has expanded far beyond the performance of simple procedures on healthy patients. Currently,

a broad range of major procedures are performed on patients who frequently have complex preexisting medical conditions. The availability of improved anesthetic and analgesic drugs minimizes the anesthetic side effects and facilitates the recovery process, as do the increasing availability of minimally invasive surgical techniques. Equally important has been a philosophical change that challenged outdated and conservative practices, demanding unnecessary postoperative inpatient admission. Ambulatory surgery now accounts for approximately 80% of the elective surgeries in the United States.[6] Ambulatory surgery also constitutes a large proportion of elective surgical activity in the United Kingdom and increasingly in many other countries worldwide, although rates for individual procedures still vary.[7]

DEFINITIONS

Although ambulatory surgery is widely practiced, the precise definition can vary across countries and healthcare systems. For consistency, we have used the definition proposed by the cofounder of the IAAS: "A surgical day case is a patient who is admitted for investigation or operation on a planned non-resident basis and who none the less requires facilities for recovery. The procedure should not require an overnight stay in a hospital bed."[8] This definition requires the patient to be managed with the intention of same-day discharge from the outset, in addition to admission, operation, and discharge all occurring on the same calendar day. Including management intention in the definition ensures no incentive is provided to discharge a planned inpatient at short notice, who would be without all of the preparation and support required for optimal postoperative care.

Short-stay surgery embraces all of the principles of ambulatory surgery and includes a postoperative overnight hospital stay. Extended observation may be prudent for certain patients with significant comorbidities, lack of social support, or for those who have undergone a procedure that is either too extensive or performed too late in the day to be compatible with same-day discharge. We have included short-stay surgery in this chapter because the objectives of minimizing physiologic disturbance to improve the quality of recovery and reduce the length of stay are the same as those of ambulatory surgery and much of the perioperative management is similar.

Benefits of Ambulatory Surgery

In order for surgery to be performed on an ambulatory basis there must be reduced tissue trauma, enhanced recovery with minimal adverse events, and the provision of effective postoperative analgesia, appropriate information, and postoperative support. Patients appreciate the more efficient scheduling of surgery, and the comfort and convenience of recovering in the familiar home environment. There are also financial advantages associated with ambulatory surgery due to the elimination of costs associated with overnight admission. In both the United States and the United Kingdom, procedures that are compatible with ambulatory surgery receive the same payment (from insurance companies and regional budget holders, respectively), irrespective of the length of stay. Therefore, if a patient does stay overnight, the extra costs are borne by the facility. Since 2010 in the United Kingdom, a higher level of funding has been available for an increasing number of procedures when performed on an ambulatory basis,[9] in order to incentivize best practice and finance any necessary pathway redesign.

Facilities for Ambulatory Surgery

In the United States, the American Society of Anesthesiologists (ASA) provides guidelines for ambulatory surgical facilities,[10] including statements pertaining to adherence to local regulations, staffing requirements, and minimum equipment standards. Quality standards are set and enforced by government regulation, licensing, or accreditation. In the United States and Canada, hospital-based ambulatory surgical facilities receive accreditation through The Joint Commission (TJC), Det Norske Veritas (DNV), and the Healthcare Facilities Accreditation Program. Ambulatory surgery centers and office-based surgery locations can receive accreditation through the Accreditation Association for Ambulatory Health Care, American Association for Accreditation of Ambulatory Surgery Facilities, or TJC. In the United States, the Centers for Medicare & Medicaid Services (CMS) has its own inspection program in addition to accepting accreditation decisions from the listed organizations.

A multitude of designs exist for ambulatory surgical facilities. Some have been purpose designed, and others have evolved by adapting existing facilities. The facilities delivering ambulatory care services also vary by country, but they can be broadly categorized into four models of care, each with its own advantages and disadvantages.[11]

HOSPITAL INTEGRATED

The simplest model of ambulatory surgery is one with shared inpatient surgical facilities, but with separate areas for preoperative preparation and recovery of ambulatory patients. This model of care is most often inefficient and brings the risk for ambulatory procedures being delayed or even canceled in favor of urgent or emergent inpatient procedures. However, by dedicating certain operating sessions to ambulatory surgery and using strict protocols, efficiency in one such unit has been described as almost equal to that of a self-contained unit.[12] The design is flexible, allowing the proportions of ambulatory and inpatient surgery to vary from day to day, and, as new procedures are transferred to ambulatory surgery, it does not require duplication of equipment and skills in a separate facility.

HOSPITAL SELF-CONTAINED

These self-contained units are functionally and structurally separate from inpatient facilities with their own reception, admission areas, operating rooms, recovery areas, and administrative facilities. This design promotes a patient-focused flow of care. It ensures functional separation from urgent and emergency work while maintaining the accessibility of resources available in the main hospital. In many ways it is an ideal model of care. However, the local capacity for ambulatory surgery may be reached, and duplication

of operating room equipment and skills may then occur for those procedures still commonly performed on both an ambulatory and inpatient basis.

FREESTANDING

Freestanding ambulatory surgery centers ensure complete separation of perioperative care from inpatient and emergency work. This improves efficiency and allows complete focus on a workflow designed for ambulatory care. While rare perioperative complications may occur that require elevation of care or additional resources, appropriate patient selection and preparation minimize this risk. Some freestanding units have the capacity for overnight stays to provide additional nurse-monitored recovery. However, all freestanding units must have a detailed plan for the care of patients who need urgent or emergent transfer to a nearby hospital. Ambulatory surgery centers vary from highly specialized, single-surgery facilities performing ambulatory total joint replacements or bariatric procedures to those that can accommodate multiple specialties and support a variety of service lines.

OFFICE-BASED

Performing ambulatory surgery, diagnostic procedures, or both in a facility associated with a physician's office is a rapidly expanding model of care within the United States.[6] The main advantages are increased convenience for the patient and surgeon, and lower total procedure costs. Office-based services and facilities have historically been subject to less regulatory requirements when compared to those imposed on ambulatory surgery centers. Furthermore, they may have more significant limitations with respect to equipment, personnel, and environment along with reduced capability when managing perioperative complications. These limitations, however, are rapidly changing. In the United States, physician offices that provide services that include procedures involving moderate to deep sedation or general anesthesia may be subject to state regulatory requirements for accreditation and adherence to standards with respect to governance, facility environment of care, availability of equipment, credentialing of staff, and continued medical education for personnel. A more detailed discussion of office-based anesthesia can be found later in the chapter.

Patient Selection Criteria

SURGICAL FACTORS

The development of minimally invasive surgery, improvements in surgical technique and pain control, and the availability of shorter-acting anesthetics have dramatically increased the range of surgical procedures compatible with same-day discharge. While the duration of surgery has traditionally been a determinant of outcome, the extent of surgical trauma now appears to be the more significant determinant. There should be no expectation of significant blood loss, large perioperative fluid shifts, or the need for complex or specialized postoperative care. Surgical complications remain the single greatest cause of unanticipated hospital admission.[13,14] In the United States and the United Kingdom, an overnight stay for patients who have undergone an ambulatory surgery procedure in any venue receives no additional payment, so the extra costs are borne by the facility. The British Association of Day Surgery publishes a directory of over 200 different surgical procedures and suggests aspirational targets for the proportions of each that are suitable for either ambulatory or short-stay surgery.[15] A selection of these are shown in Table 72.1.

TABLE 72.1 A Selection of Surgical Procedures Which can be Performed on an Ambulatory Basis

Specialty	Examples of Surgical Procedures
Breast surgery	Excision/biopsy including wide local excision, sentinel node biopsy, simple mastectomy, microdochectomy, and other operations on nipple
General surgery	Perianal fistulae, pilonidal sinus, hemorrhoidectomy, open or laparoscopic hernia repair, laparoscopic cholecystectomy, adrenalectomy, splenectomy, fundoplication, gastric banding
Gynecology	Cervical surgery, laparoscopic tubal ligation, oophorectomy, hysterectomy, anterior and posterior repair
Head and neck	Dental procedures, excision of salivary glands, thyroidectomy, and parathyroidectomy
Ophthalmology	Cataract surgery, strabismus surgery, vitrectomy, nasolacrimal and all eyelid surgery
Orthopedics	Diagnostic and therapeutic arthroscopic surgery, anterior cruciate ligament repair, carpal tunnel release, bunion surgery, fracture reductions and removal of metalwork, lumbar microdiscectomy, minimally invasive hip surgery, unicompartmental knee surgery
Otolaryngology	Myringotomy and tympanoplasty, rhinoplasty, procedures on nasal septum and turbinates, polypectomy, adenotonsillectomy, laryngoscopy, and endoscopic sinus surgery
Urology	Endoscopic bladder and ureteric surgery, transurethral laser prostatectomy, circumcision, orchidectomy, laparoscopic nephrectomy, pyeloplasty, and prostatectomy
Vascular surgery	Varicose vein surgery, dialysis fistula creation, transluminal arterial surgery

Laparoscopic cholecystectomy is now a routine ambulatory surgical procedure in many countries, and increasingly same-day discharge is seen as safe and beneficial after a variety of advanced laparoscopic procedures, including fundoplication,[16] hysterectomy,[17] nephrectomy,[18] pyeloplasty,[19] radical prostatectomy,[20] and gastric banding.[21] Minimally invasive approaches have also facilitated same-day discharge following unicompartmental knee[22] and hip arthroplasty.[23,24] One series of 2000 patients undergoing laparoscopic Roux-en-Y gastric bypass for morbid obesity reported 84% being discharged within 23 hours with a readmission rate of less than 2%.[25]

Even specialties like neurosurgery, traditionally associated with complex inpatient care, have begun to embrace day surgery. Same-day discharge of selected patients undergoing awake craniotomy for supratentorial tumors was first described in 2001.[26] More recently, some patients

requiring general anesthesia for tumor resection[27] and even aneurysm clipping[28] have been discharged on the day of surgery. Increasingly, a number of non-elective procedures, such as abscesses, incarcerated hernia repairs, and appendectomies, are being managed through day surgery pathways.[29] In parallel, several less invasive procedures, such as diagnostic or therapeutic hysteroscopy, are moving from ambulatory surgery into the procedure room, outpatient clinic, or office.[30]

While postoperative pain control in the home environment may present substantial challenges, perhaps the greatest barrier to the development of ambulatory surgery is conservatism, based on incorrect perceptions and concern about serious complications that might occur following discharge. For example, despite convincing data that most primary hemorrhages are evident within 6 to 8 hours of tonsillectomy,[31,32] an overnight stay is still routine in some countries while others discharge 80% of patients or more on the day of surgery.[7] Similarly, ambulatory thyroid surgery was first shown to be safe and effective in 1986,[33] yet its widespread adoption has been slow,[34] predominantly because of concerns about bleeding and airway compromise. Such complications are rare, especially when surgery is undertaken by specialists who perform a high volume of cases with assiduous hemostasis, allowing short times to discharge to be achieved.[35] Performing thyroidectomy under local anesthesia also appears to increase ambulatory surgery rates,[36] perhaps because of the careful surgical technique required. In the case of breast surgery, concerns about postoperative psychological support has delayed transfer of mastectomy and other cancer operations into ambulatory care in the United Kingdom, although it is now recognized that early discharge improves the psychological well-being of these patients by minimizing the time away from home.[37] Challenging conventional wisdom also may be beneficial; for example, discontinuing the routine use of drains after mastectomy or axillary node clearance does not increase morbidity, including from wound seroma, while facilitating same-day discharge.[38] Day surgery management of breast cancer is associated with fewer complications than inpatient care.[39]

MEDICAL FACTORS

In the past, ambulatory surgery has relied on relatively rigid patient selection criteria in the attempt to limit the occurrence of postoperative complications. In practice, however, most of these criteria predict the occurrence of treatable perioperative adverse events, but not the need for unanticipated admission or readmission.[40] Although an index combining age, length of surgery, and preexisting conditions, such as peripheral or cerebrovascular disease, can identify a group at higher risk for hospital admission, the specificity is poor and same-day discharge is still the most likely outcome.[41] Ambulatory surgery is very safe, with a perioperative mortality less than 1 in 11,000,[42] better than that in the general population. More recent studies have confirmed the continuing safety of ambulatory surgery, despite increasing surgical and patient complexity.[43-45]

Relatively few absolute contraindications now exist to ambulatory surgery. Patient suitability should be assessed on the basis of overall health, taking into account both the risks and benefits of early discharge, and certainly not determined by arbitrary limits, such as age, body mass index (BMI), or ASA physical status.[46] Chronic conditions should be relatively stable and must be optimally treated before any elective procedure, irrespective of the planned postoperative management. Many stable chronic diseases, such as diabetes, asthma, or epilepsy, are often better managed by the patients than by the perioperative team, and ambulatory surgery facilitates this by easing the disruption to their daily routine.[46] A distinction should be made between preexisting conditions that make a patient more difficult to manage on the day of surgery and those that increase the occurrence of late postoperative problems, which are a relative contraindication to ambulatory surgery.[47]

A good example is obesity, which is associated with numerous perioperative problems for the surgeon, anesthesiologist, and operating room personnel (see also Chapter 58). Safe care of the obese patient may require the availability of experienced staff and specialized equipment, such as longer instruments and wider operating trolleys but any risks are resolved soon after immediate recovery and are not prevented by postoperative overnight hospitalization. Obese patients benefit from ambulatory management with early mobilization, the use of short-acting drugs, and avoidance of opioid analgesia.[47] Obesity does not increase the rate of unanticipated admission, postoperative complications, readmission, or other unplanned contact with health professionals following discharge.[48] Even morbid obesity (BMI > 40 kg/m^2)[46] and super obesity (BMI > 50 kg/m^2)[49] are no longer considered absolute contraindications to same-day discharge. Obesity increases the likelihood of further comorbidities, but these should be evaluated individually.

Obstructive Sleep Apnea

Obstructive sleep apnea (OSA) occurs in the general population but is much more common in obesity. Nonetheless, most cases can be managed safely and effectively on an ambulatory basis.[50] Perioperative problems such as difficult tracheal intubation and airway obstruction should be anticipated.[51] However, patients undergoing more invasive surgery, especially involving the chest or airway, or those requiring large doses of perioperative opioids, may be less suitable.[50] Frequently, OSA is suspected but has not yet been definitively diagnosed and treated. A simple questionnaire, supplemented with some basic measurements (e.g., STOP-Bang), can identify most patients at high risk for OSA,[52] but there is insufficient evidence to recommend delaying surgery until the diagnosis is confirmed.[53] In children, OSA is now one of the main indications for tonsillectomy and this has been seen as a relative contraindication to ambulatory surgery. However, one recent study has shown that same-day discharge is still safe in the absence of other comorbidities.[54]

Age

Medical and social problems increase with age and should be evaluated and managed individually rather than applying an arbitrary upper age limit for ambulatory surgery. The risk for death or readmission within 7 days of surgery in patients over 65 years of age are 41/100,000 and 2.53%, respectively.[55] Although somewhat more frequent than values from younger patients, the major risk factors appear

to be very advanced age (older than 85 years of age), more invasive surgery, and recent inpatient hospital care.[55] The frequency of perioperative adverse cardiovascular events also increases with age. Overall, older patients had a twofold increase in the risk for intraoperative adverse cardiovascular events; however, this was seen not as a contraindication to ambulatory surgery but rather as indicating the need for more careful intraoperative management.[56] In contrast, the incidence of postoperative complications seems to be reduced in older patients.[56,57] In particular, older patients appear to experience far less postoperative pain, dizziness, nausea, and vomiting than younger patients,[56,58] and do not require a higher rate of unplanned admission or readmission. One study suggests a reduced incidence of postoperative cognitive dysfunction in older patients after ambulatory surgery compared to similar procedures performed on an inpatient basis,[59] presumably because of the use of short-acting anesthetic techniques and reduced separation from their familiar home environment. Reducing length of hospital stay after hip and knee surgery appears to confer similar benefits.[60]

At the other age extreme, the lower limit for ambulatory surgery may vary depending on the expertise and specialization of the individual facility. Premature babies have a higher risk for postoperative apnea, and hence ambulatory surgery may be inadvisable until they have reached an appropriate postconceptual age (PCA). Evaluation of several historic and retrospective studies suggests the risk for postoperative apnea is less than 5% once PCA exceeds 48 weeks, provided gestational age was at least 35 weeks, the infant was not anemic, and no apnea occurred in the recovery room.[61] However, because considerable variability exists in the incidence of apnea and the relatively small sample size of these studies, the PCA at which risk becomes acceptably low is controversial,[62] with a value of 60 weeks most commonly taken as the cutoff for ambulatory management.[63,64] Caffeine administration appears to markedly reduce the incidence of postoperative apnea in babies who were premature,[65] but this is not seen as a substitute for careful patient selection.[63] Spinal anesthesia may offer advantages to infants who were premature undergoing abdominal surgery in the first week of life, but it is distressing to the infant and has a high (28%) failure rate.[66] Compared with older studies involving more soluble anesthetics, sevoflurane and desflurane were associated with lower rates of postoperative apnea after hernia surgery in infants born at less than 37 weeks gestation and under 47 weeks PCA.[67] Although no airway interventions were required to manage apnea, episodes still occurred throughout the 12-hour postoperative observation period and were equally common with either anesthetic.[67]

Cardiovascular Disease

Hypertension is the most common cardiovascular disease and has been a frequent cause for delay and cancellation of ambulatory surgery. Although hypertension is an important risk factor for long-term health, a meta-analysis of nearly 13,000 patients showed that it increased the risk for perioperative complications by only 1.35 times,[68] an amount that may be clinically insignificant. In ambulatory surgery patients, hypertension resulted in an approximate 2.5-fold increase in the risk for perioperative cardiovascular events,[57] but these were relatively minor. Hypertension is not an independent risk factor for perioperative cardiovascular complications if the diastolic pressure is less than 110 mm Hg.[69] Higher arterial blood pressures may predispose to perioperative ischemia, arrhythmias, and cardiovascular lability, but no clear evidence indicates that deferring surgery reduces perioperative risk.[68] In the United Kingdom, patients with documented blood pressures below 160 mm Hg systolic and 100 mm Hg diastolic in the community can be accepted for elective surgery without further measurement.[70] In practice, poorly controlled hypertension is usually identified at the preoperative evaluation and can be treated before surgery is scheduled. Delaying surgery until hypertension is controlled is unlikely to be beneficial.[71]

Patients with known hypertension should continue to take their chronic medication, especially β-adrenergic blockers. β-Adrenergic blockers should not be abruptly stopped,[72] and it may be more likely that they will be unintentionally omitted if patients are advised to take all of their cardiac medications up to and including the day of surgery.[73] Controversy surrounds angiotensin-converting enzyme inhibitors (ACEIs) and angiotensin receptor blockers (ARBs). It has been considered "reasonable"[74] to continue these, as any hypotension after induction of anesthesia is usually transient and responds to intravenously administered fluids and repeated vasopressor administration. However, evidence is accumulating of an increase in mortality, stroke, and myocardial injury if ACEIs and ARBs are continued,[75] and current practice is to hold these on the day of surgery.

