During the last two decades a profound change has taken place in the way elective surgery is practiced. At present, the majority of surgical operations in the United States are performed as ambulatory surgery. This practice has increased fourfold over the last 20 years [1]. After initial hesitation, suddenly the public has overwhelmingly accepted this form of surgery for “minor” operations. At first, their acceptance was a result of pressure from third-party payers (insurance companies) as a cost-containment measure. But now both patients and their families have discovered that avoiding the hassle of hospital admission is more convenient, plus there are many advantages to recovering at home.

In the ambulatory surgical environment, patient expectations have also dramatically changed. No longer will patients accept the variable period of postoperative recuperation in a hospital bed, or the “inevitable” side effects such as pain, nausea and vomiting, malaise, light-headedness, and other complications. Since patients are generally in good health and the operation is short, patients expect a quick and complete postoperative recovery with minimal side effects from anesthesia and surgery. At present, patients expect to arrive in the ambulatory surgery facility in the morning, have the operation after minimal waiting and quick preparation (no more than 1 hour), spend a maximum of 2 to 3 hours recovering in the postanesthesia care unit (PACU; phases I and II), be escorted home, rest at home for a day or two, and then resume normal activities. Any deviation from these expectations is considered less than ideal.

A variety of technological advances (e.g., new endoscopic procedures, laser resections, extracorporeal shock wave surgery) have allowed surgeons to respond to these new expectations by simplifying surgical procedures. Anesthesiologists have also responded to the challenge, which has involved changing old attitudes toward the so-called “minor” postanesthetic side effects that used to be considered “inevitable,” changing the way some of
the older anesthetic agents are used to make them appropriate for shorter procedures, and enthusiastically incorporating the newer shorter-acting anesthetic and adjuvant drugs into their clinical practices.

### Advantages and Components of General Anesthesia

Although various forms of anesthesia are practiced for ambulatory surgery, general anesthesia remains the most common form for many of these operations. Both surgeons and patients prefer general anesthesia, and recent advances have made it much safer and more predictable. Today, recovery from general anesthesia is rapid and associated with fewer postoperative side effects.

Typical general anesthetic care for ambulatory surgery should include:

**Psychological and pharmacological preparation**

**Rapid and predictable induction of anesthesia**

**Smooth and reliable maintenance of anesthesia to ensure:**
- Hypnosis (or unconsciousness)
- Amnesia (or lack of recall)
- Surgical analgesia
- Cardiovascular stability
- Excellent surgical conditions including muscle relaxation
- Prompt and complete recovery of mental faculties and the physical capability to return home safely
- Minimum postoperative side effects (e.g., nausea, vomiting, dizziness, pain)
- Prompt return to normal activities

### Psychological and Pharmacological Preparation

The keys to successful ambulatory surgery include (1) proper selection of patient and procedure, (2) psychological and pharmacological preparations, (3) excellent perioperative anesthetic care, and (4) careful follow-up after discharge from the ambulatory facility. Selection of patients and procedures as well as psychological and pharmacological preparations are discussed in other chapters in this issue.

Since the patient is not admitted to the hospital the day before the operation, the traditional preanesthetic visit by the anesthesiologist is no longer possible. As a consequence, development of an essential “physician—patient relationship” and rapport has become more challenging for the outpatient anesthesiologist [2]. Establishment of preanesthesia clinics and telephone interviews have proved very helpful, but the final meeting between the patient and the physician on the day of the operation has become extremely important in establishing the relationship. Every patient needs psychological preparation and support. Although these supports are provided in part by other health-care professionals like the nurse and the surgeon, ultimately such support must come from the anesthesiologist. Though some patients with appropriate psychological preparation do not need a pharmacological (anxiolytic) premedicant, many others do [3]. In anxious outpatients, anxiolytic premedicants should not be withheld, because short-acting water-soluble benzodiazepines like midazolam, or short-acting opioid analgesics like fentanyl or sufentanil, provide excellent preoperative anxiolysis with little residual effect after the operation [4, 5]. Apart from the anxiolytic premedicants, some patients may also need prophylaxis against acid aspiration and postoperative nausea and vomiting.

### Essential Intraoperative Monitoring

Ambulatory surgical candidates deserve and require the same standard of perioperative monitoring and anesthetic equipment as inpatients. In the United States, essential perioperative monitoring is guided by the published standards of American Society of Anesthesiologists [6]. Thus, standard perioperative monitoring should include the continuous presence of trained anesthesia personnel who will make continual assessments of oxygenation, ventilation, circulation, and (when necessary) temperature. In addition to the clinical assessments (i.e., observation of color, chest movements, auscultation of breath sounds and heart sounds), the standard of care should also include pulse oximetry, capnography, noninvasive automated blood pressure monitoring, electrocardiography, oxygen analysis, a disconnect alarm, and the availability of thermometry.

### Induction of Anesthesia

**Intravenous Induction**

In adults, unless there is a reason for not doing so, the induction of anesthesia is invariably accomplished intravenously. Advantages of intravenous induction include quick, smooth and reliable induction of anesthesia with minimum respiratory or cardiovascular complications, or other adverse effects [7]. The pharmacokinetic profile and doses of various intravenous induction agents are shown in Table 1.

**Thiopental, Thiamylal, and Methohexital** The thiobarbiturates, sodium thiopental and thiamylal, continue to be the gold standards for intravenous induction of anesthesia because of their predictable ability to induce anesthesia in one arm/brain circulation time [8]. The pharmacokinetic
profile of these two drugs (see Table 1) makes them undesirable for brief ambulatory anesthesia, however, and their use has declined. Awakening time after a small single dose of thiopental is rapid, due to the initial redistribution of the drug from the vessel-rich organs to lean muscle and fat. Thiopental is metabolized and eliminated very slowly (elimination half-life, 10 to 12 hours). Studies have demonstrated residual psychomotor impairment 8 hours after a single dose of a thiobarbiturate. This is not only because the metabolism of the thiobarbiturates is very slow, but also because their metabolic products have significant sedative properties. It is especially unwise to administer them in large or repeated doses. Other disadvantages of the thiobarbiturates are their transient cardiovascular and respiratory depression.

