Overview of anesthesia and anesthetic choices

INTRODUCTION — The state of "anesthesia" means different things to different individuals and is as much a philosophical state as a neuro-scientific one. While the definition of anesthesia itself, as the loss of "awareness," is rather vague, a pragmatic definition of anesthesia as the provision of a combination of amnesia, analgesia (pain control), and muscle relaxation to allow the performance of surgery or interventional procedures is more useful. Anesthesiologists are also responsible for physiologic homeostasis while the patient is in the anesthetized state providing for the safest and most comfortable perioperative experience possible.

Anesthesiologists and the anesthesia care team, including Certified Registered Nurse Anesthetists (CRNAs) and Anesthesia Assistants (AAs), work to provide a wide range of perioperative services including preoperative evaluation, intraoperative management, post-operative management, intensive care unit (ICU) care, and acute and chronic pain management. The consultant anesthesiologist will function to some degree in all these roles in each patient he/she takes care of, taking into consideration numerous factors when deciding on an anesthetic plan with the surgeon and patient.

This topic discusses an overview of anesthesia and anesthetic choices focusing on intraoperative management and the risks and benefits of anesthetic choices.

GOALS OF ANESTHESIA — The primary goal of anesthesia is the maintenance of physiologic homeostasis. This includes monitoring and treatment of cardiovascular, pulmonary, neurologic and renal functions and changes during the perioperative period to minimize adverse outcomes. Optimizing intraoperative physiology may help speed recovery and provide for perioperative organ system protection.

Amnesia — Amnesia refers to the lack of memory of the intraoperative and perioperative experience. It is reliably achieved by inducing a state of unconsciousness as a result of general anesthesia. A three year study including 87,361 patients found six patients reporting recall under general anesthesia (incidence 0.0068 percent, or 1 per 14,560) [1]. This is the largest study to date looking at recall under general anesthesia. The rate of 1 in 14,560 is lower than the 0.1 and 0.9 percent rate generally reported in the literature; however, previous studies have generally focused on specific patient populations at higher risk for recall, such as obstetric, trauma or cardiac patients, while this study included a wide range of procedures. Differences may also be due to observer or surveyor bias, and perceived differences in implicit versus explicit awareness.

In addition, anesthesiologists now have better tools available for physiologic monitoring, such as end-tidal carbon dioxide (ETCO2), pulse oximetry, and anesthetic gas monitoring, which help define a safe threshold for maximal anesthetic delivery.

Emergency surgery for polytrauma carries a higher incidence of recall due to the "lighter" anesthetic used in these unstable patients. Other risk factors for intraoperative awareness include depression, cesarean delivery, and cardiac surgery [2,3]. The most likely cause of awareness is a "lighter" depth of anesthesia, which may be necessary in urgent or emergent inductions in potentially unstable patients in order to maintain blood pressure and organ perfusion. The physiologic reason for increased intraoperative awareness in patients with depressive disorder is not clear, but probably is a result of complex neurochemical interactions.
In certain circumstances amnesia may be undesirable and may be avoided by utilizing a regional anesthetic technique. The classic example is during a cesarean delivery under a neuraxial anesthetic; most mothers want to have memory of the birth of their child.

**Analgesia** — Pain control is an essential part of perioperative management. The most common methods of providing pain relief include local anesthesia, parenteral narcotics, and nonsteroidal antiinflammatory drugs (NSAIDs), neuraxial blockade with epidural or spinal anesthetics, or regional nerve blockade. There are many ways to achieve perioperative analgesia in patients, depending on the surgical procedure, underlying medical problems, risk associated with the method, and, to some degree, patient preferences. For example, patients undergoing surgery for abdominal cancer had better pain relief with an epidural infusion compared to intravenous narcotics [4].