Patients are generally unsuitable for ambulatory surgery if they have severe unstable angina that causes marked limitation of activity or pain at rest. In the absence of complications, such as arrhythmias or ventricular dysfunction, cardiac risk after myocardial infarction or revascularization procedures returns to baseline after 3 months.[76] Exercise tolerance is a major determinant of perioperative risk[76] and the inability to climb a flight of stairs (~4 metabolic equivalent tasks of activity) is highly predictive (89%) of a postoperative cardiopulmonary complication.[77]

Patients taking anticoagulants and antiplatelet drugs require careful evaluation to balance the risk for perioperative bleeding against the risk in withholding therapy. For minimally invasive procedures, the international normalized ratio can be briefly decreased to the low or subtherapeutic range, with the usual dose of oral anticoagulation resumed immediately after the procedure.[72,73] If the risk for bleeding or thromboembolism is high, low-molecular-weight heparin can be used as bridging therapy.[78] Patients are increasingly being managed with oral direct thrombin or factor Xa inhibitors (e.g., dabigatran, apixaban, rivaroxaban, and edoxaban). The effects of these agents are not reliably measured by commonly used coagulation tests, such as prothrombin time and activated partial thromboplastin time,[79] but their shortened half-lives may make bridging therapy unnecessary. Antiplatelet therapy should be continued for the recommended intervals in patients with bare metal and drug-eluting coronary artery stents, because premature discontinuation is associated with a 25% to 30% risk for stent occlusion, which in turn has a more than 60% risk for myocardial infarction and 20% to 45% risk for death.[80]

SOCIAL FACTORS

In general, if a patient's living arrangements were adequate before surgery, they should also be suitable after surgery. Some adaptations may be necessary if the patient's mobility is severely compromised by their procedure—for example, by the use of casts. Access to a telephone to summon assistance is a minimum requirement, but is rarely problematic with the ubiquitous availability of mobile telephones. Patients usually live within a reasonable traveling distance of the surgical unit, but this may be impractical in rural or sparsely populated areas. Journeys of hundreds or thousands of miles are not unheard of in parts of Scandinavia after ambulatory surgery.[47] For patients who live far away, consideration should be given to the provision of emergency care close to home and for the comfort of the patient during the journey. Patients who choose to travel long distances after ambulatory surgery usually are very satisfied with their care.[81] Hospital hotels, which provide nearby accommodation but little or no nursing care, are a higher-cost alternative for the patient and have largely been abandoned as an impractical option.

A universal safety feature is to require all patients having surgery under general anesthesia or sedation to be discharged with a responsible adult escort and the recommendation to have someone stay with them for the next 24 hours. If the 24-hour companion is mandated, patients often disregard postoperative instructions and send their escorts away if they feel well at home.[82] In the United States, it is standard practice to require that patients who have received other than unsupplemented local anesthesia be discharged with a responsible adult[10]; if not, surgery is postponed. A Canadian single-institution study reported discharging patients alone when their escort fails to arrive,[83] yet this practice did not appear to increase emergency room visits or readmission rates within 30 days. The Association of Anaesthetists of Great Britain and Ireland has suggested that an escort may be required in most (but not all) cases,[46] with exceptions when the surgery is relatively minor and anesthesia brief so the patient is not compromised by the sedative effects of anesthesia or analgesia by the time of discharge.[47] If patients are discharged alone, they should not drive themselves home[84]; several serious accidents have occurred, especially after the use of sedative doses of benzodiazepines.

Preoperative Assessment

THE ROLE OF PREOPERATIVE ASSESSMENT

An effective preoperative assessment process is essential for the delivery of safe, high-quality, and efficient ambulatory surgery.[85] Rather than trying to select specific, low-risk groups of patients, ambulatory surgery is increasingly seen as the default option for a wide range of surgical procedures, with inpatient care chosen only for those with insurmountable barriers to early discharge. Other than identifying this small group of patients, preoperative assessment is primarily required to evaluate and optimize patients and to provide appropriate information (Table 72.2). These assessment and optimization functions can be further distilled into two key questions: "Is there any benefit to this patient of being in hospital overnight after surgery?" and "Is there anything that needs to be done to enable this patient to be a day case?"[85]

TABLE 72.2 The Four Key Functions of a Preoperative Assessment and Preparation Service for Ambulatory Surgery

Function	Examples
1. Identify absolute contraindications to ambulatory surgery	Inability to identify a responsible carer other than for minor surgery with full and rapid recovery anticipated; severe uncorrectable cardiovascular disease
2. Identify need for optimization	Patient requires further investigation, therapeutic modification, or intervention to improve functional status; identify a friend, relative, or neighbor to act as carer
3. Highlight issues for anesthesiologist or other staff (which may alter management but which do not preclude ambulatory surgery)	Potentially difficult intubation necessitating advanced airway management skills; malignant hyperpyrexia susceptible patient requiring trigger-free anesthetic; latex allergy; obese patient requiring operating table/trolley with high weight limit and extra width
4. Provide patient information	Written information on preoperative preparation, medication management, preoperative fasting, etc.

MECHANISMS AND TIMING OF PREOPERATIVE ASSESSMENT

The timing of preoperative assessment is crucial, because it must be done early enough in the pathway to allow for any necessary investigations and optimization without delaying the planned procedure. This becomes increasingly difficult as the interval between the decision to operate and the date of surgery becomes shorter. Ideally, preoperative assessment should immediately follow the decision to operate, by providing a "one-stop shop." This type of service, in which preoperative assessment immediately follows the surgical consultation, is highly valued by patients,[86] although it can be difficult to manage because of variations in the demand for the service. An alternative is to use a basic screening tool to identify those patients who can proceed directly to surgery and those who require further investigation or management (Fig. 72.1).

A case can be made for all patients to be seen in a preoperative assessment clinic; however, in practice this places a major demand on resources and is also inconvenient for patients who may need to take additional time off work. Screening allows many patients to undergo assessment by telephone or questionnaire, with clinic attendance required only if unexpected problems are uncovered or if requested by the patient. When telephone assessment was chosen for all young healthy patients scheduled for minor breast surgery, only 2% of patients had problems identified that required further assessment in the ambulatory surgery center.[87] By using a computerized information-gathering and triage tool, combined with some basic information about

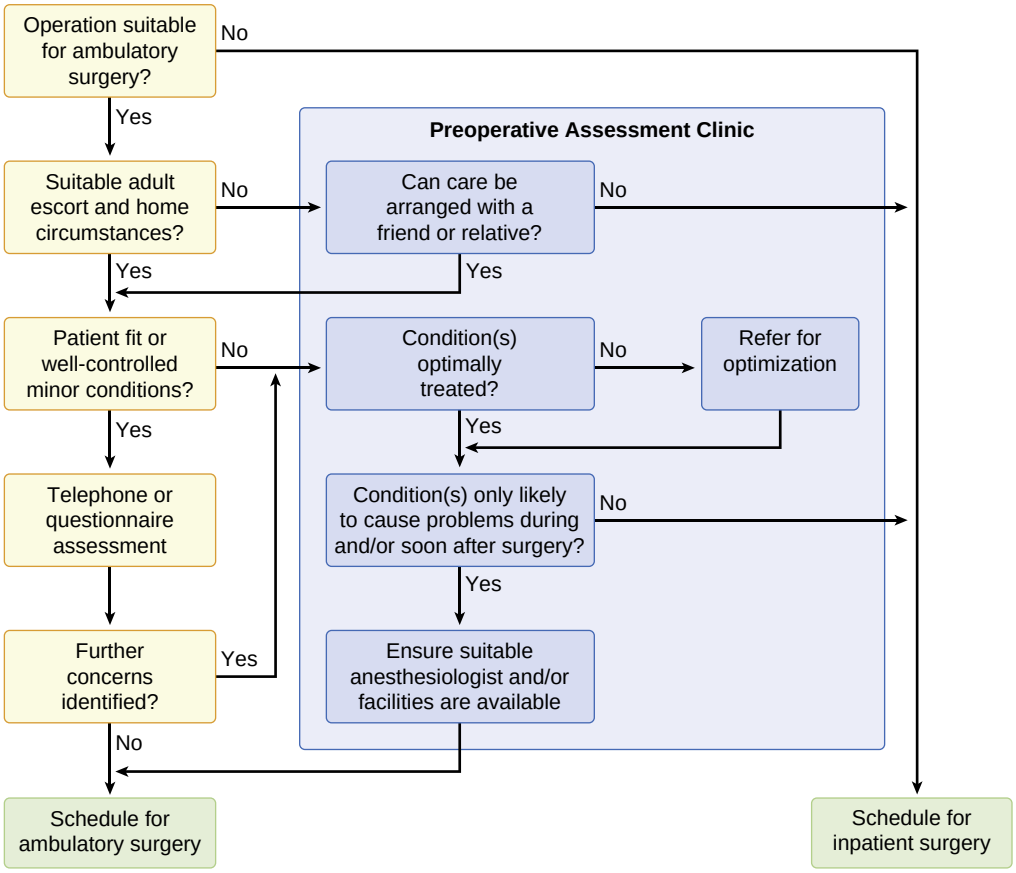

Fig. 72.1 Flowchart illustrating the basic process for selecting patients for ambulatory surgery. The pathway incorporates a screening process for patients who may not require a full face-to-face assessment in the clinic. (Modified and adapted from Smith I, Hammond C. Day case surgery. In: Radford M, Williamson A, Evans C, eds. *Preoperative Assessment and Perioperative Management*. Keswick: M&K Books; 2011:267–280. With permission.)

the planned procedure, approximately onethird of ambulatory patients did not need to see an anesthesiologist before the day of surgery.[88] This approach eliminates the need for a face-to-face assessment before the day of surgery but does not eliminate an evaluation of the patient's medical information in advance of surgery. In contrast, advance face-to-face preoperative assessment is more advisable for older patients, in whom multiple comorbidities, polypharmacy, and social problems are all more likely.[89] Early discharge planning is also important for older patients, to address environmental issues that can be improved to support recovery.[90]

In the United Kingdom, preoperative assessment is usually performed by nurses working closely to protocols and supported by anesthesiologists who provide advice and personally assess the more complex patients.[91] In the United States, anesthesiologist-led, protocol-driven preoperative assessment is often used for healthy patients having minor procedures. However, these preoperative evaluation clinics are frequently used in US hospitals, not just for ambulatory patients with more complex medical or surgical issues but also for the majority of inpatient surgery cases that are admitted on the morning of surgery. More complex patients have their anesthesia preassessment performed by an anesthesiologist. A comprehensive preoperative history and physical evaluation by a physician extender is often also provided in the preoperative assessment clinic for the surgeon. Using a physician extender to assist in preoperative evaluation maintains patient safety and satisfaction, promotes flexibility with scheduling of providers, and increases staff satisfaction.[92] Appropriately trained nurses were just as effective as trainee medical staff in detecting information likely to influence subsequent patient management, but they ordered significantly fewer unnecessary tests.[93]

Patients generally rate their preoperative assessment clinic experience very favorably, with their greatest concerns relating to waiting times.[94] Scheduling appointments of approximately twice as long for patients of ASA physical status grades III and IV than for those of grades I and II has been shown to reduce backlogs and maximum waiting times for preoperative evaluation to an acceptable level of about 10 minutes.[95]

PREOPERATIVE INVESTIGATION

The history and physical examination remain key elements of preoperative risk assessment, despite the availability of more sophisticated technologies.[76] In fact, most useful information can be obtained from the history, supplemented by simple observation of the patient.[96] Basic physical examination, such as routine chest auscultation, is often considered unhelpful in adult ambulatory surgery patients,[85,97] because findings that are unaccompanied by symptoms or functional limitation do not alter management. Although

aortic stenosis may remain asymptomatic until it is quite severe, chest auscultation may be unreliable in its detection. In one high-risk population, 31% of patients without a detectable murmur nevertheless had some degree of aortic stenosis that was moderate or severe in 10% of cases,[98] whereas 31% of patients with a suggestive murmur did not have aortic stenosis on echocardiography. Ten patients with severe aortic stenosis (valve area 1 cm^2 or less, gradient 35-58 mm Hg) tolerated an unmodified anesthesia regimen for electroconvulsive therapy on 144 occasions without problems,[99] suggesting that ambulatory surgical patients with undiagnosed aortic stenosis may not inevitably be at excessive risk, when combined with appropriate procedure selection.

It is recognized that routine laboratory investigations are unhelpful because they may generate false-positive results or do not alter subsequent management.[100] In addition, such tests increase costs, are unpleasant and time-consuming for patients, and may lead to repeat testing with even further expense and delays. Consequently, many authorities recommend selective testing, based on indications from the patient's clinical evaluation and demographics.[101,102]

Although comorbidities become more prevalent with age, additional preoperative testing for older patients may still be unnecessary. In patients 70 years of age or older, routine preoperative blood test results were not predictive of postoperative complications.[103] While preoperative electrocardiograms of patients over 50 years of age detected abnormalities, such as bundle branch blocks, predictive of postoperative myocardial infarction, the recordings did not provide additional predictive value to that obtained from the patient history.[104] The National Institute for Health and Care Excellence no longer advocates patient age be used as a criteria for routine preoperative testing and also recommends few, if any, tests for healthy patients undergoing minor or intermediate surgery.[102] One large pilot study demonstrated that the elimination of all preoperative testing resulted in no increase in adverse events in the perioperative period and did not alter the rate of unanticipated admission or readmission within 30 days compared to indicated testing.[105]

Patient Preparation

Preoperative assessment plays a fundamental role in preparing patients for their ambulatory surgery experience. This may include ensuring appropriate social support is in place, checking that preexisting conditions are optimally treated, and providing information.

PROVISION OF INFORMATION

Patients need to be informed about what will happen on the day of surgery, because a well-prepared patient is likely to be more relaxed and more satisfied with the service provided.[85] A well-informed patient is also more likely to comply with important instructions and protocols, such as fasting intervals and management of regular medications. Many patients are disproportionately worried about highly unlikely outcomes, such as death and awareness,[106] yet somewhat less concerned about more common consequences such as nausea, vomiting, and postoperative discomfort. The preoperative discussion should help to allay the anxiety associated with unlikely risks. It was found that a specially designed website with text, animation, and video significantly increased patients' knowledge about anesthesia when compared with a combination of verbal and written information.[107]

Patients should be given specific information, preferably supplemented in writing, about how to manage their usual medications in the preoperative period. Some drugs (e.g., warfarin) should be stopped several days before surgery[78] and some hypoglycemic agents omitted before surgery.[108,109] However, other important medications should not be omitted.[73,74,80]

Information about medications should include over-the-counter and herbal products, which are commonly used but often regarded by patients as harmless and safe.[110] Despite some serious consequences and interactions associated with herbal medications,[111] not all practices specifically ask and advise patients about these products on a routine basis. (see also Chapter 33).[112]

PREOPERATIVE FASTING

Almost universal agreement now exists that the safe fasting interval for clear liquids is no more than 2 hours, in contrast to 6 hours for light meals.[113,114] These fasting intervals result in safe gastric volumes even in obese adults,[115] children,[116] and patients with diabetes and gastrointestinal (GI) reflux.[114] Indeed, a 2-hour interval is probably conservative, given that the stomach empties clear fluids exponentially, with a half-time of approximately 10 minutes.[117]

Despite guidelines based on decades of research, implementation remains poor, with many patients fasting for excessive periods and experiencing significant discomfort.[118-120] Rather than focusing on a minimum fasting time, patients should be encouraged to keep drinking until the latest time necessary for safety to reduce preoperative dehydration and its associated consequences.[114] In practice, this may mean asking patients to have a drink just before they leave home or even providing a drink on arrival if surgery is still more than 2 hours away. Advising patients to drink on the morning of surgery also makes it easier for them to take their medications. Milk added to tea or coffee does not appear to delay gastric emptying[121-123] and, in the United Kingdom, may provide more palatable choices of preoperative beverage. The US practice is for clear fluids only. Recently, it has been shown that allowing patients unrestricted access to water right up until they were called to the operating room significantly reduced the incidence of postoperative nausea and vomiting (PONV) without increasing the occurrence of clinically-significant pulmonary aspiration.[124] Practices such as chewing gum before surgery also may not be harmful. No consistent evidence exists of a clinically important increase in gastric volume associated with gum chewing in adults,[114,125] while in children it may promote gastric emptying and could also serve as a useful route for premedication.[126]

Besides feelings of thirst and hunger, excessive fasting also results in hypoglycemia in significant numbers of patients, with 14% of fasted healthy female ambulatory surgical patients having an admission blood glucose

value of 45 mg/dL (2.5 mmol/L) or less.[127] Preoperative oral carbohydrates have been shown to improve subjective well-being, reduce thirst and hunger, and reduce postoperative insulin resistance, although convincing evidence of reduced length of stay is lacking,[114] at least for shorter procedures.[128]

PREMEDICATION

Premedication traditionally refers to the administration of medications to relieve anxiety before surgery. However, the term encompasses any medication given in the preoperative period and therefore includes prophylactic analgesia and antiemesis agents, as well as drugs used to promote gastric emptying or counteract acid secretions.