Methohexital, a methoxybarbiturate, has a shorter elimination half-life and is therefore cleared more quickly from the body, providing a slight advantage over thiopental. Methohexital’s other side effects, however (e.g., myoclonus, coughing, hiccuping) during anesthesia may make it less satisfactory than other available drugs for ambulatory anesthesia. Cardiovascular and respiratory depression also occur after methohexital, similar to thiopental.

### Table 1. Pharmacokinetic Profiles of Drugs Used for Intravenous Induction of General Anesthesia

<table>
<thead>
<tr>
<th>Drug</th>
<th>Induction Dose (mg/kg)</th>
<th>Half-life (min)</th>
<th>Distribution Half-life (min)</th>
<th>Clearance (ml/min)</th>
<th>Protein Binding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiopental</td>
<td>3.0–6.0</td>
<td>2–4</td>
<td>5–6</td>
<td>10–12</td>
<td>83</td>
</tr>
<tr>
<td>Methohexital</td>
<td>1.0–2.0</td>
<td>2–4</td>
<td>2–4</td>
<td>2–3</td>
<td>3</td>
</tr>
<tr>
<td>Etomidate</td>
<td>0.2–0.4</td>
<td>2–4</td>
<td>11–17</td>
<td>2–8</td>
<td>71</td>
</tr>
<tr>
<td>Ketamine</td>
<td>0.75–1.5</td>
<td>2–4</td>
<td>7–15</td>
<td>1400–2800</td>
<td>97</td>
</tr>
<tr>
<td>Midazolam</td>
<td>0.1–0.2</td>
<td>2–4</td>
<td>1400–2800</td>
<td>97</td>
<td></td>
</tr>
</tbody>
</table>

Lower doses are recommended when these drugs are used in combination with narcotic anesthetics and when administered to geriatric or compromised patients.

**Etomidate**  
Etomidate, a carboxylated imidazole, produces rapid induction of anesthesia with minimum depression of the cardiovascular system [9]. Its rapid redistribution and rapid hepatic metabolism secondary to hydrolysis to inactive metabolites account for its short action and quick recovery time. Although recovery is fast, etomidate has several disadvantages. Intravenous injection of etomidate causes pain at the injection site as well as myoclonus, effects similar to methohexital. Furthermore, there is a high incidence of postoperative venous thrombosis at the site of injection. There is also a high incidence of nausea and vomiting after etomidate, which can delay discharge from the ambulatory facility. The other unique disadvantage of etomidate is its ability to suppress adrenocortical function, especially after its use by continuous infusion [10]. Thus, etomidate is not a widely used induction agent for ambulatory anesthesia, except in cardiovascular-compromised patients.

**Propofol**  
Propofol, a substituted isopropyl phenol, is currently the most common induction agent for adult ambulatory anesthesia [11]. It is insoluble in water and is therefore supplied in an emulsion form in soybean oil, egg phosphatide, and glycerol. When injected intravenously, propofol causes prompt, smooth, and reliable induction of anesthesia. The anesthetic effect is quickly terminated by rapid redistribution. In addition, its rapid hepatic metabolism into inactive products, and resultant high clearance rate, results in a “clear-headed” arousal with a nominal hangover effect [12]. Psychomotor function also returns to baseline quickly.
Another notable advantage of propofol is its antiemetic property [13]. The incidence of postoperative nausea and vomiting (PONV) after propofol anesthesia is low, even after operations that are known to be associated with a high incidence of PONV (e.g., laparoscopy, termination of pregnancy, strabismus surgery, tonsillectomy). The antiemetic effect is most noticeable when propofol is used for both induction and maintenance of anesthesia. However, significant reduction of postoperative nausea has been achieved even after a single induction dose, compared to an equivalent dose of thiopental. Thus, the patient usually awakens alert and feeling well after the operation. The rapid recovery and low incidence of PONV after propofol anesthesia may translate into cost savings. The PACU nurse is able to handle the patient more easily during the immediate postoperative period (fewer airway and respiratory problems), and the patient can be discharged from the PACU (both phases I and II) earlier than with most other types of general anesthesia.

Propofol does have some disadvantages. When injected intravenously, especially in a small vein, the patient may experience significant pain. This can be minimized if lidocaine, 20-40 mg, is injected in the same vein just prior to the injection of propofol. Some anesthesiologists prefer to add the lidocaine to the same syringe as propofol. Like thiopental, propofol also causes transient cardiac and respiratory depression. These effects are often observed when propofol is rapidly injected as a bolus dose and are exaggerated in hypovolemic and elderly patients. The cardiorespiratory depressant effects can be minimized by correcting hypovolemia before induction (i.e., volume loading), by choosing a smaller induction dose (e.g., 1.5 mg/kg), and by injecting the induction dose more slowly. For example, injecting the induction dose of propofol in a continuous infusion via a syringe pump (e.g., 600 µg/kg/min) until the patient falls asleep will minimize the cardiorespiratory side effects.

Midazolam and Ketamine Neither midazolam nor ketamine is commonly used as an induction agent for ambulatory anesthesia [14]. Onset of anesthesia with these agents is slow (several minutes) and a rather high dose is needed to induce anesthesia. Although both midazolam and ketamine have reasonably short elimination half-lives, the high doses necessary for induction make them relatively long-acting [15, 16]. The clinical effects of these agents may extend well into the postoperative period after short ambulatory operations. The prolonged sedative and anterograde amnesic effects of midazolam [17] and the psychotomimetic effects (illusions, delirium) of ketamine [14] during the postoperative period make these agents unsuitable for routine induction of ambulatory anesthesia.

The sedative and amnesic effects of midazolam can be reversed with the specific benzodiazepine receptor antagonist flumazenil [18]. The initial dose of flumazenil is 0.2 mg, titrated in 0.2-mg increments every minute until a total dosage of 1.0 mg is given, or until the sedation is adequately reversed. The half-life of flumazenil, however, is shorter than that of midazolam, and resedation is a potential problem in the ambulatory setting.