Multimodal or balanced analgesia employs more than one modality of pain control to obtain additive or synergistic beneficial analgesia while reducing the undesirable side effects of opioids [5]. It may involve systemic administration of analgesic drugs with different mechanisms of action, but can also include the concurrent use of regional analgesia [5]. This approach reduces the length of in-hospital stay and return to full activity sooner after surgery. (See "Management of postoperative pain".)

**Neuromuscular blockade** — One of the most important requirements for optimal operating conditions is that the patient remains still during surgery. This goal can be achieved using different techniques, the most popular of which is neuromuscular blockade. Neuromuscular blocking agents block the acetylcholine receptors at the neuromuscular junctions of striated muscle to provide "relaxation" of the major muscle groups in the body. These medications do not have effects on smooth or cardiac muscle and are associated with few adverse effects when used judiciously. A balanced anesthetic technique, using a combination of volatile anesthetics, analgesics, and benzodiazepines achieves excellent immobility and analgesia without necessitating the use of neuromuscular blocking agents. Neuraxial or peripheral nerve blocks provide excellent anesthesia during surgery of the extremities.

**TYPES OF ANESTHESIA**

**General anesthesia** — General anesthesia (GA) is appropriate for most complex surgical procedures. A general anesthetic can be divided into three distinct phases: induction, maintenance, and emergence.

**Induction** — Induction of general anesthesia for adults is usually achieved with the injection of intravenous medications. The most commonly used induction agent in the United States is propofol because of its favorable recovery profile and short elimination half-life (resulting in less prolonged sedation and less nausea than sodium pentothal, a barbiturate induction agent). A study of over 4000 patients found an 18 percent reduction in postoperative nausea and vomiting with propofol compared propofol to sodium pentothal [6]. When used for induction, propofol causes bradycardia and hypotension in 4.2 percent and 15.7 percent of patients, respectively [7].

Other less common induction agents include etomidate and ketamine. These agents have lower rates of hemodynamic instability than propofol and may be used in specific situations.

- **Etomidate** may be used when vasodilation and cardiac depression are particularly undesirable, since etomidate does not cause profound hypotension. Etomidate causes a burning sensation on administration and a higher rate of postoperative nausea than other anesthetics. A significant cautionary drawback to the use of etomidate is that even a single dose can cause adrenal insufficiency [8]. (See "Causes of primary adrenal insufficiency (Addison's disease)", section on 'Drugs'.)

- **Ketamine** is a phencyclidine derivative and rapid acting dissociative general anesthetic. The benefits of ketamine include significant analgesia and preservation of respiratory drive. Ketamine also causes bronchodilation, which may be beneficial in patients with reactive airways. Used alone, it may have cardiovascular stimulant properties and/or unpleasant emergence reactions such as hallucinations, vivid dreams, or delirium. Benzodiazepines can be used in combination with ketamine to reduce these side effects [9].

**Mainteance** — Maintenance of anesthesia can be achieved with volatile or intravenous (IV) anesthetics. Volatile agents remain a popular choice among anesthesiologists because of their ease of delivery, reliable
recovery, excellent safety profile, and modest cost.

The most severe adverse effect of all the volatile anesthetics is fulminant hepatic necrosis caused by halothane. The incidence of this rare event was 1 in 35,000 patients [10]. The now more widely used halogenated volatile anesthetics, sevoflurane and desflurane have been associated with only isolated case reports of hepatotoxicity. In most of these cases, there was some degree of underlying hepatic pathology.

Nitrous oxide has been used in combination with volatile anesthetic agents. Nitrous oxide is fairly insoluble, providing the advantage of quick and reliable recovery, and less myocardial depression. However, the incidence of adverse reactions to nitrous oxide is probably more significant than previously thought. Common adverse reactions include nausea and diffusional hypoxemia upon emergence from anesthesia. (See 'Emergence' below.) In addition, the relative insolubility of nitrous oxide compared to nitrogen can cause expansion of air filled compartments in the body, with adverse effects such as rupture of pulmonary blebs (pneumothorax) or further expansion of an existing pneumothorax [11].