Management of Anxiety

The use of anxiolytic premedication is now uncommon in ambulatory anesthesia,[129,130] probably because of concerns that these medications will delay recovery. In fact, one meta-analysis found no evidence that anxiolytic premedication delayed the discharge of ambulatory patients, although impaired performance in some tests of psychomotor function was found and the authors questioned the relevance of some of the older studies to modern ambulatory practice now that short-acting anesthetics are the norm.[131]

Anxiety is nevertheless common in ambulatory surgery patients,[129] with up to twothirds showing symptoms. A preoperative consultation more than 2 weeks before surgery can reduce patient anxiety and improve satisfaction, especially if the anesthesiologist was perceived as empathic.[132] Patient satisfaction was further improved when their intraoperative care was provided by the same anesthesiologist who performed the preoperative consultation.[132]

Anxiolytic Premedication

Given that anxiety was commonly reported, doubtless some patients will benefit from anxiolytic premedication, but what is the optimal regimen? Oral midazolam provided more anxiolysis than temazepam but also produced more sedation and amnesia, resulted in more oversedated patients, and delayed recovery.[133] Oral alprazolam produced comparable anxiety reduction to midazolam without causing amnesia,[134] but it also caused greater impairment of psychomotor function in the early postoperative period. Neither anxiolytic premedication delayed clinical recovery, but this may be a relatively crude assessment tool, because recovery primarily depends on other factors. Intravenous midazolam given shortly before induction of anesthesia reduced both anxiety and postoperative nausea.[135] Such relatively late administration will not reduce anxiety while the patient waits preoperatively, but may be useful in a patient who needs to have an uncomfortable procedure before surgery, such as mammographic needle localization, in which satisfaction with both the procedure and subsequent breast biopsy was improved.[136]

Premedication is more commonly used in children. In one investigation, premedication with oral midazolam 0.2 mg/kg reduced emergence agitation associated with sevoflurane anesthesia without significant delay in recovery,[137] and doses up to 0.5 mg/kg did not delay recovery.[138] However, other patients have experienced delayed recovery at this dose[139,140] while not always having a reduction in anxiety.[140] The less stringent recovery endpoints needed for children compared with the independent functioning needed for adults should be kept in mind. Premedication with oral midazolam may itself provoke anxiety in children, but giving the child a small toy to play with first has been shown to be effective in reducing this anxiety.[141] Unfortunately, the effect of the toy as an alternative to midazolam was not evaluated. Play therapy and distraction can be more effective than midazolam in reducing anxiety in children, although this may require an elaborate approach.[142] A preoperative educational program portrayed as a "Saturday morning club" also reduced anxiety,[143] although the authors questioned whether the benefits achieved were worth the time and resources required. A simpler and highly effective approach is to allow children to watch age-appropriate video clips or movies during anesthetic induction with intravenous (South Korea) or inhaled (Canada) techniques.[144,145] A preoperative educational DVD also encouraged more positive parental involvement during the recovery period and reduced children's postoperative pain.[146]

Because of variable efficacy and the potential for delayed recovery, alternatives to benzodiazepine premedication have been sought. In children, oral transmucosal fentanyl reduced preoperative anxiety and postoperative agitation, but a high incidence of predictable side effects, such as PONV and delayed discharge, limited its usefulness.[147] Selective α_2-adrenergic agonists have potentially useful sedative and analgesic effects, yet despite years of study they still have no clearly defined role in ambulatory surgery in which their advantages outweigh the risks for adverse events.[148] Clonidine is commonly used in pediatric practice, particularly to reduce agitation during emergence,[149] but the promising results of clinical trials do not always translate well into routine clinical practice and its effects on induction anxiety are less persuasive.[150]

Analgesic Premedication

Ambulatory patients are commonly premedicated with prophylactic oral analgesia in the expectation of achieving analgesic levels in the early postoperative period. Because the duration of action of acetaminophen (paracetamol) is relatively short (4-6 hours), it is unlikely to provide worthwhile postoperative analgesia, other than for an extremely short procedure. When patients received oral acetaminophen 1 g an hour before arthroscopic knee surgery, barely a third had plasma levels in the therapeutic analgesic range 30 minutes after arriving in recovery, whereas therapeutic levels were consistently achieved with intraoperative intravenous administration.[151]

The nonsteroidal antiinflammatory drugs (NSAIDs) are consistently more effective as analgesic premedicants. Some evidence indicates that NSAIDs have a small preemptive analgesic effect (i.e., they achieve a superior effect if given before rather than after surgery),[152,153] although one of the studies most strongly supporting this conclusion has been called into question.[154] Preoperative parecoxib followed by postoperative valdecoxib significantly reduced the opioid analgesic requirements and the incidence of opioid-related adverse effects after laparoscopic cholecystectomy.[155] As well as providing effective postoperative analgesia, etoricoxib

premedication had an anesthetic-sparing effect during ambulatory ankle surgery.[156] Using a common dental model of postoperative pain, preoperative ibuprofen, diclofenac, and acetaminophen with codeine effectively controlled early postoperative pain.[157] Similarly, rofecoxib and ketorolac were equally effective in controlling postoperative pain after ambulatory surgery,[158] as were ibuprofen and ketorolac.[159] Sustained-release preparations of NSAIDs improve convenience by allowing earlier preoperative administration and a prolonged postoperative effect. Modified-release ibuprofen 1.6 g delayed the time until rescue analgesia was required after ambulatory third molar surgery in contrast to standard ibuprofen.[160] Several of these NSAIDs (and most cyclooxygenase-2 [COX-2] inhibitors are unavailable in the United States.

Selective COX-2 inhibitors are no more effective and offer few advantages over traditional NSAIDs in ambulatory surgery. Despite any inhibition of platelet function, the amount of blood loss seen during high-risk surgery, such as tonsillectomy, was not reduced in comparison with nonselective NSAIDs.[161,162] Nonetheless, COX-2 inhibitors are preferred by surgeons, so age-appropriate doses of oral celecoxib are used as premedication in the United States. Attempts to limit GI adverse effects, which are rare in acute use, has introduced other side effects and led to some drugs being withdrawn.[163] Selective COX-2 inhibitors may be better tolerated in patients with aspirin-sensitive asthma.[164]

Several other drugs have been evaluated for premedication. Controlled-release oxycodone did not improve pain scores or reduce opioid requirements within 24 hours of ambulatory gynecologic laparoscopic surgery.[165] In combination with ibuprofen, pregabalin 150 mg reduced median pain scores at rest and in motion after gynecologic laparoscopic surgery, but did not reduce postoperative analgesic requirements.[166] Perioperative administration of pregabalin 75 mg provided short-lived pain reduction after laparoscopic cholecystectomy, and a meta-analysis confirmed limited analgesic benefit, no reduction in opioid side effects, and increased sedation from its use.[167] Even less effective was pretreatment with magnesium sulfate 4 g, which had no impact on postoperative pain or analgesic consumption in patients undergoing ambulatory ilioinguinal hernia repair or varicose vein surgery.[168]

Prophylactic Antiemetics

Patients at moderate-to-frequent risk for PONV should receive prophylactic antiemetics. Preoperative steroids can provide both analgesic and antiemetic prophylaxis. Some investigators have given dexamethasone as premedication,[169,170] but it is more usually given after induction of anesthesia to reduce administration side effects.

Antacid and Gastrokinetic Premedication

The incidence of aspiration of gastric contents is infrequent in fasted elective surgical patients. Despite improvements in several surrogate measures, insufficient evidence exists of clinical benefit (i.e., a reduction in morbidity or mortality from aspiration) to recommend the routine use of antacids, metoclopramide, H_2-receptor antagonists, or proton pump inhibitors before elective ambulatory surgery.[113,114] Patients who are receiving these medications chronically should take them before surgery. Patients who regularly suffer from significant acid reflux in the fasted state will also benefit from the head-up tilt position during induction of anesthesia. This approach also may be useful in the supermorbidly obese patient undergoing bariatric surgery, in whom the use of prophylactic proton pump inhibitors and sodium citrate may be considered.[51]

Anesthetic Techniques

CHOICE OF TECHNIQUE

Ambulatory surgery requires the same basic standards as inpatient surgery in terms of facilities, staffing, and provision of equipment for delivery of anesthetic drugs, monitoring, and resuscitation. Quality, safety, efficiency, and the cost of drugs and equipment are all important considerations in choosing an anesthetic technique for ambulatory surgery. The choice of specific anesthetic drugs or techniques should enable appropriate and controllable intraoperative conditions followed by rapid recovery with minimal side effects and a prompt return to normal psychomotor activity. Achieving these aims also requires careful attention to the details of analgesia, antiemesis, and fluid management, and requires experienced staff to deliver a high-quality, efficient, and cost-effective service.

No single ideal anesthetic drug or technique for ambulatory surgery exists, and the choice depends on both surgical and patient factors. General anesthesia commonly remains the most popular technique with both patients and surgeons, in some cases despite clear benefits of local or regional anesthetic techniques.[171] Spinal anesthesia can be useful for lower extremity and perineal procedures, but must be modified for use in the ambulatory setting by the use of low-dose techniques[172,173] or short-acting drugs[174] to prevent delays in discharge because of residual motor or sympathetic block. Infiltration of local anesthesia, peripheral nerve blocks, or both facilitate the recovery process by reducing postoperative pain and minimizing the need for opioid analgesics after general anesthesia and should be used whenever possible. Many ambulatory procedures also can be performed using local anesthetic techniques, supplemented, if necessary, with sedatives or analgesic drugs, or both.

GENERAL ANESTHESIA

General anesthesia remains a popular choice with patients, surgeons, and anesthesia providers. Induction of general anesthesia is typically achieved with a rapid and short-acting intravenous anesthetic, although inhaled induction is often used in children and needle-phobic adults. Intravenous drugs are also popular for maintenance of anesthesia, especially where the availability of target-controlled infusion (TCI) systems simplifies delivery,[175] but the use of short-acting inhaled anesthetics, usually without nitrous oxide (N_2O), is more common due to greater ease of administration and lower risk of intraoperative awareness. No single anesthetic technique is clearly superior for ambulatory surgery. Other factors, such as the experience of the anesthesiologist, the use of adjuvant drugs, and the art of anesthesia, are still important to deliver the best quality care.[176]

INTRAVENOUS ANESTHESIA

Methohexital is of little more than historical interest while the long duration of thiopental means it has little or no role in ambulatory anesthesia. The same applies to benzodiazepines and ketamine when used at the doses needed to induce general anesthesia. Etomidate is associated with myoclonus, pain on injection, and a high incidence of PONV. Although reformulation of etomidate in a lipid solvent can reduce some of these disadvantages,[177] persisting concerns about suppression of adrenal steroidogenesis[178] have curtailed its use. The search for new and improved intravenous anesthetic drugs has seen several promising compounds evaluated,[179,180] but no really novel anesthetics have yet become available[181] and propofol remains the most practical intravenous anesthetic for ambulatory anesthesia.

Propofol

Propofol has many of the properties of an ideal anesthetic induction drug and is popular because it rapidly and smoothly induces anesthesia without airway irritation and results in a rapid recovery with an infrequent incidence of early PONV[182] and a clear head. Propofol has some disadvantages, however, including pain on injection, involuntary movements, transient apnea, and hypotension after induction of anesthesia. Numerous strategies have been proposed to reduce pain on injection, of which the use of a large antecubital vein or pretreatment with lidocaine in conjunction with venous occlusion are the most effective,[183] and superior to altering the formulation of propofol.[184]

Some of the adverse effects of propofol can be minimized by reducing the propofol dose by coinduction with adjuvant drugs, the most common being midazolam. Pretreatment with midazolam 0.1 mg/kg allowed anesthesia to be induced with a decreased propofol dose and also attenuated the resultant hemodynamic changes.[185] A substantial decrease in the propofol dose can be achieved even when midazolam is administered up to 10 minutes before induction of anesthesia, a technique that also can make the induction experience for the patient more pleasant.[186] However, this approach may delay recovery. Midazolam 0.03 mg/kg halved the required propofol dose but significantly impaired psychomotor recovery, even though awakening times were not delayed.[187] Coinduction with short-acting opioids, such as alfentanil, can improve the quality of induction and ease of laryngeal mask airway (LMA) insertion, but at the expense of an increased incidence of hypotension and prolonged apnea.[188] Similarly, fentanyl reduced propofol dose and improved conditions for LMA insertion, but also prolonged respiratory depression.[189] Furthermore, the use of 1 μg/kg[190] or fixed doses of 75 μg[191] to 100 μg[192] of perioperative fentanyl increase the incidence of PONV. Giving an initial bolus of 30 mg of propofol reduced the total propofol induction dose to a degree similar to that achieved by 2 mg of midazolam.[193] This technique, which has been termed propofol autocoinduction,[194] can reduce propofol dose and hypotension to a degree comparable to that with midazolam pretreatment but without delaying recovery. Following the concepts of opioid minimization and enhanced recovery after surgery, propofol coinduction can also be performed with intravenous lidocaine.

The pharmacokinetics of propofol allow it to be used as a variable rate infusion to maintain anesthesia, either in association with N_2O or combined with alfentanil or remifentanil as total intravenous anesthesia (TIVA). Recovery after anesthesia maintained with propofol is typically no faster compared to volatile anesthetics after an induction dose of propofol,[182] and initial awakening may be delayed compared to that with the shorter-acting inhaled anethetics.[195] These differences in emergence times are no more than 2 to 3 minutes[196] and so not of clinical significance. Recovery to home readiness may occur up to 15 minutes sooner after propofol than isoflurane but is no faster than sevoflurane or desflurane. There are conflicting reports on whether propofol may be more[197] or less[198] likely than inhaled anesthetics to impair cognitive dysfunction after ambulatory anesthesia in older patients. One consistent feature of propofol anesthesia is a less frequent incidence of early PONV in contrast to the use of inhaled anesthetics.[182,196,199] However, even this benefit has been described as of doubtful clinical relevance, except when the baseline incidence of PONV is very high.[199] The reduction in PONV achieved by TIVA, specifically the use of propofol and the omission of N_2O, was similar to that produced by the use of single-drug antiemetic prophylaxis.[200] Furthermore, any reduction in PONV appears to be confined to the early recovery phase as propofol use for ambulatory surgery does not alter the rate of unanticipated hospital admission and increases the incidence of nausea following discharge, probably because long-acting antiemetics (e.g., dexamethasone) had not been given.[201]

Outside of the United States, delivery of propofol is increasingly performed by TCI, which makes the delivery of propofol easier, with fewer interventions required by the anesthesiologist, in contrast to manual infusions.[202] However, it does not improve the quality of anesthesia, shorten recovery time, or reduce adverse events,[202,203] although the quality of trials performed to date is poor. A further issue is that TCI systems calculate the predicted plasma propofol concentration and considerable variation exists between this and the actual measured value.[203] Further sources of error are introduced when the effect site, rather than the plasma concentration, is targeted.[204] Currently two different pharmacokinetic models are in common use, both derived from healthy subjects. The choice of model may make relatively little difference in the young, fit patient, but performance differs considerably in older patients[204] and neither model is reliable in the morbidly obese.[204,205] Even newer pharmacokinetic models developed specifically with data from obese patients have a tendency to underestimate plasma propofol concentrations.[206]

INHALED ANESTHETICS

Volatile anesthetics remain the most popular choice for the maintenance of ambulatory anesthesia because of their ease of administration, controllability, and rapid emergence. Halothane and enflurane are now of historical interest only, and use of isoflurane has declined considerably as less-soluble, shorter-acting drugs have become available.

Sevoflurane

The low solubility and minimal airway irritation of sevoflurane make it a readily controllable, short-acting anesthetic

for ambulatory surgery.[195] In contrast to isoflurane, sevoflurane resulted in significantly earlier awakening and orientation, caused less postoperative drowsiness, and facilitated earlier discharge by an average of 25 minutes.[196] Compared to propofol, orientation occurred earlier but the time to home readiness was similar.[196] The lack of airway irritation with sevoflurane means that rapid increases in inspired concentration are well tolerated,[207] facilitating control of anesthetic depth. This is in contrast to the cough reflex[208] and transient increases in heart rate and blood pressure, which sudden changes in isoflurane or desflurane concentration may provoke.[209]

Lack of airway irritation makes sevoflurane almost ideal for inhaled induction, which may be especially desirable in children and needle-phobic adults.[195] An 8% bolus induction of sevoflurane in adult patients can be faster than with propofol, with a similar rate of different side effects.[210] Sevoflurane induction also caused significantly less depression of mean arterial pressure than propofol in older patients and was equally as well accepted as an induction choice.[211] Using sevoflurane for volatile induction and maintenance of anesthesia (VIMA) has several benefits for ambulatory patients, but is associated with a greater incidence of PONV than when propofol is used for induction, maintenance, or both, of anesthesia.[195] This appears to be in part due to coadministered opioids, which are rarely needed with VIMA, because omitting the opioids minimizes the problem.[190,210,212] In children, the rapid emergence from sevoflurane (and desflurane) anesthesia is associated with a high incidence of emergence delirium, especially if inadequate measures are in place to control postoperative pain.[213] Numerous strategies have been evaluated to reduce emergence delirium. Midazolam premedication is ineffective, but supplemental use of fentanyl 1 μg/kg, propofol, ketamine, and α_2-adrenergic agonists all reduce agitation to some degree.[149] Although emergence delirium is undesirable, it is not associated with any long-term consequences and does not delay recovery room discharge.[214] There is insufficient evidence of adequate quality to show whether propofol TIVA reduces the risk of behavioral disturbances (or PONV) compared with inhaled anesthesia.[215]

Desflurane

With its low blood solubility, desflurane should be an ideal anesthetic for ambulatory anesthesia. However, meta-analysis of 25 randomized studies showed that patients receiving desflurane followed commands, had their trachea extubated, and were oriented only 1.0 to 1.2 minutes earlier than those receiving sevoflurane for up to 3.1 hours.[216] No differences were found in recovery room stay[217] or incidence of PONV.[216] Concerns about the more frequent incidence of airway irritation with desflurane may limit the rapidity with which anesthetic depth can be altered,[209] although relatively few problems were encountered in patients spontaneously breathing desflurane through an LMA when coadministered with fentanyl.[218,219] Although desflurane has lower fat solubility than sevoflurane, the rate of diffusion into the fat compartment is extremely slow with either inhaled anesthetic; therefore, lower fat solubility does not make the case for use of desflurane as the ideal agent for morbidly obese patients unless procedure length is very long. In practice, some studies of ambulatory surgery in the morbidly obese have found more rapid recovery after desflurane than sevoflurane,[220] whereas others found emergence and recovery to be similar with either drug.[221]

ANESTHETIC ADJUVANTS

Some adjuvant drugs are frequently administered to supplement the effects of general anesthesia and in an effort to reduce adverse effects.

Nitrous Oxide

Although N_2O is by far the oldest anesthetic drug still in use, its role is regularly questioned. N_2O is weakly emetogenic, yet its omission only significantly decreases vomiting when the baseline incidence is high and has no effect on nausea or the complete control of PONV.[222] Others have found the effects of omitting N_2O to be "modest."[223] This may be because the alternatives, specifically a higher inhaled anesthetic concentration or the use of supplemental opioids, also induce PONV. The effect of N_2O on PONV appears to be time-dependent. There was no clinically significant effect from at least an hour's exposure,[224] allowing N_2O to retain a place in modern ambulatory anesthesia where its use also improves the quality, speed, and safety of induction of anesthesia, facilitates faster recovery, and reduces overall costs.[225]

Opioid Analgesics

The indiscriminate use of opioid analgesics should be discouraged in ambulatory surgery to avoid PONV and unplanned admission.[226,227] Although long-lasting drugs such as morphine are especially detrimental, even the ultra–short-acting opioid remifentanil resulted in a 35% incidence of PONV when used with desflurane and multimodal prophylaxis, compared with only 4% when all opioids were avoided.[228] For minor to intermediate ambulatory surgery procedures, the routine administration of as little as 1 μg/kg of fentanyl serves only to increase the incidence of PONV,[229] and its omission does not worsen postoperative pain, provided prophylactic analgesia is ensured with local anesthetic infiltration and preoperative NSAIDs.[190] However, small doses of fentanyl may be useful to provide additional analgesia toward the end of more painful procedures.