Inhalation Induction

It is very rare to induce anesthesia in adults by an inhalation method, because intravenously induced anesthesia is quicker and more pleasant for the patient and more easily managed by the anesthesiologist. For intravenous induction, however, intravenous access is needed and sometimes difficult to obtain, even in adults. In those patients, it may be preferable to perform inhalation induction rather than persisting with innumerable attempts to attain venous access.

The ideal characteristics that make an inhaled agent useful for inhalation induction are: (1) low blood-gas solubility, (2) pleasant smell, (3) nonirritating to the airway, and (4) high potency. No currently available inhaled agent possesses all of these properties [19].

Nitrous oxide has a very low blood-gas solubility (0.47), is pleasant to inhale, and is nonirritating to the airway, but has a very low potency (MAC, 105%). Halothane has a pleasant smell, is nonirritating, and is fairly potent (MAC, 0.75%); however, its blood-gas solubility is high (2.5). Isoflurane and enfurane have a lower blood-gas solubility (1.2 and 1.6, respectively), but are somewhat irritating to the airway. The newest volatile agent, desflurane, initially appeared to be an ideal agent because of its very low blood-gas solubility (0.42). Desflurane, however, has been a disappointment as an induction agent because it is highly irritating to the airway; it also has a low potency (MAC, 6-7%). Sevoflurane, an investigational agent, has a low blood-gas solubility (0.7), is nonirritating, and has a fairly high potency (MAC, 1.6%). Thus sevoflurane, if approved, could be an excellent agent for inhalation induction.

At present, however, halothane, enfurane, or isoflurane (in that order) seem to best fulfill the requirements for inhalation induction. A single vital capacity breath with up to 5 MAC of inhaled anesthetic in oxygen is a novel way to perform rapid inhalation induction. Taking advantage of the “second gas effect” phenomenon by mixing nitrous oxide to the inspired mixture makes inhalation induction smoother and quicker. Characteristics of commonly used inhaled anesthetics are summarized in Table 2.

Maintenance of Anesthesia

Inhalation Method

About 20 years ago, when ambulatory surgery was a novelty, general anesthesia for ambulatory surgery was provided entirely by an inhalation method. Use of opioid analgesics and muscle relaxants (and endotracheal
tubes) was thought to be inappropriate. Although some minor ambulatory operations such as a D&C or cone biopsy can be easily performed using only inhalation anesthetics, the so-called “balanced anesthesia” has become the technique of choice for most ambulatory operations.

**Total Intravenous Anesthesia**

The concept of total intravenous anesthesia (TIVA)—that is, providing anesthesia exclusively by intravenous agents—is not new. Concern about the harmful effects of the trace concentrations of the inhaled anesthetics in the environment (waste gases) provided the initial incentive for developing TIVA as a viable clinical entity. In principle, complete and reliable anesthesia can be provided entirely by intravenous agents [20, 21]. The three major components of general anesthesia (i.e., hypnosis, analgesia, and muscle relaxation) can be provided by specific intravenous agents. However, the method was not practical until short-acting intravenous anesthetic agents with high clearance and few side effects (e.g., propofol) and a practical and simple syringe pump delivery system were developed [22]. The concept was further advanced when short-acting, rapidly metabolized opioid analogues (e.g., alfentanil and remifentanil) and intermediate and short-acting noncumulative muscle relaxants (e.g., atracurium, vecuronium, mivacurium) became available. Long-acting drugs that have low clearance rates and are cumulative should not be used for continuous infusion. In the near future, computer-driven infusion pumps that can deliver intravenous agents to achieve a constant targeted plasma concentration will be commercially available, making TIVA even easier to use in clinical practice [23, 24].

In practice, a short-acting intravenous anesthetic agent like propofol and a short-acting opioid like alfentanil (or remifentanil) are continuously infused at variable rates to achieve and maintain a constant and predictable clinical effect. Infusion schemes for intravenous anesthetic agents are summarized in Table 3. Muscle relaxation, if necessary, is provided either with a third infusion of a muscle relaxant or by incremental intravenous boluses.

The variability in patient responses, lack of a reliable method to monitor the depth of anesthesia, and concern about awareness during anesthesia remain the primary reasons why TIVA has not been more widely accepted by anesthesiologists. Although many anesthesiologists adhere to a part of the TIVA principle by providing anesthesia by continuous infusion of intravenous anesthetics (with or without opioids and muscle relaxants), they add nitrous oxide in the inhaled mixture to prevent awareness. For situations such as endoscopic procedures of the airway, where an inhalation anesthetic cannot be delivered easily, TIVA may be the best alternative. In such situations, the addition of an amnestic agent like midazolam is advisable to prevent awareness [14].
Table 3. Infusion Schemes for Anesthesia, Sedation, or Analgesia*

<table>
<thead>
<tr>
<th>Drug</th>
<th>Anesthesia Loading Dose (µg/kg)</th>
<th>Anesthesia Maintenance Infusion (µg/kg/min)</th>
<th>Sedation or Analgesia Loading Dose (µg/kg)</th>
<th>Sedation or Analgesia Maintenance Infusion (µg/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analgesics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfentanil</td>
<td>50–150</td>
<td>0.5–3.0</td>
<td>10–25</td>
<td>0.25–1.0</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>5–15</td>
<td>0.03–0.1</td>
<td>1–3</td>
<td>0.01–0.03</td>
</tr>
<tr>
<td>Sufentanil</td>
<td>1–3</td>
<td>0.01–0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypnotics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ketamine</td>
<td>1500–2500</td>
<td>25–75</td>
<td>500–1000</td>
<td>10–20</td>
</tr>
<tr>
<td>Propofol</td>
<td>1000–2500</td>
<td>50–150</td>
<td>250–1000</td>
<td>10–50</td>
</tr>
<tr>
<td>Midazolam</td>
<td>50–150</td>
<td>0.25–1.5</td>
<td>25–100</td>
<td>0.25–1.0</td>
</tr>
<tr>
<td>Methohexitol</td>
<td>1500–2500</td>
<td>50–150</td>
<td>250–1000</td>
<td>10–50</td>
</tr>
</tbody>
</table>

*After the loading dose, a high infusion rate should be used initially to compensate for distribution to peripheral tissues. The infusion rate should then be titrated to the lowest infusion rate that will maintain the desired end point.