Nitrous oxide inactivates vitamin B12 with deleterious effects in selected patients. There have been at least five case reports of severe neurodegeneration when administering nitrous oxide to vitamin B12 deficient patients [12]. Vitamin B12 inactivation induced by nitrous oxide can also cause megaloblastic changes in the bone marrow and peripheral blood [11]. These effects may be particularly important in children [13].

Maintenance of the anesthetized state with intravenous anesthetics is rapidly becoming a popular alternative to volatile gas anesthesia for certain procedures (eg, breast biopsy) and a necessity for procedures like bronchoscopy. Continuous infusions of one or a combination of medications are used to provide amnesia and analgesia. A typical regimen involves the combined administration of propofol and remifentanil, two relatively short-acting intravenous agents.

The efficacy of total intravenous anesthesia (TIVA) with propofol and remifentanil was compared to volatile gas anesthesia with desflurane (plus fentanyl) in a randomized trial of 49 patients undergoing elective abdominal prostatectomy [14]. TIVA was associated with a significant reduction in the incidence of postoperative nausea and vomiting (zero versus 33 percent). On the other hand, the times to extubation and return of cognitive function were significantly longer with TIVA (by 5 to 6 minutes). There were no significant differences in postanesthetic care unit (PACU) discharge times or mini-mental status scores between the groups. Overall costs were higher in the TIVA group (59 versus 35 Euros).

Emergence — Emergence or "waking up" from general anesthesia is a crucial time in which the anesthesiologist welcomes the patient back to a restored state of consciousness. With this return of consciousness there is a short period of time in which the patient's body is aware of the emergence without a full return to consciousness. This results in autonomic hyper-responsiveness which may manifest as hypertension, tachycardia, bronchospasm, or laryngospasm. Short acting narcotics, beta blockers, or lidocaine can blunt these responses in patients, when these responses may be harmful (eg ischemic heart disease).

Neuraxial anesthesia — Spinal or epidural anesthesia may be used as a primary anesthetic for patients undergoing surgery of the lower extremities or abdomen. (See "Neuraxial analgesia and anesthesia for labor and delivery: Options" and "Management of postoperative pain", section on 'Neuraxial analgesia'.)

Spinal anesthesia — To perform spinal anesthesia a small gauge needle is inserted into a lumbar (usually L3-L4 or L4-L5) interspace until it reaches the subarachnoid space. Next, local anesthetic is injected to produce temporary numbness and muscle relaxation. The anesthetic duration and dermatomal level of blockade can be adjusted by using different local anesthetics and adjusting baricity and patient position.

Spinal anesthesia is most popular for lower extremity orthopedic procedures in appropriate patients. A comparison of general anesthesia and spinal anesthesia for total hip arthroplasty demonstrated a decrease in surgical time by 12 percent, blood loss by 25 percent, and intraoperative transfusion requirement by 50 percent when using spinal anesthesia [15].

The use of spinal anesthesia may decrease the incidence of thrombotic phenomena such as deep venous thrombosis (DVT) or pulmonary embolus (PE), which are a major cause of postoperative morbidity in lower extremity surgery. In one study, the incidence of DVT by venogram was 40 percent in the spinal anesthesia group versus 76 percent in the general anesthesia group after repair of femoral neck fractures [16]. It should be noted that this study was published prior to the routine use of perioperative thromboprophylaxis
which has reduced the rate of thrombotic complications.

**Epidural anesthesia and analgesia** — Epidural anesthesia is achieved with the placement of a small gauge flexible catheter into the epidural space via a needle using either a loss of resistance (more commonly used) or hanging drop technique. Repeat dosing of local anesthetic and adjunctive medications for prolonged intraoperative management is possible by leaving a catheter in the central neuraxial space for infusion. Furthermore, this catheter may remain in place for postoperative analgesia.