Opioids are an essential component of TIVA, but the antiemetic effect of propofol minimizes the incidence of PONV in contrast to the use of the same opioid with inhaled anesthetics.[230] Compared to alfentanil, remifentanil provides more effective suppression of intraoperative responses without prolonging awakening.[231] However, there is increasing evidence emerging that remifentanil is associated with both acute opioid tolerance and opioid-induced hyperalgesia,[232,233] which can increase postoperative analgesic requirements. This hyperalgesia is partially reduced by NSAIDs[233] and by concurrent N_2O administration,[234] although remifentanil is usually used as an N_2O replacement.

Nonopioid Analgesia

For longer or more invasive procedures, intravenous acetaminophen given toward the end of surgery also can have a beneficial effect,[151,235] comparable to that of the opioid tramadol.[236] For shorter procedures, acetaminophen can be given orally before the anesthetic, at much lower cost.

Cardiovascular Drugs

Although intraoperative hemodynamic disturbances are usually managed by increasing the primary anesthetic concentration, administering an opioid analgesic, or both, it may be more appropriate to treat these responses with cardiovascular drugs. Using an infusion of esmolol as an alternative to alfentanil to control heart rate reduced emergence times after arthroscopy,[237] and substituting esmolol for remifentanil reduced nausea after gynecologic laparoscopy.[228] Using a combination of esmolol and nicardipine to blunt increases in heart rate and arterial blood pressure, respectively, prevented the need for increases in inspired anesthetic concentration and consequently shortened emergence and recovery times.[238] Ambulatory patients who received esmolol intraoperatively for hemodynamic control also had significantly smaller requirements for postoperative opioid analgesia.[238,239] Administration of a continuous infusion of esmolol during laparoscopic gynecologic surgery reduced sevoflurane consumption by 18%, shortened recovery room stay, reduced postoperative pain scores, and reduced fentanyl requirements.[240] In a similar study, an esmolol infusion decreased intraoperative remifentanil requirements and again resulted in lower postoperative pain scores and halved the dose of rescue fentanyl.[241] Labetalol may be a cost-effective alternative to esmolol for longer cases, especially in older patients in whom it is less likely to cause inadvertent hypotension.[242]

Neuromuscular Blocking Drugs

Neuromuscular blocking drugs (NMBDs) may be used in ambulatory anesthesia to facilitate endotracheal intubation or to provide profound surgical relaxation. Although several of the available compounds are suitable, muscle pain after administration of succinylcholine and concerns about residual neuromuscular block from intermediate-duration NMBDs after brief procedures have fueled the search for alternatives. The search for a nondepolarizing equivalent to succinylcholine has been unsuccessful to date. The most promising candidate, rapacuronium, was withdrawn from clinical use because of a frequent incidence of severe bronchospasm, although other factors such as inconvenient administration, declining use of endotracheal intubation, and high costs also contributed to its lack of commercial success.[243] The search for a rapid-onset, short-acting nondepolarizing NMBD continues with investigation of several fumarate compounds, of which gantacurium was found to have rapid onset and brief duration, but was also associated with histamine release.[244] Subsequent attention has moved toward designing a molecule of intermediate duration, but which can be rapidly reversed at any time by administering L-cysteine.[244]

An alternative to short-acting NMBDs is terminating the neuromuscular blockade with sugammadex, which can rapidly and completely reverse rocuronium (or vecuronium) independent of the degree of residual neuromuscular block.[245] Sugammadex is very expensive compared to neostigmine, although in the United States the cost of neostigmine has risen dramatically. Currently no reliable evaluations have been done on the cost-effectiveness of sugammadex in routine clinical practice. Although improved recovery times resulting from the elimination of residual neuromuscular block by sugammadex may potentially be cost-effective, this depends on the productivity of staff during the time saved and would probably require major changes to the workflow for actual benefits to be realized.[245]

Endotracheal intubation also can be achieved without the use of NMBDs, thereby avoiding all of their adverse effects. This practice is most common in children, for procedures in which airway protection, but not prolonged muscle relaxation, is required. The optimum technique depends on personal experience and preference, but most commonly involves deep sevoflurane anesthesia[246] or propofol supplemented by remifentanil or alfentanil.[247] For adults, a dose of remifentanil 3 μg/kg with propofol 2 mg/kg is recommended,[248] but satisfactory conditions can be obtained with remifentanil 2 μg/kg, thereby reducing the side effects of bradycardia and hypotension.

AIRWAY MANAGEMENT

Many ambulatory surgical patients can be managed with an LMA, which results in a significantly less frequent incidence of sore throat, hoarseness, coughing, and laryngospasm compared to inserting a tracheal tube.[249] The LMA can occasionally cause pressure trauma to a variety of cranial nerves, in particular the recurrent laryngeal nerve, whereas hoarseness and vocal cord injuries are common after the use of endotracheal intubation during short-term anesthesia.[250] The LMA is relatively easy to insert with patients in the prone position,[251] making it a simple way of managing procedures such as pilonidal sinus repair or surgery to the short saphenous vein.

Traditionally, endotracheal intubation has been advocated for laparoscopic procedures and surgery in obese patients, but further development of the LMA and more confidence in its use may be changing this. The ProSeal LMA (Teleflex, Morrisville, NC) has been modified to provide increased seal pressure, reduce gastric inflation, provide for gastric drainage, and, therefore, allow potentially better protection against aspiration of gastric contents while maintaining similar insertion characteristics.[252] At least one large consecutive series by an experienced user appears to support these benefits in routine clinical practice, without the constraints of a clinical trial.[253] During laparoscopic cholecystectomy, the ProSeal LMA provided adequate pulmonary ventilation without gastric distention in nonobese patients, although it was somewhat less effective than endotracheal intubation in the obese.[254] A recent review found that second-generation LMAs (with higher seal pressures and a drain channel) achieve adequate ventilation during laparoscopic cholecystectomy with a very low incidence of regurgitation and aspiration, but still cannot yet be regarded as completely safe.[255]

Provided safety can be ensured, avoiding endotracheal intubation by using the ProSeal LMA for laparoscopic surgery appears to offer considerable advantages, including considerably smoother emergence with significantly less coughing.[254,256] In laparoscopic gynecologic procedures, the ProSeal LMA was associated with lower pain scores at 2 and 6 hours, with reduced analgesic requirements and less nausea at the same times.[257] Similarly, in females undergoing gynecologic laparoscopic or breast surgery, it reduced the absolute risk for PONV by 40% and also reduced

sore throats, analgesic requirements, and recovery room stay.[258] During laparoscopic gastric banding, the ProSeal LMA reduced the intraoperative stress response and also shortened recovery room stay and hospital discharge.[259]

Since the expiration of LMA patents, many manufacturers have introduced similar designs, often using different materials to produce a low-cost disposable product. Often little or no data are available on the effectiveness or safety of these generic products.[260] Furthermore, the success of the LMA led to the development of many new supraglottic airways of myriad designs. Some of these may offer advantages in ambulatory surgery,[261] although there is often little or no comparative data with the LMA. Anesthesiologists should therefore be wary of the claims made for new airway devices until they have been adequately evaluated.[262]

One supraglottic airway that has been extensively evaluated is the i-gel (Intersurgical, East Syracuse, New York), which has a contoured noninflating cuff and gastric drainage channel. The i-gel is faster to insert and results in less sore throat than the LMA with a seal pressure intermediate between first- and second-generation LMAs.[263]

REGIONAL ANESTHESIA

Spinal Anesthesia

The use of spinal anesthesia makes ambulatory surgery accessible to some patients for whom the risks of general anesthesia are excessive. It also increases patient choice, allows participation in intraoperative decision making (e.g., in sports injuries), and provides beneficial postoperative analgesia. Various ambulatory surgical procedures, such as transurethral prostatectomy, female incontinence surgery, and ankle and foot surgery, are well suited to spinal anesthesia.

The ready availability of fine-gauge, pencil-point spinal needles has reduced the incidence of significant postdural puncture headache to 0.5% to 1%.[264] The main challenge now is to prevent prolonged motor block or impairment of joint position sense from delaying discharge. Although lidocaine has an appropriate duration for ambulatory surgery, its use in spinal anesthesia has virtually ceased as a result of a high incidence of transient neurologic syndrome (TNS).[265] Until fairly recently, bupivacaine was the most obvious alternative, being devoid of TNS, but causing unacceptable delays in home discharge if used in standard doses.

For its acceptance in ambulatory surgery, bupivacaine spinal anesthesia needs to be "modified."[266] Reducing the dose of bupivacaine shortens recovery, whereas the use of patient positioning or the addition of adjuvants, such as fentanyl, ensures adequate analgesia for surgery. These techniques can be summarized as selective spinal anesthesia (SSA), defined as "the practice of employing minimal doses of intrathecal agents so that only the nerve roots supplying a specific area and only the modalities that require to be anaesthetized are affected."[267] SSA provides analgesia suitable for surgery, and light touch, temperature, proprioception, motor, and sympathetic function are all preserved.[267] This results in remarkable cardiovascular stability but can make the block difficult to test, and patient cooperation is important to the success of this technique.

A variety of SSA regimens have been described,[173] which typically permit discharge within a little over 3 hours after surgery.[268] The addition of fentanyl marginally delays recovery and is associated with pruritus[268] (although most cases do not require treatment), but also reduces postoperative pain and analgesic requirements.[269] For unilateral knee arthroscopy, 4 to 5 mg of hyperbaric bupivacaine appears to be sufficient without adjuvants, provided the patient is kept in the lateral position.[269] Clonidine has also been used to supplement low-dose spinal anesthesia, but it may prolong motor block, exacerbate hypotension, and delay voiding.[148]

Spinal anesthesia may contribute to postoperative urinary retention. This is uncommon in low-risk patients, but may be more likely in older patients, with certain procedures and when more than 7 mg of bupivacaine is used.[266] The risk for urinary retention is particularly high after inguinal hernia surgery,[270] but simple infiltration anesthesia is often sufficient for this procedure and may be a more appropriate choice.[171,271]

New Drugs for Ambulatory Spinal Anesthesia

With the increasing popularity of ambulatory spinal anesthesia, some older local anesthetics have been reevaluated and, in some countries, marketed for spinal use.[174] Of these, prilocaine and 2-chloroprocaine have been evaluated the most.[272,273] Hyperbaric prilocaine has a faster onset and shorter duration than the plain preparation,[272] with patients receiving 40 mg of 2% hyperbaric prilocaine being home ready in 208 ± 68 minutes.[274] This is comparable to discharge times reported with low-dose bupivacaine plus fentanyl,[268] although 13% of the patients receiving hyperbaric prilocaine required supplementation for inadequate analgesia toward the end of surgery, which was scheduled to last for less than an hour.[274] Doses of 40 to 60 mg achieve analgesia of about 90 minutes duration for lower abdominal or limb procedures, while 10 to 30 mg is adequate for perineal surgery of up to 40 minutes, with home discharge usually achievable within 4 hours.[272] The duration of 2-chloroprocaine is even shorter, with recovery being significantly faster than that of low-dose bupivacaine[275] or articaine[174] and comparable to that of lidocaine.[276] The addition of fentanyl appears to extend the block duration of both 2-chloroprocaine[273] and prilocaine[272] with little delay in recovery in either case. TNS is much less common than with lidocaine, but still occasionally reported after both prilocaine[277] and 2-chloroprocaine.[273]

Ambulatory spinal anesthesia that relies on short-acting local anesthetics should be compared with the cardiovascular stability of SSA. Prilocaine 20 mg combined with 20 μg fentanyl was associated with a lower incidence of clinically significant hypotension compared with bupivacaine 7.5 mg with fentanyl 20 μg.[278] However, the doses of bupivacaine and fentanyl used in both groups were somewhat higher than usual.

Epidural Anesthesia

Epidural analgesia is seldom used in adult ambulatory anesthesia. Although it allows the block duration to be extended by using a catheter technique, this is offset by the time required in establishing the block and less certainty of success, as well as the risk for inadvertent intravascular injection or dural puncture. In knee arthroscopy, recovery after 15 to 20 mL of epidural

TABLE 72.3 Some Common Upper and Lower Extremity Blocks Used for Adult Ambulatory Surgery

Type of Block	Type of Surgery	Bolus Dose (Perioperative)	Continuous Infusion	Patient-controlled regional analgesia (PCRA)
Interscalene block	Surgery around the shoulder	Bupivacaine/*levo*-bupivacaine 0.25-0.5%, 20-40 mL *or* Ropivacaine 0.5%, 20-40 mL	Ropivacaine 0.2% 5 mL/h	Ropivacaine 0.2% 5 mL/h
Supra- or infra-clavicular block	Surgery around elbow, wrist, and hand	Bupivacaine/*levo*-bupivacaine 0.25-0.5%, 20-40 mL *or* Ropivacaine 0.5%, 20-40 mL	Ropivacaine 0.2% 5 mL/h	Ropivacaine 0.2% 5 mL/h
Sciatic nerve block	Posterior cruciate ligament repair, foot and ankle surgery	Bupivacaine/*levo*-bupivacaine 0.25-0.5%, 20-40 mL *or* Ropivacaine 0.5%, 20-40 mL	Ropivacaine 0.2% 5 mL/h	Ropivacaine 0.2% 5 mL/h
Femoral nerve block	Knee arthroplasty, anterior cruciate ligament repair	Bupivacaine/*levo*-bupivacaine 0.25-0.5%, 20-40 mL *or* Ropivacaine 0.5%, 20-40 mL	Ropivacaine 0.1% 5 mL/h	Ropivacaine 0.1%, 10 mL with 60 min lock-out time
Paravertebral block (thoracic)	Breast surgery	Bupivacaine/*levo*-bupivacaine 0.25-0.5%, 20-40 mL *or* Ropivacaine 0.5%, 20-40 mL	Ropivacaine 0.2% 5 mL/h	Ropivacaine 0.2% 5 mL/h

Doses are approximations, with lower doses recommended when using ultrasound techniques. Depending on the type of surgery, multiple nerves may need to be blocked to get good postoperative pain relief. When using catheter techniques, disposable pumps with pre-filled local anesthetics may be given to the patient with suitable written and verbal instructions.

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3% 2-chloroprocaine was more rapid than spinal procaine with 20 μg fentanyl[279] and also had a decreased incidence of pruritus. Recovery after epidural 3% 2-chloroprocaine required fewer top-up injections and permitted discharge an hour sooner after ambulatory knee arthroscopy than with 1.5% epidural lidocaine.[280] However, the use of epidural 2-chloroprocaine has a more frequent incidence of back pain.[281]

In children, caudal epidural analgesia—for example, using levobupivacaine 0.5 to 1 mL/kg of 0.25%—is popular for postoperative pain relief.[64] The technique is most useful for bilateral surgery or other situations in which the maximum safe dose would not permit an adequate volume for wound infiltration. After circumcision, caudal analgesia was no better than parenteral or systemic analgesia or dorsal nerve block in reducing analgesic requirements, nausea, or vomiting.[282] However, motor block and leg weakness were significantly more common in boys receiving a caudal block. The addition of clonidine[283] or dexmedetomidine[284] augments caudal analgesia, but concerns remain about the frequency of sedative and hemodynamic side effects and the risk for neurotoxicity.[148,283]

Intravenous Regional Anesthesia

Intravenous regional anesthesia (IVRA) (Bier block) is a simple, reliable method of analgesia most commonly used in the upper limb, but sometimes also used effectively in the lower extremity.[285] In the United Kingdom and Europe, prilocaine is the preferred local anesthetic because of its high therapeutic index.[286] Lidocaine has also been used for many years,[285] and appears to be a safe alternative.[287] Ropivacaine has also been extensively evaluated for IVRA. Compared to lidocaine, 0.2% to 0.375% ropivacaine resulted in prolonged and improved postoperative analgesia.[288-290] However, compared to prilocaine, ropivacaine's onset was slower, no useful prolongation of postoperative analgesia occurred, and ropivacaine plasma concentrations were more than double those of prilocaine, despite a 60% lower dose.[286]

IVRA was a cost-effective alternative to general anesthesia for outpatient hand surgery, being equally rapid to administer and with faster recovery and fewer postoperative complications.[291] However, analgesia was inadequate in approximately 11% of cases, which required supplemental local anesthesia, repeat of the block, and even conversion to general anesthesia. IVRA was also cost effective, and quicker to perform, compared to brachial plexus block, but with a 4.4% failure rate due to tourniquet pain.[292]

A variety of adjuvants have been used in IVRA to decrease tourniquet pain, improve block quality, and prolong analgesia after cuff deflation.[293] Opioids are relatively ineffective and cause nausea, vomiting, and dizziness after tourniquet deflation,[293] but several NSAIDs have been shown to be beneficial. Lornoxicam[294] decreased tourniquet pain and improved postoperative analgesia and tenoxicam improved postoperative pain,[293] but the effects of ketorolac are unclear after most of the evidence showing its efficacy in IVRA was withdrawn.[154] Dexamethasone improved both block quality and postoperative analgesia.[295] Similar results have been observed with the α_2-adrenoceptor agonist dexmedetomidine,[296,297] whereas clonidine delayed tourniquet pain without improving postoperative analgesia.[298]

Other Local and Regional Anesthetic Techniques

A wide range of other regional anesthetic techniques can be used to facilitate ambulatory surgery or provide postoperative analgesia (Table 72.3).[299] The applicability of these techniques depends on the nature of the planned procedure, the patient, the preferences of the surgeon and anesthesiologist, as well as the skill and experience of the anesthesiologist performing the block. Benefits include excellent postoperative analgesia and reduced PONV, but this must be offset against pain and discomfort while performing the block, the difficulty of transitioning to satisfactory analgesia when the block wears off, and the risk for perioperative nerve injuries. Regional anesthesia may be contraindicated in patients with bleeding problems or those taking anticoagulants, as well as in patients with local infections. Regional anesthesia

has a high failure rate in inexperienced hands, especially in the morbidly obese patient, although ultrasound guidance appears to improve the success rate of many blocks and can reduce pain during block placement.[300] While there is no conclusive evidence that ultrasound guidance reduces the incidence of peripheral nerve injury, it does appear to reduce local anesthetic systemic toxicity and lowers the incidence of hemidiaphragmatic paresis and pneumothorax associated with certain blocks.[301]

Simpler locoregional techniques may be more appropriate for some procedures. Intraarticular local anesthesia produces a moderate and relatively brief reduction in postoperative pain after arthroscopic knee surgery, but this is still considered to be of clinical significance in ambulatory surgery.[302] In many cases, simple wound infiltration may be as effective as central and proximal peripheral blocks and allows patients to mobilize more quickly.[303] Concerns about the possible risk for infection, or systemic toxicity resulting from large volumes of local anesthetic, appear unfounded in clinical practice.[303]