Balanced Anesthesia

Balanced anesthesia remains the most common form of general anesthesia for ambulatory surgery. After induction of anesthesia with an intravenous agent, anesthesia is maintained with a combination of a variety of agents to achieve the anesthetic state that will provide hypnosis, amnesia, analgesia, muscle relaxation, and hemodynamic stability. The classes of agents used in this method are inhaled anesthetics, intravenous anesthetics, opioid analgesics, muscle relaxants, and adjuvants. Each component will be discussed separately.

Inhaled Anesthetics in Balanced Anesthesia

Since the days of ether, anesthesiologists have depended on inhaled anesthetics to provide basic anesthesia. Conceptually, a medication (inhaled anesthetic) can be administered via the lungs to achieve a required central nervous system effect (anesthesia). Over the years, we have learned that the ideal inhaled anesthetic, especially for ambulatory surgery [25], should:

1. have low blood-gas solubility for quick onset and offset,
2. be stable in vitro, and not degradable in various environments (e.g., soda lime) to avoid inhalation of toxic degradation products,
3. be inert in vivo, and not metabolized, to minimize potential for organ toxicity,
4. be potent, so that enough oxygen can be provided with it,
5. be nonflammable and nonexplosive in the presence of oxygen, air, or nitrous oxide,
6. not cause arrhythmias even in the presence of catecholamines,
7. cause no organ toxicity,
8. not depress cardiorespiratory systems, and
9. have a saturated vapor pressure (SVP) between 150 and 400 mm Hg, so that dispensing from a vaporizer is not complicated.

Obviously, such an ideal inhaled anesthetic does not exist. The characteristics of selected inhaled anesthetics are given in Table 2 for comparison purposes. Brief discussions of these commonly used inhaled anesthetics for ambulatory anesthesia follow.

Halothane, Enflurane, and Isoflurane At present, isoflurane, with its low blood-gas solubility (1.4) and minimal potential for metabolism and organ toxicity, remains the most common volatile anesthetic agent for ambulatory anesthesia [25]. Enflurane, with a blood-gas solubility of 1.8, is preferred by some anesthesiologists because it appears to cause less tachycardia intraoperatively and less respiratory irritability like coughing, salivation, and laryngospasm at emergence. Halothane is rarely used in adults for maintenance of anesthesia, because of concerns about hepatotoxicity, a higher incidence of ventricular arrhythmias, and its relatively high blood-gas solubility. These characteristics make recovery from halothane anesthesia slower, especially in obese patients.

Desflurane Desflurane, a fluorinated methyl-ethyl ether, recently gained approval by the Food and Drug Administration [26]. Its unusually low blood-gas solubility (0.42) is less than that of nitrous oxide (0.47). This characteristic of desflurane should make the onset and offset of anesthesia extremely fast, and also allows quick intraoperative alteration of the depth of anesthesia. Desflurane is practically inert both in vitro and in vivo, reducing the potential for organ toxicity. These attributes may appear to make desflurane an ideal inhaled anesthetic for ambulatory anesthesia; however, the initial enthusiasm for desflurane has been somewhat tempered by some of its side effects. As noted earlier, desflurane has a pungent smell and produces severe irritation of the respiratory tract (coughing, salivation, laryngospasm) during inhalation induction. The same problem, to a lesser extent, is also present as the patient emerges from desflurane anesthesia [27]. Other disadvantages include its low boiling point (23°C) and high saturated vapor pressure (669 mm Hg), which make storage and dispensing of the agent somewhat complicated. A special heated vaporizer is needed to dispense desflurane. In addition, storage in hot climates can be difficult. Other problems with desflurane include an increased incidence of PONV compared to propofol, especially when used with nitrous oxide; transient tachycardia, when used in high concentrations or when the inspired concentration is quickly increased; and its relatively low potency (MAC, 6%), which makes it less cost-effective. Cardiovascular depression
after desflurane is similar to that of isoflurane. In spite of some of these problems, desflurane is likely to become an important anesthetic agent for maintenance of anesthesia in the ambulatory setting.

Sevoflurane  The other "newer" volatile anesthetic agent, sevoflurane, is a fluorinated methyl-isopropyl ether [26]. It is currently undergoing clinical trial in the United States. Like desflurane, it has a low blood-gas partition coefficient (0.7). Unlike desflurane, however, it is not pungent and does not cause airway irritability. So, not only is sevoflurane's onset and early recovery likely to be fast, but airway irritability during induction and emergence is minimal. These characteristics of sevoflurane are going to be good news for pediatric ambulatory anesthesia, where inhalation induction is the norm. Unfortunately, sevoflurane is not as stable as desflurane. There is significant degradation of sevoflurane in the presence of soda lime and significant biodegradation in the body [28]. Fortunately, the in vitro degradation products do not appear to be toxic.

Nitrous Oxide  For almost 150 years nitrous oxide has been used as a supplement to anesthesia. Even today, it is the most common inhalation anesthetic for general anesthesia. Nitrous oxide's continuing popularity is due to: (1) its very low blood-gas solubility (0.47), (2) its amnestic and analgesic effects, which reduce the MAC of expensive volatile anesthetics and reduce the need for costly opioid analgesics, (3) its benign effect on the cardiovascular and respiratory systems, (4) its relative inertness, and no significant organ toxicity, especially after short-term usage, and (5) its low cost.