Studies comparing general anesthesia versus epidural anesthesia for lower extremity vascular surgery and inguinal herniorrhaphy have noted a decrease in both platelet aggregation and overall perioperative stress responses when using epidural anesthesia [17,18]. Because of the favorable effect on perioperative stress response, epidural catheters may be used in combination with general anesthesia to provide analgesia even if not used as the primary anesthetic.

Epidural analgesia has been shown to be beneficial in several situations. In patients undergoing major aortic surgery, patients receiving combined of general and epidural analgesia had a significantly lower incidence of death and major perioperative complications (myocardial infarction, stroke, respiratory failure) than the general anesthesia only group (22 versus 37 percent) [19].

**Complications** — The benefits of neuraxial anesthesia are associated with some risks, which are uncommon but can be serious. The most common adverse event associated with neuraxial blockade is post-dural puncture headache.

The incidence of dural puncture with the larger epidural insertion needles is close to 1 percent [20], whereas, the incidence of post-dural puncture headache after spinal anesthesia is lower because small gauge pencil point needles are more commonly used. A prospective, blinded, randomized trial of over 1000 obstetric patients compared Quincke and Atracan cutting needles to pencil point needles (Gertie Marx, Sprotte and Whitacre) [21]. There was a significantly lower rate of post-dural puncture headache in the pencil point group (2.8 to 4 percent versus 5 to 9 percent).

The incidence of spinal hematoma and epidural abscess after neuraxial anesthesia have been noted to be 0.05 and 0.1 percent with the need for operative intervention at 0.01 percent [22]. There is some controversy regarding the level of anticoagulation at which the incidence of spinal hematomas outweighs the benefit of neuraxial anesthesia. This is a decision that should ultimately be left to the consulting anesthesiologist. (See "Adverse effects of neuraxial analgesia and anesthesia for obstetrics".)

The use of aspirin should not influence the decision to place a neuraxial block [23]. Clopidrogel has been associated with several case reports of epidural hematomas [24,25]. The American Society of Regional Anesthesia and Pain Medicine (ASRA) currently recommends a waiting period of 14 days between the last dose of ticlopidine and 7 days after the last dose of clopidrogel before the placement of a neuraxial block [26].

**Peripheral nerve block** — Selective nerve blocks are another anesthetic option commonly used for procedures involving the extremities. The most common nerve groups blocked are the brachial plexus (interscalene block, infraclavicular block, axillary block), the sciatic nerve (posterior or lateral approach), and the femoral nerve group (3 in 1 block). (See "Overview of peripheral nerve blocks" and "Peripheral nerve block: Techniques".)

Selective nerve blocks may be used for operative anesthesia or post-operative pain control. The major advantage of selective nerve blockade is relaxation and analgesia of the selected area without the hemodynamic instability associated with general anesthesia or neuraxial blockade.

The safety of these procedures has improved dramatically with the use of nerve stimulators and ultrasound guidance for needle and catheter placements. A study of 1398 patients noted the incidence of local inflammation to be 0.6 percent, local infection to be 0.2 percent, with no serious cases of neurologic injury [27]. There was one retroperitoneal hematoma noted in the study group with an incidence of inadvertent vascular puncture of 6 percent [27].

**Intravenous regional block** — Intravenous regional block (Bier block) is an alternative to peripheral nerve block for extremity surgery, usually the hand or forearm. This technique can also be applied in pain therapy (eg, chronic regional pain syndrome) [28].
The technique uses a 20 to 22 gauge intravenous cannula placed usually in the hand for administration of local anesthetic in conjunction with one double tourniquet or two single pneumatic tourniquets placed proximally in the arm. The tourniquets must be auto-insufflating to maintain a fixed pre-determined pressure.