Infiltration anesthesia offers advantages for many ambulatory procedures and is the method of choice for inguinal hernia repair.[171] Several large series have confirmed excellent results with this highly cost-effective technique, with 79% of patients requiring oral analgesia for 7 days or less after surgery[304] and 91% of patients returning to normal activities within 5 days.[305] Repair under local anesthesia is not an independent factor for hernia recurrence, although this is influenced by the type of hernia and the level of surgical experience.[306] Infiltration anesthesia resulted in fewer medical and urological complications after groin hernia repair than either general or regional anesthesia.[271] If spinal anesthesia is chosen for groin hernia repair, the anesthesiologist should be aware of the increased risk for urinary retention and other medical complications, especially in older patients.[271]

The concept of simple wound infiltration has been further developed into local infiltration analgesia (LIA), used for major orthopedic ambulatory surgery. This multimodal technique was developed for the control of pain after inpatient knee and hip surgery in Australia by Kerr and Kohan.[307] Their technique used a mixture of 300 mg ropivacaine with 30 mg ketorolac and 1.5 mg epinephrine diluted to 150 to 200 mL with saline, infiltrated into all the tissue planes of the surgical field over approximately an hour as the operation progressed. A catheter was placed into the wound to permit later repeat dosing. In the original series of 325 patients, mainly undergoing elective hip resurfacing but including some primary hip and knee replacements, pain was well controlled (numerical pain score 0-3) without morphine in twothirds of patients, most of whom could walk with assistance 5 to 6 hours after surgery; 71% were discharged, walking independently after a single night stay (Fig. 72.2).[307] These promising results have been confirmed in a blinded, randomized trial in patients undergoing unicompartmental knee arthroplasty, where a similar LIA regimen significantly reduced pain and opioid consumption and decreased the median length of stay by 2 days, with 68% of patients discharged after a 1-night stay.[308] A recent review suggests that LIA is beneficial after knee surgery, even when combined with multimodal systemic analgesia, but adds little additional analgesia after hip surgery when a multimodal regimen is also used.[309]

A limitation of infiltration anesthesia in general is the relatively short duration of pain relief it provides, even with long-acting drugs such as bupivacaine. The encapsulation of bupivacaine into a biodegradable carrier offers the prospect of extended-duration local anesthesia, which has demonstrated significant analgesic effects for at least 96 hours in pilot studies.[310] Several potential problems need to be solved before widespread application, however, including ensuring that the large doses of local anesthetic contained within the carrier are not rapidly released, leading to toxicity, or that the encapsulating materials do not break down into harmful products.[311] One extended-duration preparation of bupivacaine, Exparel, which uses an established liposomal-based drug delivery system (Lipo Foam, Contour^{MD}), is currently approved by the US Food and Drug Administration (FDA). Early trial results report improved pain scores and reduced opioid analgesic consumption compared to plain bupivacaine during the first 24 to 48 hours or more after bunion surgery,[312] knee replacement,[313] and breast augmentation.[314] Myalgia was observed after administration of liposomal bupivacaine in six patients in one study,[314] but a 2-year follow up from the same group reported no long-term complications.[315] Several studies appear to support the efficacy and patient acceptability of liposomal bupivacaine after abdominal wall reconstruction, mastectomy, and mammoplasty, although the quality of comparative studies to date is poor.[316] However, systematic reviews suggest no improvement over conventional analgesia for shoulder arthroplasty[317] or bilateral knee surgery[318] and only marginal benefits of questionable clinical significance after unilateral knee surgery.[319] Catheter techniques also can extend the duration of effective local or regional analgesia, reducing pain scores, opioid-related side effects, and length of hospital stay, as well as improving patient satisfaction.[320]

Several naturally occurring alkaloid toxins, which may have the potential to provide longer lasting and safer local anesthesia, have been considered.[311] A preliminary study with neosaxitoxin, an extracellular sodium channel blocker, described superior analgesia compared to that with bupivacaine at 12 hours after laparoscopic cholecystectomy.[321] Subcutaneous injection of neosaxitoxin in combination with bupivacaine and epinephrine produced a five-fold increase in analgesic duration compared with bupivacaine alone, without an apparent increase in toxicity.[322]

SEDATION

Although some procedures may be performed with local or regional anesthesia alone, additional drugs are often required for anxiolysis, to provide additional analgesia and to attain suitable operating conditions by helping the patient lie still in an appropriate position. The level of sedation required varies with each therapeutic, diagnostic, or surgical procedure and must be individually adjusted to achieve a balance of patient comfort and safety.[323]

The ASA defines three levels of sedation according to the responsiveness of the patient.[324] With minimal sedation a degree of anxiolysis is reached, but the patient is normally responsive and has a clear airway. During moderate (conscious) sedation the patient is sleepier but responds purposefully to verbal or tactile stimuli. Spontaneous ventilation

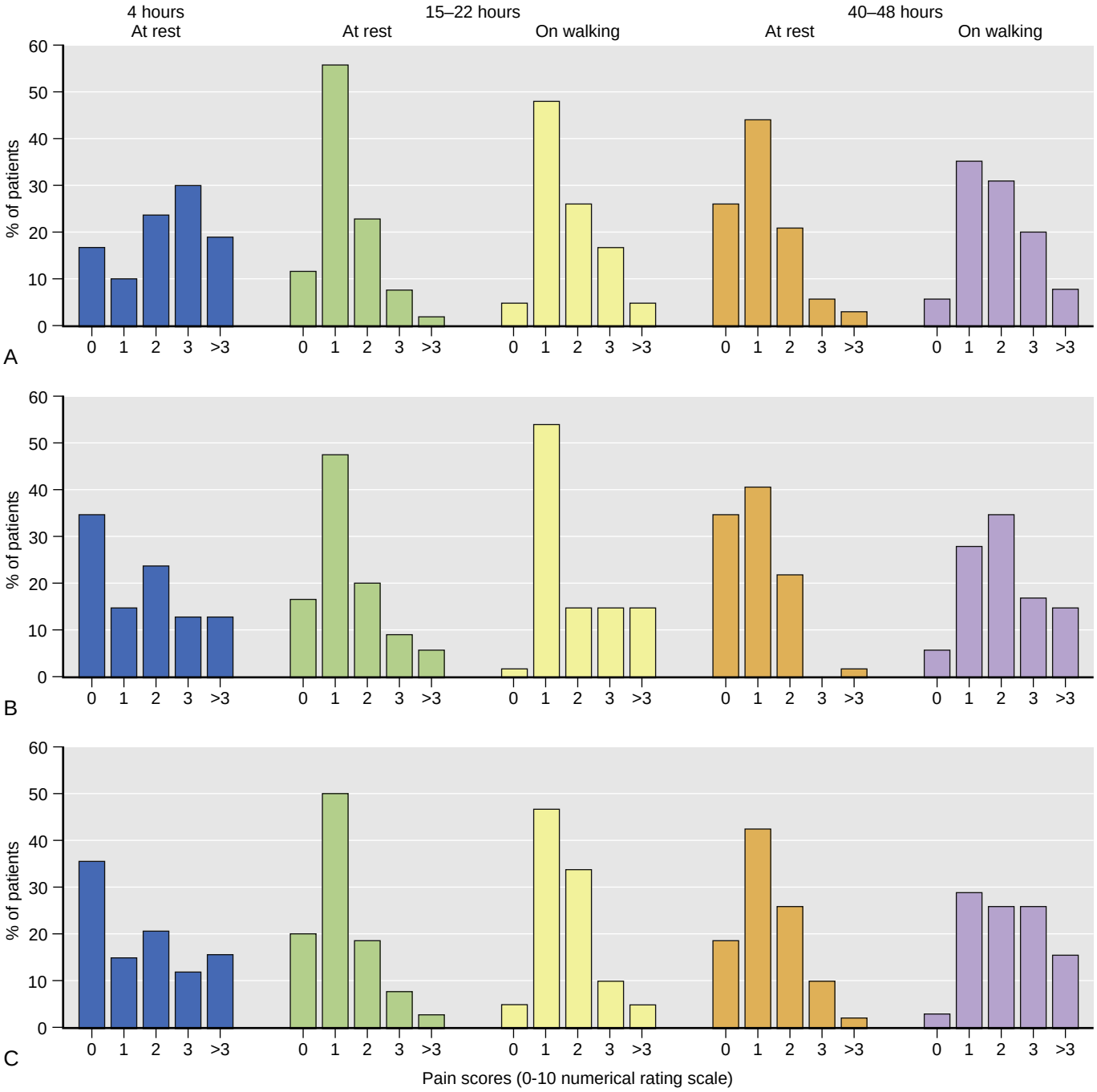

Fig. 72.2 Numerical pain scores at various time points after hip resurfacing arthroplasty (A; *n* = 185), total hip replacement (B; *n* = 54), and total knee replacement (C; *n* = 86) in patients receiving local infiltration anesthesia. (Data from Kerr DR, Kohan L. Local infiltration analgesia: a technique for the control of acute postoperative pain following knee and hip surgery: a case study of 325 patients. *Acta Orthop.* 2008;79[2]:174–183.)

is usually adequate and interventions are not required to maintain a patent airway. With deep sedation, the patient can respond purposefully only to repeated or painful stimuli and may require a degree of airway or ventilatory support. Far from being discrete, these sedative levels lie on a continuum (Fig. 72.3), which becomes general anesthesia when the patient loses consciousness and is unarousable even with painful stimuli.[324] Careful monitoring is essential, and the standard of care for patients receiving sedation should be the same as for patients undergoing general or regional anesthesia and includes all of the usual aspects of anesthesia care.[325] Unfortunately, a widely held belief among physicians and patients is that sedation is a safer form of care,[326] but an ASA closed claims database analysis revealed that the risks for death or permanent brain damage are similar to those of general anesthesia.[327] Predictably, the greatest risk for harm comes from respiratory depression by opioids and sedative-hypnotic drugs, and many cases could have been prevented by better monitoring and improved vigilance.[328]

The US term monitored anesthesia care (MAC) is sometimes erroneously used to describe sedation administered by an anesthesiologist. However, the ASA has a specific

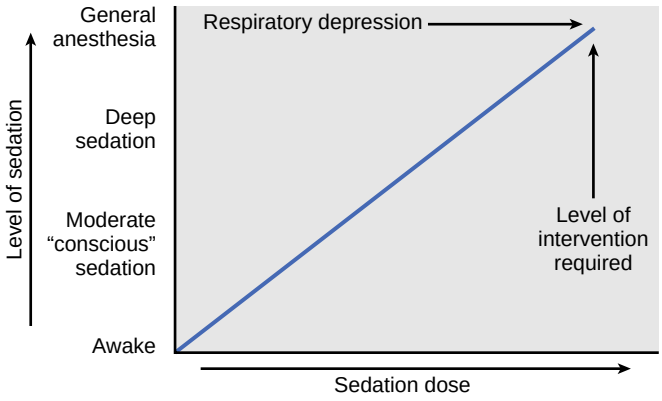

Fig. 72.3 The continuum of sedation and general anesthesia. (Reproduced from Ahuja M, Armstrong I. Sedation. In: Smith I, McWhinnie D, Jackson I, eds. *Day Case Surgery*. London: Oxford University Press; 2012:109–132. With permission.)

definition of MAC, which is a billing term used to describe an anesthesia service that includes all perianesthesia aspects of care.[325] MAC may include varying levels of sedation, including conversion to general anesthesia, when necessary. However, "if the patient loses consciousness and the ability to respond purposefully, the anesthesia care is a general anesthetic, irrespective of whether airway instrumentation is required."[325]

Choice of Sedatives

The specific requirements for supplemental sedative and analgesic drugs depend on the procedure undertaken, the skill of the operator in using local anesthesia, and the experiences and expectations of the individual patient. The use of pharmacologic agents can be reduced by compassionate patient management at every stage, preoperative explanation, and the use of distractions, such as deep breathing, conversation, and listening to music.[326] Adjuvant drugs should be chosen to deliver those specific aspects that are required,[329] such as reduction of anxiety, sedation to relieve boredom or aid immobility, and analgesia for pain that is not amenable to further infiltration of local anesthetic.

Midazolam

Midazolam produces anxiolysis and dose-related hypnosis and is a popular component of sedation. It also produces marked antegrade amnesia. At times this may be beneficial, but it is not always welcomed by patients.[330] Midazolam is preferred to other benzodiazepines because it is water-soluble, does not cause venoirritation or pain on injection, is rapid-acting, and has a relatively short-elimination half-life of about 2 to 4 hours. As sole anesthetic, a single dose of 0.05 to 0.1 mg/kg allows reasonably predictable recovery after brief procedures, but individual responses are highly variable.[331] Recovery is also considerably slower if repeat or prolonged administration is required.

Propofol

Propofol is an excellent sedative-hypnotic because its pharmacokinetic properties result in a rapid recovery from the effects of a single bolus dose and a continuous infusion. Propofol is a relatively pure hypnotic, providing no analgesia and only moderate amnesia. Infusion rates of 25 to 75 μg/kg/min are typically used,[332] but the short duration of action facilitates titration to effect.

Because of the excellent conditions that can be achieved and the superiority of recovery compared with that of midazolam,[333] demand for propofol sedation is growing rapidly in areas such as endoscopy in which anesthesiologists have not traditionally been involved. Propofol can rapidly cause apnea, before loss of consciousness, even in sedative doses, and unintended transition to general anesthesia is a constant risk. The safety of nonanesthesiologist administration of propofol is therefore controversial. In the United Kingdom, the Royal College of Anaesthetists and the British Society of Gastroenterology jointly state that propofol sedation for complex upper GI endoscopic procedures should be administered only by an "appropriately trained anaesthetist."[334] In the United States, the FDA package insert states that propofol may be given "only by persons trained in the administration of general anesthesia," which the ASA supports.[335] However, the American Society for Gastrointestinal Endoscopy considers propofol use safe by anyone "proficient in the management of upper and lower airway complications, including manual techniques for reestablishing airway patency" and holding at least basic life support certification.[336]

Advocates of endoscopist-administered propofol claim a very low rate of airway complications (0.1%) and a mortality (4 in 646,080) less than that associated with endoscopist-administered midazolam-opioid sedation.[337] Their data also reveal a wide range for the frequency with which rescue airway support was required, suggesting considerable variation, either in technique or willingness to intervene to protect the airway.[337] When anesthesiologists administered propofol for patients undergoing endoscopic retrograde cholangiopancreatography (ERCP), deeper levels of sedation or general anesthesia were often intended and sedation-related adverse events were far more common (21%), especially in patients of higher ASA physical status classification, but were managed without adverse consequence or delay, and high levels of patient and operator satisfaction were achieved.[338] A more recent study of anesthesiologist-administered propofol sedation has revealed a very similar (23%) incidence of significant unplanned events.[339]

Potential New Sedatives

Fospropofol was a water-soluble phosphate ester prodrug of propofol, with a slower onset of action and longer duration. Although approved in the United States for sedation in adults in 2009, restriction of its use to anesthesiologists[340] and a lack of any clear advantage over propofol prevented its commercial success.

Remimazolam is a new ester-based benzodiazepine, designed to be rapidly broken down by ubiquitous tissue esterases into an inactive metabolite. Preliminary findings suggest a faster onset and shorter duration than midazolam after a single dose,[341] although not all procedures could be completed without "rescue" sedation. Remimazolam may have a role as a sedative for brief (<10 minute) procedures, but its behavior after repeated dosing and its consequent role as a sedative have yet to be evaluated.[341]

Analgesic Adjuvants

Opioids are useful for procedures in which pain cannot reliably be blocked with local anesthesia alone.[323] Compared

to alfentanil in women undergoing breast biopsy, remifentanil resulted in lower pain scores during deep dissection and reduced the need for supplemental local anesthesia.[342] Remifentanil was a useful adjuvant to propofol sedation during transvaginal tape insertion[343] and in achieving optimal conditions for awake craniotomy,[344] surgery that is increasingly being performed as a day and short-stay procedure.[26] Remifentanil produced lower pain scores than fentanyl in patients receiving propofol sedation during hysteroscopy, but it did not improve recovery or patient satisfaction.[345] For hysteroscopic surgery, paracervical block supplemented by a remifentanil infusion permitted earlier mobilization and discharge compared to TIVA, and the sedation technique was also preferred by a higher proportion of patients. Remifentanil is usually delivered by infusion, but intermittent bolus doses may be more effective for some procedures.[346] Hyperalgesia after remifentanil administration remains a concern.