When used in conjunction with intravenous anesthetics like propofol, nitrous oxide reduces the chance of awareness without prolonging the recovery time. On the other hand, nitrous oxide is not without controversies [29]. The primary controversy about its use has to do with its alleged ability to increase the incidence of PONV. Even after a large number of published reports, some confirming and some refuting the claim, this controversy still persists [30]. It would appear that in certain circumstances, especially when used with narcotics, nitrous oxide can increase the incidence of PONV. Its potential advantages, however, outweigh any possible unproven disadvantages. Thus there is no reason to abandon nitrous oxide from the practice of ambulatory anesthesia.

Intravenous Anesthetics for Maintenance of General Anesthesia

As discussed earlier, until recently there was no noncumulative anesthetic agent with minimal side effects for use in continuous infusion for maintenance of anesthesia. The introduction of propofol and the simultaneous availability of simple and practical syringe pumps have changed all that. In fact, continuous infusion of propofol has become a very common method for the maintenance of anesthesia for ambulatory surgery. Infusion schemes of different intravenous anesthetics, sedatives, and analgesics are listed in Table 3.

Propofol Infusion  Because propofol is a fast-acting anesthetic with a short elimination half-life and a very high clearance (noncumulative), it is an ideal agent for continuous infusion [22]. Results of several pharmaco-kinetic studies, as well as clinical experience, show that a continuous infusion should be started at variable rates, with a simultaneous initial loading dose of 1.5–2.5 mg/kg. The usual initial infusion rate is 200 µg/kg/min, reduced 10 to 15 minutes later to 150 µg/kg/min, and subsequently reduced to a maintenance dose of 100 µg/kg/min [12].

One innovative way to administer propofol is to give the loading dose via the same syringe pump at a rate of approximately 600 µg/kg/min until the patient goes to sleep and then to turn the rate down to 100–200 µg/kg/min. When the loading dose is given slowly by continuous infusion via the syringe pump the hypotension and apnea associated with rapid bolus injections can be avoided. Because of individual variability, the rate may be readjusted throughout the operation depending on clinical signs of depth of anesthesia. Although awareness is unlikely at these dosing regimens, it is possible [31]. Awareness may occur in cases where there is unexpected and unrecognized pump failure, disruption of the intravenous line, or miscalculation of the dose. To avoid the possibility of awareness and to reduce the amount of intraoperative opioid usage, unless contraindicated, nitrous oxide should be routinely added at a concentration of 50 to 70% in the inspired mixture while using infusion of propofol for maintenance of anesthesia. Occasionally, this dosing regimen is not sufficient to maintain hemodynamic stability. In those situations, one should be careful not to overdose the patient with propofol or large doses of an opioid narcotic analgesic. If the patient is unconscious, it is appropriate to add a suitable adrenergic blocking agent intravenously, and where "light" anesthesia is suspected, a low dose of volatile anesthetic (isoflurane or desflurane) in the inspired mixture should be considered.

Of course, instead of using a continuous infusion technique, propofol can also be used for maintenance of anesthesia through small (20–40 mg) incremental boluses. However, this method is not recommended because it is cumbersome and, more importantly, it is likely to produce the so-called "peaks and valleys" in plasma (and brain) concentrations, resulting in a greater chance of intraoperative awareness.

Other Intravenous Anesthetics  Etomidate, midazolam, and ketamine can also be used for maintenance of continuous infusion anesthesia [32]. An infusion of midazolam (0.25–1.5 µg/kg/min), along with an infusion
of a short-acting narcotic, will provide good anesthetic conditions, but in reality it has no advantage over propofol infusion. Moreover, a midazolam/narcotic mixture is likely to prolong recovery time. Although both midazolam and mu agonists have specific antagonists (e.g., flumazenil and naloxone, respectively) this regimen makes them expensive. Because of its analgesic and dissociative effects, low-dose infusion of ketamine (10–20 μg/kg/min) may be used as an adjunct to other anesthetics like propofol or midazolam (see Table 3) [33].

**Intraoperative Analgesics**

Use of intraoperative analgesics constitutes a pivotal element of balanced anesthesia. Judicious use of intraoperative opioid/analgesics reduces the requirement of the anesthetics (volatile or intravenous), provides cardiovascular stability by suppressing sympathetic stimulations, and provides a more comfortable postoperative awakening when a sufficient plasma level of the analgesic is extended into the immediate postoperative period. Disadvantages of intraoperative opioid analgesics include chest wall rigidity, bradycardia, occasional hypotension, increased incidence of PONV, postoperative dizziness, drowsiness, and respiratory depression. Pharmacokinetic profiles of commonly used opioid analgesics are summarized in Table 4.

**Morphine and Meperidine** Morphine and meperidine, the slow- and long-acting mu-receptor agonist narcotic analgesics, are rarely used for ambulatory anesthesia. The incidence of opioid-induced side effects, especially PONV, drowsiness, dizziness, and constipation, are much higher with these agents than with their more potent, short-acting counterparts, like fentanyl derivatives.

**Fentanyl, Sufentanil, Alfentanil, and Remifentanil** The fentanyl compounds are synthetic mu-receptor agonists that are commonly used for ambulatory anesthesia [34]. They are much more potent and have faster onset of action and shorter duration of action than morphine and meperidine. Fentanyl is the prototype in this group, and is probably the most useful. It is about 100 times as potent as morphine. Although its plasma elimination half-life is similar to that of morphine (3–4 h), its clinical effect is much shorter, especially after an analgesic dose [35]. Fentanyl not only reduces the requirements of expensive volatile and intravenous anesthetics and provides intraoperative hemodynamic stability, but patients receiving intraoperative fentanyl awaken more comfortable. Fentanyl is also a generic compound that is relatively inexpensive. The recommended dose of fentanyl for intraoperative use for ambulatory surgery varies from 1 to 5 μg/kg, although rarely is a dose of more than 3 μg/kg required.