After the intravenous cannula and tourniquets are in place, the extremity is exsanguinated from distal to proximal using an Esmarch bandage. The tourniquet is inflated. When the pressure in the tourniquet is stable, the Esmarch bandage is removed. Local anesthetic (0.5%) is injected into the intravenous line. Signs and symptoms of anesthesia (numbness, insensitivity) develop in three to five minutes followed by motor paralysis. If the surgery is to involve the hand, the intravenous cannula is removed before the hand is prepped and draped. If tourniquet pain becomes an issue, a second tourniquet can be placed within the zone of anesthesia and inflated and the more proximal tourniquet that is causing discomfort deflated. Insufflation times are limited to a maximum of 1.5 to 2 hours, and the insufflation time should not be less than 30 minutes [28]. Although if the procedure takes less time than anticipated, the tourniquet can be can very briefly partially deflated and then reinflated to gradually release the lidocaine for systemic breakdown.

The inflation pressure of pneumatic tourniquets is debated. Tourniquet pressures exceeding 150 mmHg of the systolic pressure cannot guarantee the absence of systemic local anesthetic toxicity [29]. Tourniquet pressures that are 100 mmHg greater than brachial systolic pressure should be adequate. For most patients, insufflation pressure of 250 mmHg for the upper extremity, 300 mmHg for the lower extremity, and 230 mmHg in pediatric patients can be used.

The volume of local anesthetic required to achieve the block using the dilute concentration of local anesthetic (0.5%) is about 40 to 50 mL for the upper extremity and 60 to 80 mL for the lower extremity injected at a rate of 3 mL/sec (table 1).

Once the tourniquet is released, sensation returns quickly. Because of the rapid recovery, intravenous regional anesthesia is useful for patients undergoing ambulatory or emergency department procedures of the extremities.

Although the technique has a high degree of safety, serious toxic reactions to local anesthetic occur in about 1.6 percent of patients and include somnolence, incoherence, seizures, and cardiac arrest. These are typically due to accidental cuff deflation within 20 min of local anesthetic injection, but have also been reported during tourniquet inflation [29,30]. (See "Infiltration of local anesthetics", section on 'Systemic toxicity'.)

Other complications include self-limited skin discoloration or petechiae, thrombophlebitis, compartment syndrome and nerve damage. Treatment of these complications is discussed elsewhere. (See "Catheter-induced upper extremity venous thrombosis", section on 'Treatment' and "Superficial thrombophlebitis of the lower extremity", section on 'Treatment' and "Acute compartment syndrome", section on 'Management'.)

**Monitored anesthesia care** — Monitored anesthesia care (MAC) is an amorphous spectrum of perioperative services which generally includes intraoperative physiologic monitoring, provision of analgesia and anxiolysis, and further intervention and support as necessary [31]. Classically, MAC anesthesia does not involve complete loss of consciousness and patients should be made aware that they have a high likelihood of intraoperative recall. The surgeon needs to provide adequate local anesthesia for MAC to be successful since sedation does not ensure pain control. The patient should also understand that they will feel pushing and pulling although they should not experience sharp pain providing the local anesthesia is adequate.

**Sedation** — The American Society of Anesthesiologists makes a clear distinction between moderate or conscious sedation (often administered by non-anesthesiologists) and deep sedation (table 2) [31]. The provider of deep sedation must be prepared and qualified to convert to general anesthesia when necessary. By contrast, moderate sedation should not induce such depth of sedation that the patient cannot maintain airway integrity [31].

A study examining the closed claims associated with MAC anesthesia observed that the majority of claims resulted from oversedation and respiratory depression [32]. Better monitoring and vigilance would have prevented the majority of these occurrences.

**PREOPERATIVE RISK ASSESSMENT** — An accurate assessment of the likelihood of complications is an
important part of the preoperative evaluation. It is essential to differentiate between the potential risk solely attributable to administration of anesthesia versus those risks which the anesthesia provider may modify (See individual topic reviews on preoperative risk assessment of patients with specific medical disorders).

"Perioperative" risk is multifactorial, and depends upon the interaction of anesthesia-, patient- and surgery-specific factors [33]. With respect to anesthesia, both the effects of the agents and the skills of the anesthetic practitioner are important. Similarly, the nature of the surgical procedure and the surgeon’s skill impacts perioperative risk. From the patient’s perspective, potential complications of the co-existing disease must be weighed against the risk of anesthetic or surgical complications.