Both clonidine and dexmedetomidine have potentially useful analgesic, anxiolytic, and sedative properties. The slow onset and offset of clonidine and frequent reports of cardiovascular instability mean that neither drug has established a routine place in sedation,[148,347] although dexmedetomidine may be a useful analgesic adjuvant in awake craniotomy.[348] Ketamine improved analgesia when used to supplement propofol sedation, but an increase in PONV, psychomimetic side effects, and delayed discharge were observed at higher doses.[349]

Delivery of Sedation

Because of the varying needs to provide hypnosis, anxiolysis, analgesia, and amnesia, use of drug combinations is common during anesthesiologist-administered sedation. Preceding a propofol infusion with a 2 mg dose of midazolam improved anxiety, sedation, and amnesia for early intraoperative events with no detrimental effect on postoperative sedation, amnesia, or recovery times.[350] However, using drug combinations increases the risk for interactions, leading to adverse effects. At sedative doses, propofol and remifentanil each have only a modest effect on heart rate and arterial blood pressure, but their effect on respiration is strikingly synergistic, with the potential for severe respiratory depression.[351] Respiratory depression is also enhanced by the interaction of midazolam and remifentanil.[352] Antagonists of benzodiazepines and opioids may be useful in cases of unintended overdose, but should not be routinely relied on to reverse deep sedation because of their short duration of action, which may permit resedation before[353] or after discharge.[354] It is also possible to achieve high rates of patient satisfaction without procedural recall when using intermittent bolus doses of propofol alone for endoscopic procedures.[355]

As with TIVA, the stability and control of sedation regimens can be improved by using TCI systems.[356] Target concentrations of 0.5 to 2 μg/mL for propofol and 0.5 to 1 ng/mL for remifentanil are typical,[323,347] but should be titrated to individual effect. Effective sedation is usually judged by clinical endpoints or scores. Bispectral index (BIS) changes with increasing sedation, but is too variable[357] to be useful routinely and was not effective as an endpoint for midazolam sedation.[358] BIS monitoring did not improve the quality of sedation or reduce the propofol dose or rates of hypoxemic, bradycardic, or hypotensive complications during ERCP.[359] However, BIS-guided TCI propofol may be useful in the management of patients with intellectual disability,[360] in whom clinical signs may be less reliable. Allowing patients to adjust their own sedation level by patient-controlled sedation resulted in less propofol being used compared with a continuous infusion and was significantly more popular with patients.[361] However, this approach necessarily requires comparatively light levels of sedation and appears to be an undesirable option for a significant proportion of patients.[362]

Inhaled sedation by a low dose of sevoflurane is an alternative technique that provides good control of sedation and rapid recovery.[363,364] However, it can be complicated by a frequent incidence of perioperative excitement and an increased risk for transition to general anesthesia.[365]

Monitoring Depth of Anesthesia

Many devices are now available to monitor the hypnotic component of anesthesia as a supplement to our traditional reliance on autonomic signs. Most monitor electroencephalogram signals, recorded either spontaneously or evoked in response to a stimulus, which are then processed into a dimensionless number, usually ranging from 0 to 100. Precisely which variables are recorded and how they are processed can be proprietary information,[366] and the specific values corresponding to adequate anesthesia also vary among monitors.[367]

BIS was the first licensed monitor and is the most extensively studied, yet whether it can actually prevent awareness with recall remains controversial.[367] In ambulatory anesthesia, in which awareness is uncommon,[368] more interest has been shown on whether BIS and similar devices can reduce excessive anesthetic delivery, thereby improving the speed and quality of recovery and reducing costs. Two meta-analyses have shown that titrating anesthesia to achieve BIS values of 40 to 60 results in trivial (2-4 minutes) reductions in awakening times, shortens recovery room stay by just 4 to 8 minutes, and fails to facilitate earlier home discharge.[369,370] BIS titration also produced a very modest reduction in PONV (32% vs. 38%).[369] Despite reductions in anesthetic drug usage, the cost savings were substantially less than the disposable costs associated with BIS.[369] Monitoring with auditory evoked potentials achieved similar small reductions in drug usage and awakening times, comparable to those seen with BIS.[371,372] Discharge times were unchanged in one study[371] but were shortened by both BIS and auditory evoked potential monitoring in another study in a very similar population.[372] Spectral entropy monitoring also achieved only small reductions in drug use and recovery times, although the quality of evidence was rather poor.[373]

Although a lack of clear clinical or financial benefit exists from depth of anesthesia-guided drug titration, genuine concerns have been raised about using these monitors for purposes other than those for which they were designed. Although anesthesia is usually adequate at values below 60, BIS lacks a high level of discrimination and some patients may form memories at values as low as 40.[374] Thus, titrating anesthesia, even to BIS values of 40 to 50, to reduce costs and recovery times, may unintentionally increase the risk for awareness.[366]

Recovery from Ambulatory Anesthesia

Recovery is traditionally divided into three stages. Early, phase 1 recovery occurs in a postanesthesia care unit (PACU) and entails further awakening and management of pain and nausea, with monitoring of hemodynamic stability. Intermediate recovery continues in the phase 2 (step-down) recovery or in a separate ward area and ends when the patient achieves the criteria for home discharge (see later discussion). The phase 1 and phase 2 aspects of recovery may occur in separate locations or within the same room.

EARLY RECOVERY

The recovery room or PACU should be centrally placed to all operating rooms and requires the same standard of staffing and equipment as are provided for inpatients.[375] The PACU may be shared with inpatients in some facilities, but recovery times can be shortened dramatically if there is a separated phase 1 PACU dedicated to ambulatory patients.[11] In the United States, the ratio of nurses to patients is usually lower than in the inpatient PACU, for ambulatory typically 1:3, reflecting the lower acuity of postprocedural needs.[6] Patient care should be adequately transferred to the PACU nursing staff, relaying preoperative and intraoperative problems and postoperative instructions. The nature and frequency of monitoring in the PACU is determined by the nature of surgery and the state of recovery. Because ambulatory anesthetics are typically short-acting, supplemental oxygen (O_2) administration may be unnecessary in the PACU,[376] provided the patient's saturation level of O_2 in hemoglobin (SpO_2) remains above 92% on air.

In the United Kingdom, patients may be discharged from phase 1 to phase 2 of recovery when they are awake and oriented, normothermic, able to maintain their own airway and ventilation, and demonstrate cardiovascular stability. Wounds should be reasonably dry, and pain and PONV should be minimal and adequately treated. This assessment is usually made on clinical judgment.[375] In the United States, transfer from phase 1 to phase 2 is commonly based on predefined, physician-determined criteria. Typical ambulatory criteria include being awake with stable vital signs, minimal pain, minimal nausea, and the ability to sit with minimal dizziness.[377] If more standardized data are desired, a scoring system can be used. The most commonly used system is the modified Aldrete score,[378] which assigns points on the basis of activity, ventilation, blood pressure, consciousness, and oxygenation (Table 72.4). Length of PACU stay is one of the key endpoints, along with awakening, orientation, and extubation times used to evaluate early recovery in ambulatory anesthesia research.

SECOND-STAGE RECOVERY

Second-stage recovery prepares patients for leaving the ambulatory surgery unit and taking over their own care. Patients should sit upright on trolleys or reclining chairs as an aid to mobilization. After low-dose spinal anesthesia, mobilization is usually possible within an hour of the return of full motor function, or about 2.5 to 3 hours after the start of spinal anesthesia.[172,379]

TABLE 72.4 The Modified Aldrete Recovery Score

		Score
Activity:	Able to move 4 extremities voluntarily or on command	2
	Able to move 2 extremities voluntarily or on command	1
	Unable to move extremities voluntarily or on command	0
Respiration:	Able to breathe deeply and cough freely	2
	Dyspnea or limited breathing	1
	Apneic	0
Circulation:	BP ± 20% of preanesthetic level	2
	BP ± 20%-49% of preanesthetic level	1
	BP ± 50% of preanesthetic level	0
Consciousness:	Fully awake	2
	Arousable on calling	1
	Not responding	0
Oxygenation:	Able to maintain saturation >92% on room air	2
	Needs oxygen to maintain saturation >90%	1
	Saturation <90% even with oxygen	0

The total possible score is 10; patients scoring ≥ 9 are fit for discharge from phase 1 recovery. *BP*, Blood pressure.

Reproduced from Aldrete JA. The post-anesthesia recovery score revisited (letter). *J Clin Anesth*. 1995;7:89–91. With permission.

FAST-TRACK RECOVERY

With the increased use of short-acting drugs and techniques, many patients will have already met the discharge criteria before, or by the time, they reach the PACU.[380] If this is the case, admission to the PACU will only generate unnecessary delay while further observations are performed. Instead, these patients may bypass phase 1 recovery and go directly to the phase 2 unit; this is known as fast-track recovery.

The modified Aldrete score can also be used to assess fast-track eligibility.[381] Because this score does not assess pain or PONV, which are traditionally treated in the PACU, White and Song[382] added two additional categories to derive their fast-track recovery score. Although using this score reduced the proportion of patients who met the fast-track criteria on PACU arrival, it also significantly reduced the number of patients who required parenteral analgesia or antiemetics in the step-down area.[382] Others have suggested a series of clinical criteria[383] that must all be achieved for patients to undergo fast-track recovery (Box 72.1). The criteria for transfer from phase 1 to phase 2 and the criteria for direct entry to phase 2 should be the same.

Fast-track recovery is the norm for patients who have had local anesthesia, but it is also appropriate for most patients receiving sedation[383,384] and low-dose spinal anesthesia in the United Kingdom.[172] Patients receiving general anesthesia also may be able to undergo fast-track recovery, which is appealing because improved recovery provides the patient with a higher-quality experience, enabling them to return toward normal in a more pleasant, comfortable, and facilitative environment. It also frees up the more intensive resources of phase 1 recovery for those patients who need them.

Accomplishing fast-track recovery is complex. In one facility, fast-track recovery was only achieved in just over 60% of those who met the PACU bypass criteria.[385] The use

BOX 72.1 Criteria* for Direct Admission to the Second-Stage Recovery Unit, Bypassing the Post-Anesthesia Care Unit

- Patient should be awake, alert, oriented, responsive (or returns to baseline state)
- Pain should be minimal (unlikely to require treatment with parenteral medications)
- No active bleeding should occur (unlikely to require professional treatment)
- Vital signs should be stable (unlikely to require pharmacologic intervention)
- Nausea should be minimal
- No vomiting should occur
- If nondepolarizing neuromuscular blocking agent has been used, patient should now be able to perform a 5-second head lift, or train-of-four monitoring should indicate no fade
- Oxygen saturation should be 94% or higher on room air (3 min or longer) or oxygen saturation should return to baseline on room air

*During the follow-up period, the patient should be evaluated in the operating room, immediately before discharge, using the above criteria regarding recovery from anesthesia. To bypass the post-anesthesia care unit, a patient must meet all of these criteria and, in the judgment of the anesthesiologist, be capable of transfer to the second-stage recovery unit.

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of depth of anesthesia monitoring has been claimed to facilitate fast-track recovery,[386] whereas others have not found it advantageous.[387] Accomplishing fast-track recovery requires not only anesthesia recovery readiness, but also the support of a facility-based process, including nursing and surgeon participation and environment support.

The economic case for fast-track recovery should be considered separately.[388] In some cases, fast-track recovery has shortened overall recovery stay, comparable to,[389] or even longer than,[383] the time that would have been spent in the PACU. However, nursing workload was not reduced,[389] while others have found no difference in overall recovery time.[385] Nurses in the step-down unit are not always readily available to receive patients and often report patients arriving cold or without all the fast-track criteria actually being met.[390] Although fast-track recovery appears financially beneficial, actual savings will be made only if the PACU is not needed at all or if staffing levels can be reduced, which is not supported by the evidence to date.[388] Nursing workload and costs may simply be shifted from one area to another, with no overall savings.[389] Fast-track recovery may still help to improve patient flow and may work best in small units that use staff flexibly between different areas.[388] But the most productive approach may be to enable the fastest possible path for all patients through their recovery to discharge home.

Postoperative Pain

The management of postoperative pain should begin well before the patient undergoes surgery. Patients need to have appropriate expectations about what they are likely to experience during their recovery.[391] At preoperative assessment, patients should be provided with information about the likely extent and duration of pain after surgery. They should also be advised about simple measures to reduce pain, including advice to rest in a comfortable position, raising swollen limbs, use of heat or cold packs, and the benefits of distraction. Prevention is the mainstay of pain management, yet studies have shown that pain management after ambulatory surgery is often inadequate.[392-394] Common causes are a lack of adherence to analgesic guidelines and a failure to provide multimodal analgesia.[394] Too often there is over-reliance on opioid analgesia, resulting in predictable adverse effects,[395] that are second only to inadequate pain relief in causing unnecessary hospital admission.[392]

MULTIMODAL ANALGESIA

Multimodal analgesia relies on the additive or synergistic combination of drugs acting at various points on the pain pathway.[396] Typical combinations include local anesthetic wound infiltration or regional techniques and routine NSAIDs, with small doses of opioids added as needed. Topical therapies may also be of some benefit, with both lidocaine and glyceryl trinitrate patches found to provide effective topical analgesia after a variety of ambulatory procedures.[397] Multimodal regimens have been shown to be effective after several ambulatory surgical procedures.[398,399] An opioid-sparing effect exists for several drug combinations,[400] but most evidence is limited to an opioid plus one other drug, with little evaluation of true multimodal analgesia or attempts to identify optimal combinations.[394] Analgesic efficacy appears to differ with the nature of surgery,[401] suggesting that multimodal analgesic regimens should be specifically tailored.[402] Nevertheless, reducing the opioid dose does decrease the incidence of PONV to a corresponding degree and may also reduce other opioid adverse effects, such as sedation, sleep disturbances, urinary retention, and respiratory depression.[395] As yet, no evidence indicates that multimodal analgesia improves long-term patient outcome[403] because of the small number of subjects studied and the infrequent incidence of adverse outcomes after ambulatory surgery.

RESCUE ANALGESIA

Despite prophylactic measures, some patients will experience pain on awakening after surgery. Milder cases may be amenable to treatment with additional oral analgesia, but more severe pain will usually require parenteral opioids. Long-acting parenteral opioids are rarely indicated. Fentanyl is commonly used for this purpose, and small boluses (20-25 μg) rapidly achieve analgesia. Compared to morphine, fentanyl results in more rapid control of pain and reduces the occurrence of PONV.[404] Rescue fentanyl also produced fewer adverse effects than oxycodone.[405] Administration of additional oral analgesia as soon as the pain is controlled will usually prevent a recurrence at a later stage of recovery. During the recovery period, pain should be assessed on a regular basis and treated according to protocols (Fig. 72.4).

PAIN MANAGEMENT AT HOME

In the United States, patients are often given prescriptions for postoperative analgesics, including weak opioids,

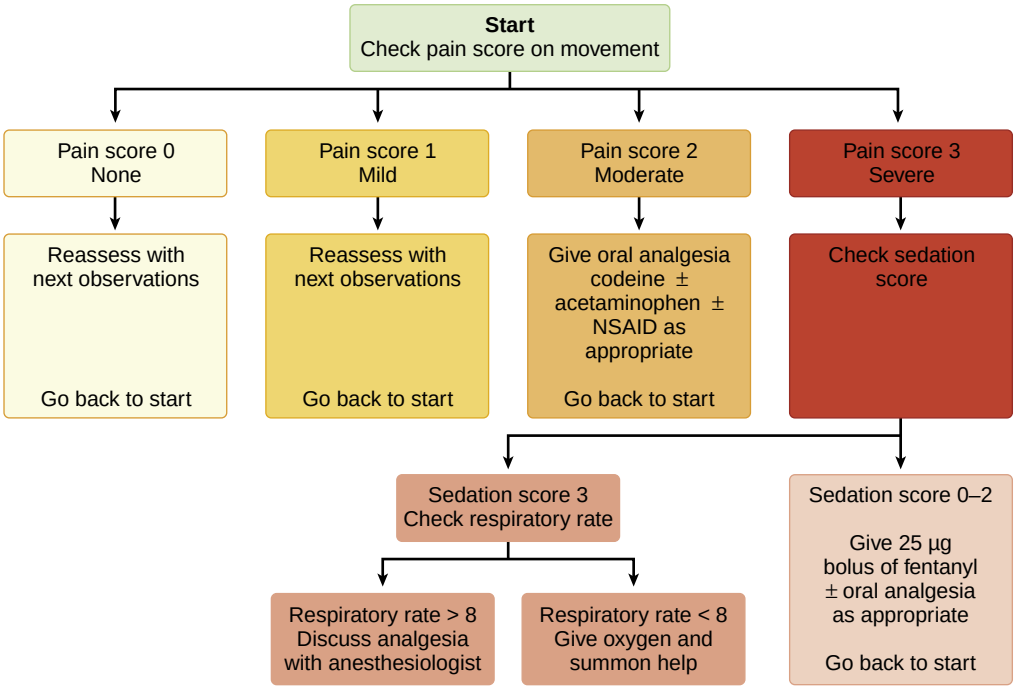

Fig. 72.4 Example of a pain management protocol for ambulatory surgery patients. *NSAID,* Nonsteroidal antiinflammatory drug. (Modified from Lipp A, Jackson I. Adult day surgery analgesia. In: Smith I, McWhinnie D, Jackson I, eds. *Day Case Surgery.* London: Oxford University Press; 2012:133–145. With permission.)

preferably before surgery so the medications will be at home when the patient needs them. In the United Kingdom, patients may be given standardized take-home analgesic packs that can be dispensed from the ambulatory surgery unit, avoiding pharmacy delays. Typical take-home analgesia includes NSAIDs and acetaminophen combined with a weak opioid. Combinations of codeine-acetaminophen[406] and hydromorphone-acetaminophen[407] are effective after many ambulatory surgical procedures, although a proportion of patients are unable to metabolize codeine to its active form, rendering it ineffective.[408] Although a single preoperative dose of pregabalin produced modest improvements in pain after ambulatory surgery, continuing its use into the postoperative period added no further benefit.[167]

Managing Opioid Complications

Although multimodal techniques aim to minimize opioid use, strong opioids can be necessary as a rescue option after more invasive surgery. Analgesics such as morphine and oxycodone provide more intense and prolonged effects, but are associated with more intense and prolonged typical opioid side effects. Novel delivery techniques, such as iontophoretic[409] or nasal[410] fentanyl, or sublingual sufentanil,[411] may improve patient convenience but do nothing to reduce adverse effects. In addition to multimodal analgesia, attempts to limit these adverse effects have included the development of drugs such as tramadol, which combine opioid and nonopioid mechanisms of action. Tramadol is effective after ambulatory surgery,[412,413] but it is still associated with a frequent incidence of unwanted effects, including sedation, dizziness, and particularly PONV.[414] Tapentadol is licensed in both the United States and the United Kingdom. It has a dual action similar to that of tramadol, with comparable efficacy to oxycodone but fewer GI adverse effects, such as nausea, vomiting, and constipation.[415] Unlike tramadol, it does not require metabolic activation or suffer from isomer-dependent pharmacodynamics.[163]

Combining oral oxycodone with naloxone (Targinact) antagonizes the GI effects, in particular preventing opioid-induced constipation, but has little effect on analgesia because first-pass metabolism prevents much naloxone from reaching the central nervous system.[163] Alvimopan is another peripherally acting µ-opioid (MOP) receptor antagonist intended to reduce opioid-induced constipation. However, peripheral MOP receptors also may partially mediate opioid-associated PONV, delayed gastric emptying, and urinary retention,[163] offering the hope that opioid analgesia without serious adverse effects may yet be a possibility.

Local Anesthetic Administration at Home

Sending patients home with perineural, incisional, and intraarticular catheters is a new and evolving area of postoperative pain management.[416] Patient-controlled regional anesthesia (PCRA) with an elastomeric balloon pump has provided effective analgesia and reduced pain intensity during mobilization when ropivacaine is delivered into a perioperatively placed wound catheter after subacromial decompression.[417] Although patients were kept in hospital for study observations and assessments, based on pain scores, the authors concluded that all patients in the active group could have been discharged within 2 hours of surgery. Another small pilot study showed excellent analgesia with continuous interscalene block, continued at home, allowing same-day discharge after a variety of shoulder operations, including open rotator cuff repair, subacromial decompression, and joint replacement.[418]

Recently, several institutions have described cases of chondrolysis that appear to be related to the use of postoperative intraarticular local anesthetic pain pumps.[419] In a series of 375 patients from one individual orthopedic surgeon, chondrolysis was observed only in cases in which

either bupivacaine or lidocaine had been infused into the joint during the postoperative period.[420] Most local anesthetics, including bupivacaine, lidocaine, and ropivacaine, are chondrotoxic to human articular cartilage in vitro, and the risk may be increased with longer exposure to higher concentrations of local anesthetic, such as with a pain pump, compared to that associated with a single injection.[421] Consequently, the use of local anesthetic infusions after shoulder surgery has declined or stopped in many institutions.