**Table 4. Pharmacokinetic Variables of Narcotic Analgesics Commonly Used in Ambulatory Anesthesia**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Relative Potency</th>
<th>Distribution Half-life (min)</th>
<th>Elimination Half-life (hr)</th>
<th>Clearance (ml/min)</th>
<th>VDSS (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphine</td>
<td>1</td>
<td>1–5 (rapid)</td>
<td>2–4</td>
<td>800–1400</td>
<td>200–250</td>
</tr>
<tr>
<td>Meperidine</td>
<td>0.1</td>
<td>4–17</td>
<td>3–4</td>
<td>700–1200</td>
<td>200–250</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>100</td>
<td>1–2 (rapid)</td>
<td>3–4</td>
<td>700–900</td>
<td>200–300</td>
</tr>
<tr>
<td>Sufentanil</td>
<td>700</td>
<td>1–3 (rapid)</td>
<td>2–4</td>
<td>600–900</td>
<td>140–200</td>
</tr>
<tr>
<td>Alfentanil</td>
<td>15</td>
<td>1–3</td>
<td>1–2</td>
<td>200–500</td>
<td>30–70</td>
</tr>
</tbody>
</table>

VDSS = volume of distribution/steady state.
Source: Adapted from reference 7.

Sufentanil is a structural analog of fentanyl, and is about 7 to 10 times more potent than fentanyl. Although its elimination half-life seems to be similar to that of fentanyl, its clearance is slightly larger, its onset of action is faster, and it has a shorter duration of action than an equivalent dose of fentanyl. Patients who receive sufentanil rather than fentanyl appear to be more alert, less drowsy, and less nauseated immediately after the operation. In a recent study [34] of the three fentanyl derivatives it was claimed that recovery after sufentanil infusion may be faster than fentanyl or alfentanil infusion. Sufentanil at a dose of 0.25–0.5 μg/kg may be sufficient for a short ambulatory procedure. If infusion is desired, an infusion rate of 0.2–0.5 μg/kg/hr is appropriate after a loading dose of 0.2–0.5 μg/kg.

Alfentanil is a less potent fentanyl derivative (potency about one-fifth of fentanyl) with a faster onset and shorter duration of action. Its faster action is related to its smaller volume of distribution, and its shorter elimination half-life (i.e., 1–2 hr) contributes to a shorter duration of action [36, 37]. The major disadvantages of alfentanil are a higher incidence of PONV and an analgesic effect that does not extend into the immediate postoperative period (due to its short duration of action). Consequently, another quick-acting analgesic must be provided to the patient for postoperative pain immediately upon awakening. Alfentanil is used either in small incremental doses or as a continuous infusion [38]. The initial and incremental doses depend on the duration of the operation. When used with propofol for a procedure lasting 30 to 40 minutes a single dose of alfentanil 50 μg/kg may be sufficient. Alternatively, especially for a longer procedure, after a loading dose of 10–20 μg/kg, an infusion of alfentanil 0.5–1.5 μg/kg/min, together with nitrous oxide, will enable good surgical conditions.

Remifentanil, a synthetic fentanyl analog, is an investigational ultra-short-acting mu-receptor opioid agonist that is currently undergoing clinical trial in the United States [39, 40]. Remifentanil is water soluble and is
rapidly metabolized by tissue esterases. The short action of remifentanil is related to its rapid metabolism. Because of its short duration of action and high clearance it is best delivered in a continuous infusion at an infusion rate titrated to the desired effect. Because of its ultra-short-acting effects, patients may wake up with considerable postoperative pain unless the infusion is gradually tapered in the PACU, while administering other longer-acting analgesics.

**Agonist–Antagonists and Partial Agonists** Several agonist–antagonist or partial agonist analgesics are on the market. They include butorphanol, nalbuphine, dezocine, and buprenorphine. Their theoretical advantages over the pure mu-receptor agonists are (1) that with increasing doses they have a “ceiling effect” with respect to respiratory depression, and (2) their lower incidence of other side effects compared to the long-acting mu-receptor agonists such as morphine [41]. However, it appears they also exhibit a ceiling effect with respect to their analgesic effect. Furthermore, these are relatively long-acting agents, and there is a high incidence of PONV, dizziness, agitation, and occasionally dysphoria after their use. These effects make them unsuitable for use in ambulatory anesthesia [42].

**Nonsteroidal Anti-inflammatory Drugs** Nonsteroidal anti-inflammatory drug (NSAID) compounds exert their analgesic effect through their ability to inhibit prostaglandin synthesis, which is a common occurrence after a noxious stimulus. The commonly used NSAIDs include aspirin, acetaminophen, ibuprofen, naproxen, phenylbutazone, and ketorolac. Of these, only ketorolac can be administered by either the intramuscular or intravenous route. The main advantages of these agents over the traditional mu-receptor agonist analgesics is that the NSAIDs have fewer opioid-related side effects (e.g., respiratory depression, PONV, constipation). Unfortunately, they have their own side effects, including increased bleeding tendency, gastric irritation, renal tubular effects, and asthmatic attacks in aspirin-allergic patients. Oral or rectal administration of acetaminophen (650 mg) before an operation can decrease the perioperative narcotic requirement. The onset of action of ketorolac is slow, even when given intravenously, so it must be given sometime before the pain stimulus. In general, ketorolac and other nonsteroidal drugs are not very effective alternatives to intraoperative opioid analgesics unless they are being utilized for mild-to-moderate pain [43, 44]. Furthermore, concern about their propensity to increase intraoperative bleeding makes their preoperative and intraoperative use controversial.

**Neuromuscular Blocking and Reversal Agents**

Many ambulatory operations can be performed under general anesthesia, without a neuromuscular blocking agent. Still, there are indications for including a neuromuscular blocking agent as part of the balanced anesthesia for ambulatory surgery, such as (1) to facilitate tracheal intubation (see discussion later in this chapter) and (2) to provide a better surgical condition (by providing muscle relaxation). The pharmacologic and pharmacokinetic profiles of the intermediate- and short-acting nondepolarizing muscle relaxants are shown in Table 5.

Neuromuscular blocking agents can be conveniently divided into four classes according to their duration of action: ultra-short-acting (suxamethonium), short-acting (mivacurium), intermediate-acting (atracurium, vecuronium, rocuronium) and long-acting (tubocurarine, pancuronium, doxacurium, pipecuronium). The long-acting agents are not suitable for ambulatory anesthesia [45–47].