In assessing anesthetic risks, several points in time are relevant. Intraoperative morbidity and mortality, any death within 48 hours of an anesthetic, and 30 day morbidity and mortality are time points used in the estimation of anesthetic and surgical risk. With respect to ambulatory surgery, 30 day outcomes may be too long and complications within the first 7 days are more relevant, based upon the pattern of hospital admissions observed in a Medicare population [34].

All of the risks, benefits and information provided clearly do not supersede the clinical judgment and expertise of any one anesthesiologist taking care of any specific patient with their unique preferences, fears, and comorbidities. Therefore, the final determination of what anesthetic is appropriate for a given patient is best left to the individual's anesthesiologist who will take into consideration the patient, procedure, practice environment, and care standards for their institution.

Risk classification systems — The American Society of Anesthesiologists (ASA) physical status classification system is a relatively simple system which has proven effective in stratifying overall preoperative risk of morbidity and mortality for patients undergoing anesthesia and surgery [35].

Patients are divided according to how their underlying medical problems produce functional impediments to their everyday activities. For example, an ASA class I patient has no underlying conditions or limitations, while a class V patient is not expected to survive the next 24 hours without the proposed intervention (table 3). Risks inherent to a specific procedure are not incorporated into the ASA class.

Over the past several decades, anesthesia related mortality rates have reduced from two deaths per 10,000 anesthetic administered to one death per 200,000 to 300,000 anesthetics administered [33,36]. This represents a tremendous improvement over prior mortality rates, a result of careful focus on anesthesia safety. Complications are much more likely to occur in patients with preexisting disease states. The relative risk of serious perioperative complications is 2.2 and 4.4 for ASA patient status III and IV, respectively, illustrating that increasing serious comorbidities (and therefore ASA classification) increases perioperative morbidity [37].

One component of preoperative evaluation is assessment of cardiac risk for patients undergoing noncardiac surgery. A tool commonly used by anesthesiologists and other clinicians involved in pre-operative assessment to stratify and minimize perioperative risk of cardiac events is the American College of Cardiology and American Heart Association (ACC/AHA) Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery [38]. These guidelines provide an evidence based algorithm for the assessment and treatment of patients' cardiac risk based on risk factors, medical history and testing as well as the surgical risk outlined above. This issue is discussed in detail elsewhere. (See "Estimation of cardiac risk prior to noncardiac surgery" and "Evaluation of preoperative pulmonary risk".)

COMMON ANESTHESIA PROCEDURES

- **Endotracheal intubation** - The placement of an endotracheal tube for airway and ventilatory maintenance is probably the most common procedure performed by anesthesiologists. After induction of anesthesia, a tube is placed via the mouth into the trachea under direct visualization using a laryngoscope (figure 1 and figure 2). The incidence of difficult intubation, requiring more than one attempt at laryngoscopy, is cited at less than 1 percent [39,40]. There are many factors which predispose patients to difficulty with airway management including obesity, limited mento-hyoid distance, limited mouth opening, limited mandibular flexibility and limited extension of the cervical spine. (See "Basic airway management in adults" and "Rapid sequence intubation in adults" and "The difficult airway in adults" and "Devices for difficult airway management in adults".)
Post operative sore throat is the most common adverse event related to endotracheal intubation with an incidence of approximately 40 percent [41]. Other problems that may be encountered during and after endotracheal intubation include aspiration of gastric contents, dislocation of arytenoid cartilage, and damage to teeth or tracheal mucosa. The risk of pulmonary aspiration for all patients undergoing tracheal intubation for surgery is 2.7 in 10,000 [42]. The incidence of aspiration is higher in patients with risk factors such as gastroesophageal dysmotility, gastroesophageal reflux disease, and obesity [43]. (See "Aspiration pneumonia in adults").