A variety of infusion pump designs are available for local anesthesia infusions or PCRA after discharge. Technical problems have been found with electronic pumps,[422] which seem to be unreliable for home use.[418] Patient satisfaction[422] has been reported with disposable elastomeric pumps, which are more reliable, although not all types function equally well and in vivo performance does not necessarily match results obtained in vitro.[423]

Postoperative Nausea and Vomiting

PONV occurs in as many as 30% of a general surgical inpatient population given no antiemetics.[424] Some patients undergoing day surgery have a much smaller risk for symptoms, cited as less than 5%[56,425] for very minor surgery, with reduced requirement for intraoperative and postoperative opioids. However, in the same studies, other ambulatory surgery patients had a predischarge incidence of PONV as high as 41%. When the potential occurrence of emetic sequelae after discharge is included in the estimation of overall risk, some authors cite an overall incidence of more than 40%, even after receiving an antiemetic.[426]

RISK ASSESSMENT AND STRATEGIES

Some have recommended that the management of PONV for ambulatory patients should involve universal multimodal pharmacologic prophylaxis to minimize the symptoms that might delay timely discharge or subsequent recurrence in the home environment.[427] However, current recommendations[428] advocate a more focused approach toward the use of preventive pharmacotherapy, having first minimized baseline risk resulting from the use of generic emetogenic stimuli, such as adequate hydration, the use of local-regional techniques, or if a general anesthetic is needed, reducing exposure to volatile anesthetics, N_2O, and opioid-based analgesia. Avoiding neostigmine was previously advocated, but may not be beneficial.[428] Individual patient factors should then be identified to stratify relative risk. The scoring system originally derived from a cohort of ear, nose, and throat patients by Apfel and colleagues in 1998[429] is popular because of its relative simplicity; yet debate continues regarding discriminating power[427] and its applicability to ambulatory surgery patients, because the predicted risk for PONV (Table 72.5) seems to be overestimated in this population, presumably as a result of the original scoring system having been developed for inpatients in Europe. This seems to be confirmed in a subsequent paper by the same author,[426] where PACU-only rates of nausea were 19.9%, vomiting 3.9%, and nausea and/or vomiting 20.7% across an ambulatory patient cohort with characteristics that would seem to predict greater risk from the original algorithm. In the same study, postdischarge rates of PONV until the second postoperative day were however higher: 36.6% nausea, 11.9% vomiting, 13.3% severe nausea, and 5.0% severe vomiting. From these data, the authors developed a predictive scoring algorithm for postdischarge nausea and vomiting (PDNV) (Table 72.6). Other scoring algorithms exist for prediction of risk for PONV in the ambulatory environment, but their relative complexity mandates the use of a calculator or computer.[425] A reevaluation of risk factors for PONV[430] reiterated the importance of those characteristics included in the original Apfel score,[424] but this algorithm included younger age and duration but not type of surgery. A simple policy whereby two antiemetic interventions were administered to all male patients and three to all females[431] resulted in better compliance and greater effectiveness than several previously published strategies,[432] although at the risk of exposing more patients to the potential harm of unnecessary antiemetics.

TABLE 72.5 Risk Factors for, and Predicted Rates of, Postoperative Nausea and Vomiting According to the Apfel Score

Risk factors	Scoring
Female	1 point
Non-smoker	1 point
History of previous PONV	1 point
Postoperative use of opioids	1 point
Maximum possible score	4 points
Number of Points	**Risk of PONV (%)**
0	10
1	21 (≈20)
2	39 (≈40)
3	61 (≈60)
4	79 (≈80)

PONV, Postoperative nausea and vomiting.
Data from Apfel CC, Laara E, Koivuranta M, et al. A simplified risk score for predicting postoperative nausea and vomiting: conclusions from cross-validations between two centers. *Anesthesiology*. 1999;91(3):693–700.

TABLE 72.6 Risk Factors for, and Predicted Rates of, Postdischarge Nausea and Vomiting

Risk Factors	Scoring
Female	1 point
Age < 50 years	1 point
History of previous PONV	1 point
Postoperative use of opioids	1 point
Nausea in PACU	1 point
Maximum possible score	5 points
Number of Points	**Risk of PONV (%)**
0	10.9 (≈10)
1	18.3 (≈20)
2	30.5 (≈30)
3	48.7 (≈50)
4	58.5 (≈60)
5	79.7 (≈80)

PACU, Post-anesthesia care unit; *PONV*, postdischarge nausea and vomiting.
Data from Apfel CC, Philip BK, Cakmakkaya OS, et al. Who is at risk for postdischarge nausea and vomiting after ambulatory surgery? *Anesthesiology*. 2012;117(3):475–486.

Antiemetic treatment should therefore be tailored to assessment of likely risk for symptoms with the use of either unimodal or multimodal prophylaxis as indicated. The IMPACT study[200] demonstrated that ondansetron 4 mg, droperidol 1.25 mg, and dexamethasone 4 mg were equally effective in reducing the risk for PONV by an order of 25% and that using these two drugs together would be approximately additive (multimodal antiemetic prescription). Specifically, the prophylactic use of one of these drugs decreases the estimated risk for PONV from 60% to 44%; use of two drugs would further decrease the incidence from 44% to 33% and three drugs to 24%. The use of TIVA with propofol with the concomitant avoidance of N_2O had similar equivalence to the use of one antiemetic.[200] However, the antiemetic effectiveness of TIVA is time-limited and patients receiving TIVA appear to have a higher risk of late PONV, starting 2 to 6 hours after surgery.[200A] Simple measures, such as the routine administration of approximately 1 to 2 L of intravenous crystalloid fluids, reduce the incidence and severity of PONV, decrease dizziness and drowsiness,[433] and reduce postoperative pain in high-risk groups.[434] Allowing patients to drink clear liquids for as long as possible before surgery can also reduce PONV.[124]

ANTIEMETIC AGENTS

First-Generation Drugs

Metoclopramide is a dopaminergic (D_2) and serotonergic (5-HT_3, peripheral 5-HT_4 at higher doses) antagonist with gastric prokinetic properties that was first described in 1964. A meta-analysis of a standard clinical dose of 10 mg showed little evidence of pharmacologic benefit for PONV,[435] but after a number of studies by Fujii were withdrawn, reanalysis suggests that there may be some benefit.[436] However, current guidelines still do not list metoclopramide for first-line treatment.[428] Higher doses, such as 20 to 25 mg, are more effective[437] but are associated with more akathisia.

Droperidol is a butyrophenone with an antiemetic effect resulting from dopaminergic receptor (D_2) antagonism that received a black box warning for the FDA-approved dose of 2.5 mg[438] or greater because of potential QT interval prolongation. This and other side effects of droperidol, such as sedation and akathisia, were significant but at higher doses than are commonly used for PONV prophylaxis,[438] which are typically 1.25 mg or less. A recent meta-analysis[439] has confirmed the antiemetic action of low-dose droperidol. Droperidol use is less in the United States since the black box warning was added but primarily for medicolegal reasons rather than because of concerns with efficacy or side effects. It is also little used in the ambulatory environment in the United Kingdom due to perceptions of adverse extrapyramidal effects, particularly akathisia, even at 0.5-mg doses.[440,441] An Australian study evaluating the incidence of akathisia in 228 women undergoing ambulatory gynecologic laparoscopy reported a rate of 29% with administration of 10 μg/kg.[442]

Antagonists of the histamine H_1 receptor have a particular efficacy in the management of nausea and vomiting precipitated by vestibular pathways, with a documented benefit in the management of travel sickness and surgical procedures for strabismus or involving the middle ear. Dimenhydrinate (a combination of diphenhydramine and 8-chlorotheophylline that was added to reduce drowsiness) has an antiemetic effectiveness deemed similar to that of both droperidol and 5-HT_3 antagonists,[443] but potential adverse reactions from these antihistamines include marked sedation, dry mouth, urinary retention, and blurred vision as a result of associated muscarinic receptor antagonism. Meclizine, an H_1-receptor antagonist and anti–motion sickness medication, is minimally sedating, long-acting, and effective for treatment of PONV and for prevention of PDNV.[444] In the United States, it is inexpensive and available without prescription, making it an attractive postdischarge choice.

A transdermal scopolamine delivery system is also available. This patch was designed to deliver a total dose of 1 mg of scopolamine at a sustained, constant rate over a period of 3 days.[445] Numerous studies have shown transdermal scopolamine to be effective in reducing the incidence and severity of PONV and PDNV, with efficacy comparable to that of ondansetron or droperidol. It has a prolonged duration but the onset is delayed, becoming effective within 2 to 4 hours of applying the patch.[446] The slow onset can be overcome by applying the patch the night before surgery. Used in this way, the incidence of nausea and vomiting was reduced from 62.5% and 37.5% to 20.8% and 8.3%, respectively, compared to placebo after gynecologic laparoscopy.[447] In the United States, clinicians apply the patch preoperatively, knowing that onset of PDNV efficacy will be in the early recovery period for shorter surgery.[445] Adverse effects, particularly dry mouth but also somnolence, dizziness, and blurred vision, are relatively common but generally described as mild.[445,447]

Serotonin 5-HT3 Receptor Antagonists

The 5-HT_3 antagonists have played a substantial role in the management of PONV since their introduction in the 1980s, because of their relatively benign adverse reaction profile compared with those of the then available drugs. Their prophylactic use is more effective when given just before the end of surgery.[448] They are effective drugs for emetic rescue therapy, with ondansetron seeming to have a more preferential effect on vomiting (number needed to treat [NNT] = 4) rather than nausea (NNT = 7).[449] Although relatively well tolerated, their side-effect profile includes an increased risk for headache (number needed to harm [NNH] = 36) and elevated liver enzymes (NNH = 31).[449] All serotonin subtype 3 antagonists have also been associated with QT interval prolongation. More recently released serotonin 5-HT_3 receptor antagonists, such as dolasetron, granisetron, and palonosetron,[450] seem to exhibit similar characteristics with equal reduction of PONV rates in high-risk patients when used for prophylaxis, though the longer half-life of these drugs (8, 10, and 40 hours, respectively) may afford better protection against symptoms after discharge. In particular, palonosetron, by nature of its unique binding properties leading to internalization of the 5-HT_3 receptor[451] and a long half-life, may have a role in the management of postdischarge symptoms.[452] A large cost remains a significant barrier to use of the newer, nongeneric serotonin antagonists.

Steroids

Dexamethasone is an effective antiemetic at intravenous doses of 4 to 5 mg (depending on local formulation).[453]

This steroid may act centrally to either modulate the release of endorphins or inhibit prostaglandin synthesis. Given its delayed onset of action, dexamethasone should be administered as early as possible *after* induction of anesthesia.[454] Prophylactic dexamethasone is also effective in reducing postoperative pain and improving the quality of recovery,[169,170] although at somewhat higher doses (typically 8 mg) than those required for an antiemetic effect. The long-term side effect profile of this dose of dexamethasone has not yet been evaluated.

Neurokinin-1 Antagonists

The role of tachykinins in the emetic pathway was first elucidated by immunohistologic studies identifying substance P in the dorsal vagal complex of the ferret, an area of the brain deemed essential in the vomiting reflex.[455] Subsequent research identified the potential value of specific antagonists to the neurokinin-1 receptor, at which substance P and neurokinins A and B interact both centrally and peripherally in the gut to suppress vomiting. Aprepitant was the first commercially released drug of this class. A preoperative oral dose of 40 mg has efficacy similar to that of ondansetron for the reduction of nausea, with a potentially superior effect in the suppression of vomiting for 48 hours after administration.[456] An intravenous prodrug formulation, fosaprepitant, was more effective than ondansetron in preventing vomiting, but not nausea, and with no effect on complete response rates for PONV in small numbers of patients undergoing gynecological[457] or lower limb[458] surgery. A multicenter study evaluating the use of oral rolapitant,[459] a competitive NK-1 antagonist with an exceptionally long half-life of 180 hours, suggested similar effectiveness in comparison with placebo and ondansetron (administered at induction) with early control of symptoms, but use of rolapitant similarly seemed to confer prolonged protection from postoperative emetic symptoms. Rolapitant does not seem to have been further evaluated in PONV and cost remains a barrier for this class of drugs as well.

MANAGING PERSISTENT NAUSEA AND VOMITING

The presence of continuing symptoms after antiemetic rescue therapy requires further clinical review. Consideration should be given to alternative causes for these symptoms, particularly hydration status, covert hypovolemia, or early infection. Review of vital signs (temperature, pulse, and arterial blood pressure), allied with clinical examination to exclude an association with concomitant worsening of abdominal pain, potential septic foci, or urinary retention, is important to exclude more sinister causes, before consideration is given to symptomatic relief.

Administering 20 mL/kg of an isotonic electrolyte solution reduces the risk for nausea and dizziness after ambulatory surgery and volume repletion should be considered to attenuate continuing symptoms.[433,460] Ephedrine 0.5 mg/kg intramuscularly is effective for prophylaxis and treatment, with efficacy comparable to that of droperidol and sedation scores lower than placebo.[461] No value exists in prescribing a previously used antiemetic drug within 6 hours of previous administration,[428] but other second-line drugs may be considered should first-line management fail. These options include small-dose promethazine (6.25 mg); small-dose intravenous naloxone; propofol 20 mg; phenothiazines, including prochlorperazine, perphenazine, or a neurokinin antagonist. For patients who have not received prophylaxis, the 5-HT_3 antagonists are the preferred treatment of PONV and the class of drugs with best proven efficacy for treatment rather than prophylaxis.[428]

Special Areas

OFFICE-BASED PRACTICE

Office-based anesthesia is a form of ambulatory anesthesia that is rapidly expanding in North America and some parts of Europe. Arguably, the first ambulatory surgery center in the United States (the Downtown Anesthesia Clinic in Sioux City, Iowa) was an office-based practice.[2] Simple, minimally invasive surgical procedures have been performed in physicians' offices for many years, using either local anesthesia or sedation. There is now a growing involvement of anesthesiologists, especially as the complexity of office-based surgery increases.

Advantages of office-based surgery include improved convenience for the patient, but the primary driver has been more control over scheduling and the work environment for the surgeon. The potential exists for significant profit going directly to the surgeon, but in addition, the lower overhead costs in this setting result in significantly lower overall costs for the procedure. For example, the total cost of a laparoscopic inguinal hernia repair was three and a half times greater when performed in a hospital setting compared with an office facility.[462] The costs of open hernia repair[462] and various rhinology procedures[463] were approximately 2.5 times less when performed in the office. In the United States, office-based surgery covers a wide range of procedures.

However, legitimate concerns have been raised about the safety of office-based surgery. One comparative study showed a more than 10-fold increase in adverse incidents and deaths for procedures performed in a physician's office compared with an ambulatory surgical center.[464] These disasters are often the result of unqualified or untrained individuals administering sedation in unsuitable or unaccredited facilities.[464,465] Deep sedation appears to be a considerable risk factor. From the ASA closed claims database, 40% of the deaths resulting from MAC occurred during facial and eye surgery, which are commonly performed in the office setting.[327] Hypoxia and hypoventilation resulting from oversedation was the most common cause of death, with poor vigilance, inadequate monitoring, and delayed resuscitation contributing to the deaths, half of which were judged to be preventable.[327] The common perception that sedation is safer than general anesthesia is not supported by these data.

In the United States, the regulation of office facilities is the responsibility of individual states, with nearly 30 states having some degree of oversight as of 2014.[466] Regulation does appear to improve safety, because no deaths were reported in a series of more than 23,000 cases from a fully accredited office staffed by board-certified anesthesiologists and surgeons.[467] In addition, safety appears to be improving

BOX 72.2 A Summary of Office-Based Surgery Practice Guidelines Collated from US Regulatory Bodies

- Employment of appropriately trained and credentialed anesthesia personnel
- Availability of properly maintained anesthesia equipment appropriate to the anesthesia care being provided
- As complete documentation of the care provided as that required at other surgical sites
- Use of standard monitoring equipment according to the American Society of Anesthesiologists policies and guidelines
- Provision of a postanesthesia care unit or recovery area that is staffed by appropriately trained nursing personnel and provision of specific discharge instructions
- Availability of emergency equipment (e.g., airway equipment, cardiac resuscitation)
- Establishment of a written plan for emergency transport of patients to a site that provides more comprehensive care should an untoward event or complication occur that requires more extensive monitoring or overnight admission of the patient
- Maintenance and documentation of a quality assurance program
- Establishment of a continuing education program for physicians and other facility personnel
- Safety standards that cannot be jeopardized for patient convenience or cost savings

in parallel with greater regulation.[466] Guidance on office-based anesthesia is available from the ASA and SAMBA,[468] and comprehensive recommendations from other organizations and experts have been published. Typical recommendations for safe office-based anesthesia are summarized in Box 72.2. In essence, the office setting must adhere to the same standards of care required in a hospital-based or freestanding ambulatory surgery facility. Strong safety processes must be in place, because the isolated office-based environment means that outside help is not immediately available.

The selection of patients for office-based anesthesia should adhere to robust guidelines for safe anesthetic care. Because perioperative complications are harder to manage in an isolated environment, selection criteria may need to be more restrictive than those currently advocated for ambulatory surgery in the hospital setting.[46] The selection process must include a matrix of procedure invasiveness, patient complexity, and the capabilities and comfort levels of the facility and its personnel.[468] Preoperative preparation should be guided by the same clinical acumen and common sense that drives the decision-making process at freestanding surgery centers, with any coexisting diseases under good control. Anesthetic techniques suitable for office-based surgical procedures are similar to those used for hospital-based and freestanding ambulatory surgery procedures. MAC remains common, although clearly a great challenge exists in "the judicious and skillful use of MAC anesthesia to achieve adequate sedation and analgesia for increasingly invasive procedures."[469] Increasingly a move toward light general anesthesia is occurring—that is, using an LMA or facemask for airway management.[470,471] Propofol, sevoflurane, and desflurane are all suitable within the office setting, although an anesthesia machine is required to deliver volatile anesthetics. Standard equipment can be installed in frequently used offices, and portable equipment has been developed for less frequent use.[465] Fast-track recovery is the ideal with patients who are awake, alert, and able to transfer themselves from operating room table to a reclining chair, thus facilitating room turnover in approximately 10 minutes and home discharge within an hour of awakening.[465] It is important to minimize PDNV.[472] Recommendations have been made for other outcome measures that should routinely be audited after office-based anesthesia.[468,473] The American Medical Association and American College of Surgeons issued a set of Office-Based Surgery Core Principles to promote safety and quality of healthcare services for office procedures requiring sedation and anesthesia.[474]

In the United Kingdom, a similar practice of office-based anesthesia for dental procedures was in place for several decades. A series of anesthetic deaths in dental offices led to several reviews, culminating in recommendations that all anesthetics be administered by accredited anesthesiologists with specific training and experience in dental anesthesia, as well as recommendations regarding resuscitation equipment and the availability of drugs needed for emergency use.[475] Partly because of the high costs of equipment and maintenance, the net result was the movement of all anesthesia out of the dental office and back into the hospital environment.[476] Subsequently, office-based anesthesia has never developed in the United Kingdom. Minor surgery under local anesthesia is performed in some specially equipped primary care surgery centers, whereas the majority of procedures that are performed in offices in the United States are managed in hospital-affiliated day surgery units, procedure rooms, or surgical outpatient clinics in the United Kingdom.