**Suxamethonium** Suxamethonium, the only depolarizing muscle relaxant in common use today, is unique because of its rapid onset of action (45–60 sec) and ultra-short-duration of action (5–7 min) [46, 48]. It provides intense muscle relaxation and is rapidly metabolized by plasma cholinesterase. This accounts for its widespread use among many anesthesiologists when muscle relaxation is required only to facilitate tracheal intubation, or to provide surgical muscle relaxation for very brief operations. Unfortunately, as a depolarizing agent, suxamethonium has several well-known side effects. In adult outpatients, postoperative myalgia is probably the most disconcerting side effect. At times, myalgia resulting from use of suxamethonium can be quite severe, lasting for 2 or 3 days. Because of these side effects, and due to the introduction of the newer short- and intermediate-acting nondepolarizing agents, suxamethonium is being used less frequently in the ambulatory setting. Nevertheless, the majority of the anesthesiologists in the United States still use suxamethonium for intubation, while others restrict its use as follows: (1) for rapid sequence intubation, (2) when a difficult tracheal intubation is suspected, (3) when difficult mask ventilation is suspected before tracheal intubation (e.g., bearded, edentulous, or short-necked persons, anatomical difficulties), (4) for short procedures (electronconvulsive therapy), (5) to break an intractable laryngospasm, and (6) to quickly terminate local anesthetic-induced convulsions.

**Atracurium and Vecuronium** Atracurium and vecuronium are the two commercially available intermediate-acting nondepolarizing agents [49]. They are very similar in their onset of action approximately 3 minutes after 2 times ED₉₅ dose, and their duration of clinical blockade is about 20 to 30 minutes. Complete recovery takes about 45 minutes after an intubation dose, although both agents are readily reversible with an anticholinesterase agent. For ambulatory procedures, lasting between 40 minutes or longer, atracurium and vecuronium are ideal muscle relaxants. For shorter operations, a smaller (e.g., ED₉₅) dose should be used for intubation. With this dose, the onset time may be slightly prolonged and an additional dose
of intravenous anesthetic (propofol) may be necessary before intubation. Atracurium has the ability to release histamine and undergoes spontaneous biodegradation in plasma at body temperature and pH (Hofmann elimination), in addition to its normal route of elimination via the kidney and liver. A large proportion of vecuronium is metabolized in the liver; the rest is eliminated via the kidney. Even in large doses, vecuronium does not have any cardiovascular side effects, although bradycardia may be observed when combined with a potent narcotic like fentanyl or alfentanil. Both vecuronium and atracurium may be used either in incremental doses at about one fourth the intubation dose, or as a continuous infusion.

Mivacurium  Mivacurium is the first short-acting nondepolarizing agent [50]. Although its onset of action is not as rapid as succinylcholine (150 vs 60 sec) and its duration of action is not as short (15 vs 6 min), it is still a major advance with respect to recovery characteristics. Since mivacurium is metabolized by plasma cholinesterases, reversal by anticholinesterase is often not necessary. Being a derivative of atracurium, mivacurium possesses a histamine-releasing property, and when given in large doses and fast, it causes flushing and hypotension. After 2 times ED₉₅ dose of mivacurium (0.15 mg/kg), tracheal intubation conditions were not as good as with succinylcholine or after an equivalent dose of vecuronium [51]. The conditions can be improved with a larger dose (e.g., 0.2 or 0.25 mg/kg), especially if given in 2 divided doses. However, increasing the dose of mivacurium also increases the incidence of hypotension and flushing. It should be noted that the laryngeal muscles have a quicker onset and offset of action than the adductor pollicis muscle. Thus, when using mivacurium, monitoring of the thumb muscles to determine the optimum time for intubation may mislead the anesthesiologist.

For maintenance of intraoperative muscle relaxation, mivacurium can be either injected in incremental doses (0.1 mg/kg) every 10 minutes, or given in a continuous infusion at 6–10 μg/kg/min. It is very important to monitor the depth of neuromuscular blockade by train-of-four stimulation of a peripheral motor nerve. There is no evidence of cumulation of mivacurium even after long infusion. Complete recovery after an intubating dose (without reversal) takes place after about 30 minutes. Use of mivacurium is cost-effective when used for short procedures lasting 30 to 40 minutes, especially when less expensive multiple dose vials are used.

Rocuronium  Rocuronium is a new intermediate-acting nondepolarizing neuromuscular blocking agent with a more rapid onset of action [52, 53]. Tracheal intubation can be performed in 60 to 90 seconds after 2 times ED₉₅ dose of rocuronium 600 μg/kg. The duration of action is similar to that of atracurium and vecuronium. Like vecuronium, rocuronium has a minimal effect on the cardiovascular system. Rocuronium may be an
excellent choice for rapid sequence intubation in cases where succinylcholine is contraindicated (e.g., open eye injury, burn, trauma).

Neostigmine, Edrophonium, and Pyridostigmine Unless complete, spontaneous recovery from the nondepolarizing agent has taken place (as is often the case after mivacurium), the effects of the nondepolarizing muscle relaxants should be reversed with an anticholinesterase and an anticholinergic drug [54]. Adequate recovery of the neuromuscular junction must be confirmed via monitoring of peripheral nerve stimulations, as well as by clinical criteria. The signs of adequate recovery by peripheral nerve stimulations are absence of fade on train-of-four stimulation, absence of post-tetanic facilitation, presence of sustained tetanus at 100-Hz stimulation, and absence of fade on double-burst stimulation. The clinical criteria for adequate recovery are sustained hand grip for at least 5 seconds, inspired negative pressure of at least 20 cm H₂O, and head lift for at least 5 seconds.

A mixture of neostigmine (2.5 mg) and glycopyrrolate (0.6 mg) is the most common reversal combination.