- **Laryngeal mask airway placement** – The laryngeal mask airway (LMA) is a popular tool for maintaining airway patency during general anesthesia (figure 3). The airway is inserted into the oropharynx after induction of general anesthesia. (See "Devices for difficult airway management in adults", section on 'Laryngeal mask airways'.) Complications associated with LMA placement include sore throat and oropharyngeal trauma. It should also be noted that the LMA is a supraglottic airway that does not prevent aspiration pneumonitis. An incidence of aspiration of 2 in 10,000 patients receiving anesthesia with an LMA has been cited, although the authors do note that these devices should be used with caution in patients with increased risk factors for aspiration [44].

- **Brain monitoring** – Awareness with recall describes intraoperative consciousness and recall of intraoperative events and is potentially psychologically devastating complication. Monitoring strategies are aimed at recognizing when the administered level of anesthesia is insufficient and may include the use a brain monitor. (See "Awareness with recall following anesthesia", section on 'Depth of anesthesia monitoring'.)

- **Peripheral intravenous catheter placement** – The vast majority of patients undergoing anesthesia have a peripheral venous cannula placed for administration of medications, intravenous fluids, and blood products. Veins of the upper limbs and hand are the most common cannulation sites used by the anesthesiologist. The use of local anesthetic prior to placement reduces pain associated with cannulation [45]. The most frequent early complications are thrombophlebitis and extravasation. Catheter infection is a complication that is most likely to occur after more than three to four days. (See "Peripheral venous access in adults".)

- **Central venous catheter insertion** – Placement of a catheter into a central vein (subclavian, jugular) may be helpful for both monitoring volume status and for the infusion of vasoactive or medications too irritating for peripheral administration. (See "Placement of central venous catheters" and "Intraoperative fluid management".)

- **Arterial catheter insertion** – Arterial catheters may be placed by anesthesiologists for continuous blood pressure monitoring or frequent blood gas analysis (evaluating respiratory and metabolic function). Arterial catheters are typically placed in the radial artery at the level of the wrist using a Seldinger technique. (See "Arterial catheterization techniques for invasive monitoring" and "Arterial blood gases".)

- **Pulmonary artery catheterization** – Pulmonary artery catheterization involves the placement of a catheter under hemodynamic and/or fluoroscopic guidance through the central venous circulation, the right atrium, right ventricle, and into the pulmonary artery. Under ideal circumstances, this catheter provides significant hemodynamic information to the practitioner including cardiac output, pulmonary artery pressure, pulmonary vascular resistance, and pulmonary artery occlusion pressure (reflecting left ventricular end diastolic pressures). There is insufficient evidence to support the routine use of pulmonary artery catheterization for high risk patients undergoing noncardiac surgery [46-48]. (See "Pulmonary artery catheterization: Indications and complications" and "Insertion of pulmonary artery catheters".)

**SUMMARY AND RECOMMENDATIONS**

- The goal of anesthesia is to provide the desired combination of analgesia, amnesia, and optimal operating conditions while ensuring physiologic homeostasis. Careful assessment of the patient
preoperatively and consideration of anesthetic choices will improve the operative outcome. (See 'Goals of anesthesia' above.)

- The types of anesthesia include general anesthesia, neuraxial anesthesia (spinal and epidural), peripheral nerve blocks, and monitored anesthetic care (sedation). Multimodal analgesia may be used to decrease opioid side effects. (See 'Types of anesthesia' above.)

- The proper choice of anesthetic depends on the planned procedure and the patient's overall health and medical problems. The American Society of Anesthesiologists (ASA) classification system is helpful for stratifying the risks of anesthesia through assessment of the patient's underlying medical problems. (See 'Risk classification systems' above.)

- Administration of anesthetic vapors and intravenous agents requires airway access, venous access, and sometimes special monitoring devices such as arterial and pulmonary artery catheters. The use of these devices depends on the planned procedure and the patient's medical risk. (See 'Common anesthesia procedures' above.)