ANESTHESIA IN REMOTE LOCATIONS

Many surgical conditions that formerly needed treatment in a hospital outpatient operating room are now being managed by interventional procedures done by nonsurgeon physicians in radiology, cardiology, and endoscopy (see also Chapter 73). In many cases, deep sedation or anesthesia is still required, meaning the anesthesiologist has to move into unfamiliar and often hazardous environments. The problems associated with these diverse locations are considered in detail in Chapter 73, but because many of the procedures are performed on an ambulatory basis or require anesthetic management according to all of the usual short-stay principles, a brief description is required here. The basic sedative and anesthetic techniques already described are suitable for most cases, but the conduct of anesthesia is likely to have to be modified according to the specific environment.

Administration of anesthesia or sedation at remote locations is associated with significant risk.[477] Some of these risks are specific to particular areas (Table 72.7) but commonly include an unfamiliar environment; small, cramped, or dark rooms; restricted patient access; inadequate or poorly trained support; restrictions on patient monitoring; and inadequate resources. An analysis of ASA closed claims arising from anesthesia care in remote locations revealed that adverse events had a higher probability of death than those arising in the operating room[478] and were primarily caused

TABLE 72.7 Some of the Hazards Associated With Anesthesia in Remote Environments

Area	Examples of specific hazards
Magnetic resonance imaging (MRI) scanner	Noise. Strong magnetic fields; no ferromagnetic equipment within scanner. Peculiarities of MRI-compatible equipment. Remote monitoring may introduce delays (e.g., capnography). Risk of induced currents causing burns in coiled cables. Compliance and dead space within extra-long breathing circuits
X-ray and interventional radiology	Radiation exposure; mobility limited by lead gowns. Often low light levels. Restricted access and unexpected movement of x-ray equipment. Patients may have significant comorbidities. Allergic reactions to contrast media. Limited patient access in CT scanner
Endoscopy suite	Dark environment, limited access. Patients may have significant comorbidities. Risk of hemodynamic disturbance with bowel preparation or vagal stimulation. Shared airway in upper endoscopy. ERCP performed in prone position with added hazards of radiology
General issues	Unfamiliar environment. Old or unfamiliar equipment. Emergency drugs and equipment may be rarely used or checked. Lack of dedicated or trained assistance. Scavenging may be difficult or absent

CT, Computed tomography; *ERCP*, endoscopic retrograde cholangiopancreatography.

by an adverse respiratory event (44%). MAC was the most common anesthetic technique, and respiratory depression secondary to oversedation accounted for over a third of the claims. Care that was substandard and preventable by better monitoring was implicated in the majority of claims associated with death.[478] In the United States, the CMS mandates that the chiefs of anesthesia services monitor and evaluate sedation practices throughout the hospital, and accrediting organizations, such as TJC and DNV, audit for compliance.

Home Readiness and Beyond

PATIENT INFORMATION

Before discharge, patients should receive postoperative instructions concerning aftercare, their transition to normal activities, and any requirements for follow-up. These instructions should be in writing[479] because retention of information is impaired during early recovery from anesthesia,[480] and ideally they should be repeated to the patient's escort. Besides general advice, discharge information should include the early warning signs for the main complications of the specific procedure the patient has undergone[479] and the action to take should these occur.

CRITERIA FOR DISCHARGE

Discharge of the patient after ambulatory surgery and anesthesia is a physician responsibility in the United States,[10]

BOX 72.3 Criteria for Facility Discharge Used at the Brigham and Women's Hospital, United States

Alert and oriented to time and place
Stable vital signs
Pain controlled by oral analgesia
Nausea or emesis mild, if present
No unexpected bleeding from operative site
Able to walk without dizziness
Patient has been given discharge instructions and prescriptions
Patient accepts readiness for discharge
Adult present to accompany patient home

Courtesy of B K Phillip.

fulfilled by physician-written discharge criteria (Box 72.3). Typically, patients should be oriented and comfortable with cardiovascular stability (including when standing) and problem-free wounds. Alternatively, discharge criteria may be incorporated into a scoring system, such as the Post-Anesthetic Discharge Scoring System.[481] Voiding urine is no longer considered an essential prerequisite for discharge in those at low risk for urinary retention, even after spinal anesthesia.[482] For patients at higher risk, the bladder volume should be assessed by ultrasound scanning[483] and the patient managed accordingly (Fig. 72.5). Actual discharge is frequently nurse-managed,[479,484] provided patients have been managed according to an appropriate protocol and have met all the necessary discharge criteria.

No rationale exists for a minimum observation period after ambulatory surgery in most cases, although patients clearly must be observed for a sufficient period to ensure cardiovascular stability. One possible exception is tonsillectomy, in which a minimum observation period of 6 to 8 hours has been advocated to detect most primary hemorrhages.[31] However, even this has been challenged, with a 4-hour observation period[485,486] or less[487] regarded as safe.

AFTERCARE AND FOLLOW-UP

Appropriate aftercare is one of the main safety features of ambulatory surgery. Acute complications may be related to anesthesia or surgery, and patients should receive careful predischarge education about what may occur for both. All patients should be provided with a 24-hour telephone number for emergency contact. This is often the ambulatory surgery unit during the daytime, but it may be necessary to provide another number or better still to automatically transfer calls when the unit closes at night.[479] In the United States, patients are also routinely given their surgeon's office and answering service number to contact directly for surgical issues. Although the United Kingdom healthcare system includes primary care doctors, they have limited experience in potentially life-threatening early postoperative complications and should not be called first. If the patient's call to the facility or physician does raise concerns, it is important that the patient be brought back for early surgical review; going to the emergency department also can introduce unnecessary delay. Because the ambulatory patient is self-caring and likely to mobilize early, symptoms of surgical complications are noticed and reported sooner

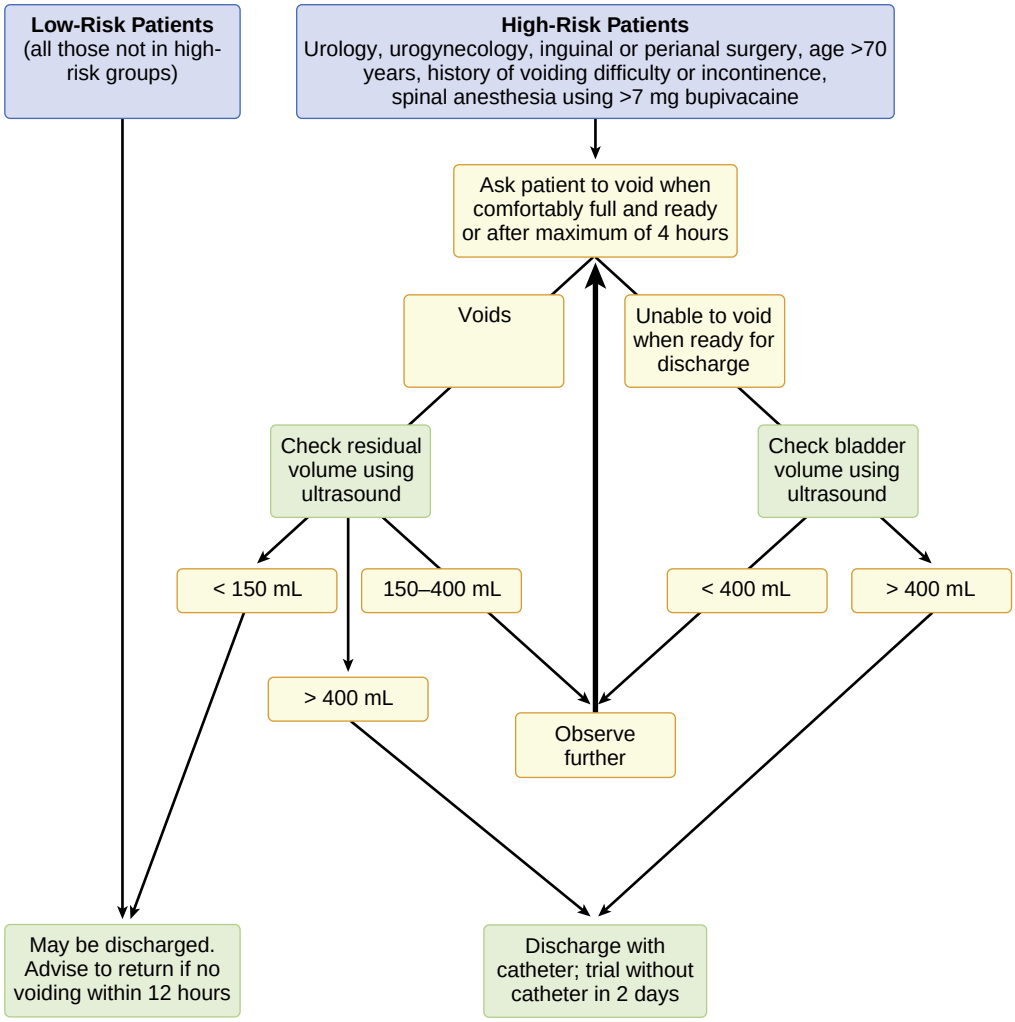

Fig. 72.5 Flowchart illustrating the management of patients who fail to void urine after ambulatory surgery. (Reproduced from British Association of Day Surgery. Spinal anaesthesia for day surgery patients. London [available from http://www.bads.co.uk]; 2010. With permission.)

than if the patient were recovering in the hospital environment, allowing earlier detection and increased safety. Daily assessment of various recovery parameters at home using a smartphone-based app was popular with patients and also appeared to improve quality of recovery, probably by providing additional reassurance.[488] The system could also be used to request contact from a nurse and was found to be more cost-effective than other forms of postdischarge contact,[489] although others found a simple telephone call, which would be cheaper still, was similarly effective.[490]

Follow-Up and Outcome Measures

The ASA has developed a set of outcome indicators specifically for ambulatory and office-based surgery and anesthesia.[491] These include outcome events of interest for days 1, 14, and 30 and ongoing continuous quality indicators. The IAAS[492] has developed a series of indicators (Table 72.8) useful in the evaluation of the overall success of organizational performance, and these mirror the advice from other national specialist societies.[46,493] Lemos and Barros[494] further defined the value of outcome reporting in a range of domains subdivided into clinical, organizational, social, and economic factors that allows the reporting of both individual and institutional performance (Table 72.9). Return-mail questionnaires can be used for patient follow-up after ambulatory surgery to help identify common sequelae that ambulatory patients should realistically expect to experience.[391] No matter how data are collected, it is important that information from quality indicators is fed back in an effective way to individual clinicians and clinical units to support continuous improvement.[495]

Adverse Effects After Ambulatory Surgery

Minor adverse events are common after ambulatory surgery and anesthesia (86%).[391] Drowsiness is the most common effect persisting after discharge (62%), and aches and sore throat are common in intubated patients (47% and 49%, respectively). Headache (25%) and dizziness (20%) also occur, but nausea and vomiting after discharge are less common (17% and 7%, respectively). Patients may take 2 to 3 days before they are able to resume their usual activities.[391] Information about these known side effects should be incorporated into the preoperative patient education and, in the United States, may be incorporated in a separate consent for anesthesia.

TABLE 72.8 Outcome Indicators for Ambulatory Surgery Suggested by the International Association for Ambulatory Surgery

Indicator	Reason
Failure to attend the ambulatory surgery center/unit	Acute medical condition Decision of the patient Organizational reasons Other reason (explain...)
Cancellation of the booked procedure after arrival at the ambulatory surgery center/unit	Pre-existing medical condition Acute medical condition Organizational reasons Other reason (explain...)
Unplanned return to the operating room on the same day	
Unplanned overnight admission	Surgical reasons Anesthetic or medical reasons Social or administrative reasons
Unplanned return of the patient to an ambulatory surgery unit or hospital	<24 h >24 h and < 28 days
Unplanned readmission of the patient to an ambulatory surgery unit or hospital	<24 h >24 h and < 28 days

TABLE 72.9 Outcome Measures in Ambulatory Surgery

Category	Specific Outcome Measures
Clinical	Perioperative cardiovascular and respiratory adverse events Minor postoperative morbidity: pain nausea and vomiting other: sore throat, headache, drowsiness Unplanned return to the operating room on the same day of surgery Unplanned overnight admission Unplanned return or admission to the day surgery unit or hospital: <24 h >24 h and < 28 days
Organizational	Proportion of elective surgery performed as day case Accessibility to ambulatory surgery programs: number of different procedures included Cancellation of booked procedures failure to arrive at the ambulatory surgery unit (ASU) Cancellation after arrival at the ASU
Social	Patient satisfaction Functional health status and quality of life
Economic	Efficiency rate of operating room utilization

ASU, Ambulatory surgery unit.

Reproduced from Lemos P, Barros F. Outcome measures. In: Smith I, McWhinnie D, Jackson I, eds. *Day Case Surgery*. London: Oxford University Press; 2012:335–344. With permission.

Acute cardiovascular events (hypertension and hypotension, dysrhythmias, cardiac ischemia, and arrest) occur with an overall frequency of 2.9%, with greater risk in patients with preexisting cardiovascular morbidity; respiratory events (hypoxemia, laryngospasm, bronchospasm, aspiration, pulmonary edema, and pneumothorax) occurred in 0.1% of the study population, with increased risk in smokers, asthmatics, and the obese.[57] Unanticipated overnight admission has a worldwide reported incidence of between 1% and 6%. Caution is required in the use of this indicator as a standard to achieve, however, unless the reasons for the admission are documented. Although the indicator may provide evidence of inadequate preoperative assessment and patient optimization, differences in surgical case mix and complexity may explain any variation across institutions. Ultraconservative selection criteria could result in an extremely low overnight admission rate and inappropriately give the impression of a highly performing unit rather than one that was excessively cautious with patient selection. Cross comparison of this indicator with rates of ambulatory care as a proportion of all elective surgery, either by specialty or specific operation, could assist with interpretation.

Patient Satisfaction With Ambulatory Surgery

Patient satisfaction is a difficult metric to define, depending somewhat on the patient's expectation of care. Nevertheless, patient satisfaction is generally very high after ambulatory surgery. The patient experience was improved when facility staff was thought to be friendly and the surgeons discussed findings before discharge,[496] and these factors were perceived by postoperative ambulatory surgery patients as being more important than management of postoperative pain, starting the intravenous line smoothly, and avoidance of delays. Others have found that provision of accurate information about the expected perioperative process is important; other factors that lead to higher satisfaction are effective postoperative analgesia, minimal emetic sequelae, staff courtesy and privacy in the unit, short waiting times before surgery, no perception of being rushed, postoperative telephone contact, and naturally, good surgical outcome.[492]

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73 Non-Operating Room Anesthesia

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KEY POINTS

- The non-operating room arena represents an expansion of the traditional environment for anesthesia practice with significant implications for patients and providers. As technology advances and patient acuity increases, non-operating room anesthesia (NORA) cases have become more demanding in terms of both patient management and required resources and support services.
- Financial and operational constraints create additional challenges. Significant differences in practice result from the fact that NORA cases occur in places remote from the operating room (OR) and are performed frequently by medical proceduralists who are less familiar with the scope and clinical issues related to the practice of anesthesiology. In addition, anesthesiologists may be less familiar with the demands of providing an anesthetic in an environment outside of the OR and, in some cases, in which the proposed procedure and needed equipment restrict mobility and access to patients or where radiation exposure or other risks pose other challenges.
- This chapter serves as a general guide to the key principles of anesthetic management associated with procedures performed outside of the OR, and highlights some of the adaptations, both cultural and practical, that must be addressed in order to provide safe and optimal care that meets the need of the providers and patients.

Overview: Defining Non-Operating Room Anesthesia—What It Is and How We Got Here

Non-operating room anesthesia (NORA) refers to all procedures performed in locations other than the operating room (OR) and includes diverse environments and procedures, often associated with challenges not regularly confronted for procedures performed in the OR. Historically, cases managed outside of the OR were minor, infrequent, and involved relatively stable patients with limited comorbidities. They seldom required involvement of an anesthesia provider; more commonly sedation, if needed, was provided by a nurse supervised by the proceduralist. Over the past 2 to 3 decades, NORA cases have expanded considerably, now involving care provided by every medical specialty and, for many hospitals, accounting for increasing volume and revenue equivalent to that of the OR. Most important for the anesthesiologists is that the NORA cases are now often as demanding as the most advanced surgical OR procedures. They constitute a major expansion of our practice perimeter and require the same, if not more, planning and attention to operational efficiency as is required for cases performed in the OR.

In the United States, the number of NORA cases has continued to climb over the past decade. The percentage of cases increased from 28% to 36% from 2010 to 2014 alone.[1] This continued escalation of NORA procedures now requiring the care of an anesthesia provider is based on rapid technologic developments and innovations that have expanded the array of possible procedures ranging from simple same-day procedures to complex cardiac procedures that necessitate postprocedure monitoring and care in the intensive care unit. Anesthesiology support is also required because patients with underlying medical conditions and increasing age are now being offered procedures that were previously unavailable to them. As a result, an increasing number of patients undergoing NORA procedures are older and more likely to be classified as having American Society of Anesthesiologists (ASA) class III-V physical status as compared with patients undergoing procedures in the OR.[1] In fact, many NORA cases are performed on patients deemed "high risk for surgery," including patients who in the past would not have been considered candidates for any medical intervention. Although some of these "minimally invasive" procedures are considered to be lower risk for the patient, the anesthetic issues are often very complex with significant potential for physiologic changes that require intensive management.

The increase in procedures performed outside of the OR has been accompanied by increasing oversight related to the safety of anesthesia in remote locations. An analysis of the ASA Closed Claims database found that remote location claims demonstrated a higher proportion of claims for death compared with OR claims (54% vs. 29%) and involved older and sicker patients. Fifty percent of remote location claims involved monitored anesthesia care—a reflection of the importance of close monitoring and management of patients by a skilled anesthesia provider who is able to transition the management to include initiation of general anesthesia or other interventions to address complex clinical issues.