Edrophonium (0.5–1.0 mg/kg) with atropine (1.0 mg) is an alternate method of reversal. Reversal with edrophonium, especially when the neuromuscular blockade is not very deep (e.g., all the four twitches are present on train-of-four stimulation), is faster than neostigmine, but there is no other obvious advantage of edrophonium over neostigmine. Pyridostigmine, which has a slow onset of action but a longer duration of action as a reversal agent, is not indicated in ambulatory anesthesia, since long-acting neuromuscular agents are contraindicated in the ambulatory setting.

Airway Management

Face Mask

General anesthesia can be provided for many ambulatory procedures without intubating the trachea. Procedures that can be managed without tracheal intubation are D&C, cone biopsy, superficial operations (orthopedic or general surgery) on the extremities and trunk, inguinal hernia repair, and hydrocele operations. During these operations the airway can usually be managed via an appropriate-sized face mask and possibly with an oropharyngeal (Guedel) or nasopharyngeal airway.

Tracheal Intubation

The indications for tracheal intubation during ambulatory surgery are as follows:

1. To allow easy surgical access (e.g., operations in the head and neck area)

2. To secure the airway where an existing anatomical problem or the operative procedure may compromise the airway when the patient is anesthetized (e.g., operation in the airway, anatomical abnormality of the head and neck)

3. To protect the airway when pulmonary aspiration is probable (e.g., in diabetic and pregnant patients, when operating in mouth, when the stomach is full, during increased intra-abdominal pressure, as in laparoscopic procedures)

4. To provide surgical relaxation by using a neuromuscular blocking agent (e.g., laparoscopic procedure, laparotomy, thoracoscopy, or thoracotomy)

Laryngeal Mask Airway

With the recent introduction of the laryngeal mask airway (LMA) device, we now have an alternative method to manage the airway during ambulatory anesthesia. The LMA looks like a boat-shaped miniature face mask attached to the end of a short plastic tube [55] (Fig). The mask, when properly placed and inflated with air, sits directly on the laryngeal inlet. The distal end of the tube is connected to the anesthetic circuit. The tube is made entirely of surgical silicone, which can be resterilized by autoclaving. The LMA is usually placed blindly into the mouth in either a deeply anesthetized patient or a topically anesthetized, awake patient. In general, there are three indications for LMA: (1) in spontaneously breathing anesthetized patients, in place of a face mask or an endotracheal tube; (2) in place of an endotracheal tube, as long as the inflation pressure is not more than 20 cm H₂O when ventilation is controlled; and (3) to manage an expected or unexpected difficult airway and/or tracheal intubation [56, 57].

The major concern with the LMA is that it does not protect against gastric regurgitation and pulmonary aspiration. The LMA should not be used (1) where gastric regurgitation and pulmonary aspiration are probable, and (2) where controlled ventilation is likely to require a high inflation pressure (> 20 cm H₂O) (e.g., bronchospastic disease or morbid obesity).

The LMA is supplied in five sizes: 1, 2, 2.5, 3, and 4. The smaller three sizes (1, 2, and 2.5) are for pediatric use; no. 3 is suitable for small adults and no. 4 for average and large adults. Because propofol tends to relax the jaw and pharyngeal muscles better than thiopental, propofol anesthesia is ideal for the insertion of the LMA. After testing for leaks, the posterior aspect of the appropriate-sized LMA is lubricated with a water-soluble lubricant after fully deflating the cuff. The LMA can be inserted either after adequate general anesthesia or after good topical anesthesia of the mouth and upper airway. The patient is completely anesthetized with propofol (as described earlier in the chapter) or with a volatile anesthetic and placed in the classic supine "sniffing" position. The LMA is then inserted via the mouth blindly in the midline, with concavity for-
ward, by pressing on the anterior shaft with the tip of the index finger toward the hard palate and guiding it toward the pharynx. When the upper esophageal sphincter is reached a characteristic resistance is felt. Depending on the size of LMA, the cuff is then inflated with 10 to 30 ml of air, before attaching the tube to the anesthetic circuit. Anesthesia can then be maintained either with a continuous infusion of propofol or with a volatile anesthetic agent. At the end of the operation, the LMA may be left in place until the patient is awake; this avoids aspiration of accumulated pharyngeal secretions. However, it should be remembered that regurgitation of stomach content and pulmonary aspiration are possible while the LMA is in place, especially when the patient is waking up coughing and bucking.

Innumerable case reports and anecdotes have been published in which the LMA has been a life-saver in cases of expected or unexpected airway failure. In such a situation, either the LMA may be used in place of an endotracheal tube or a 6-mm endotracheal tube may be inserted (blindly or with the help of fiberoptic bronchoscopy) in the trachea through the lumen of the LMA after the LMA has already been placed.

This alternative form of airway management offers many potential benefits for outpatients scheduled for surgery. In patients who do not need endotracheal intubation, the LMA provides more reliable airway control compared to the face mask and it frees up the anesthesiologist’s hands. In cases where it is used as an alternative to an endotracheal tube, there are less hemodynamic alterations. Whether the LMA causes less airway trauma or sore throat is still debatable. Nevertheless, use of the LMA in ambulatory anesthetic practice is likely to increase in the future.

**Summary**

General anesthesia is the most common form of anesthetic management for ambulatory surgery. Patients, in general, prefer general anesthesia because it is less anxiety provoking. During the last decade, the availability of several short-acting agents with high clearance has made general anesthetic techniques much safer and more predictable for outpatients. Besides, general anesthesia today is associated with a quick and full recovery with minimal postoperative side effects.

Proper preanesthetic psychological and, when necessary, pharmacological preparation as well as proper selection of anesthetic agents are the keys to the success of general anesthetic technique for ambulatory surgery. Although both TIVA and total inhalation anesthetic techniques have their advocates, balanced anesthesia is most popular. The introduction of several new agents (e.g., propofol, desflurane, vecuronium, atracurium, mivacurium, rocuronium, alfentanil, ondansetron, ketorolac) has made ambulatory general anesthesia less challenging and more interesting. In the future, the new anesthetic sevoflurane, and the new opioid remifentanil, may prove useful for ambulatory anesthesia. The LMA has all but revolutionized airway management during general anesthesia for ambulatory surgery.

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