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REFERENCES


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### Local anesthetics used for regional anesthesia

<table>
<thead>
<tr>
<th>Agent</th>
<th>Speed on onset</th>
<th>Duration</th>
<th>Maximum dose plain (mg/kg)</th>
<th>Maximum dose with vasoconstrictor (mg/kg)</th>
<th>pKa (25°C)</th>
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<tbody>
<tr>
<td><strong>Ester agents</strong></td>
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<tr>
<td>Procaine</td>
<td>Slow</td>
<td>Short</td>
<td>8</td>
<td>10</td>
<td>9</td>
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<tr>
<td>2-Chloroprocaine</td>
<td>Rapid</td>
<td>Short</td>
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<td><strong>Amide agents</strong></td>
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<td>Intermediate</td>
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<td>Responsiveness</td>
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<td>Airway</td>
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<td>Spontaneous ventilation</td>
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<td>Cardiovascular function</td>
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### ASA physical status classification system

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<th>Physical status</th>
<th>Functional status</th>
<th>Examples</th>
<th>Risk status</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Healthy, no disease outside surgical process</td>
<td>Can walk up one flight of stairs or two level city blocks without distress</td>
<td>Little or no anxiety</td>
<td>Little or no risk</td>
<td>&lt;0.03 percent</td>
</tr>
<tr>
<td>2</td>
<td>Mild to moderate systemic disease, medically well controlled, with no functional limitation</td>
<td>Can walk up one flight of stairs or two level city blocks but will have to stop after completion of the exercise because of distress</td>
<td>ASA I with extreme anxiety and fear, a respiratory condition, pregnancy or active allergies</td>
<td>Well controlled disease states including diabetes, hypertension, obesity, epilepsy, asthma or thyroid conditions</td>
<td>0.2 percent</td>
</tr>
<tr>
<td>3</td>
<td>Severe systemic disease that results in functional limitation</td>
<td>Can walk up one flight of stairs or two level city blocks but will have to stop enroute because of distress</td>
<td>H/O angina pectoris, H/O MI, H/O CVA, HF &gt;6 months ago, COPD, diabetes with vascular complications, poorly controlled HTN, morbid obesity</td>
<td>Yellow flag for treatment</td>
<td>1.2 percent</td>
</tr>
<tr>
<td>4</td>
<td>Severe incapacitating disease process that is a constant threat to life</td>
<td>Unable to walk up one flight of stairs or two level city blocks. Distress is present even at rest.</td>
<td>H/O unstable angina, MI or CVA within last 6 months; severe HF, severe COPD; uncontrolled diabetes, HTN, epilepsy or thyroid condition Advanced pulmonary, renal or hepatic dysfunction</td>
<td>Red flag for treatment The risk may be too great for elective surgical procedure Medical consultation needed for emergency treatment</td>
<td>8 percent</td>
</tr>
<tr>
<td>5</td>
<td>Moribund patient not expected to survive 24 hours without an operation</td>
<td>Ruptured abdominal aneurysm, pulmonary embolus, head injury with increased intracranial pressure</td>
<td>Red flag for treatment Elective treatment is contraindicated, however emergency surgery may be necessary</td>
<td>34 percent</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A declared brain-dead patient being maintained for harvesting of</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>organs</td>
<td>Any patient in whom an emergency operation is required</td>
<td>Otherwise healthy young woman requiring D&amp;C for persistent vaginal bleeding</td>
<td>Increased risk</td>
<td></td>
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<tr>
<td>E</td>
<td>Suffix to indicate emergency surgery for any class</td>
<td>Otherwise healthy young woman requiring D&amp;C for persistent vaginal bleeding</td>
<td></td>
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</tr>
</tbody>
</table>

Placement of endotracheal tube

Note that the tongue is swept to the left side by the curved blade.
Endotracheal intubation

Note that a pillow is placed behind the patient's head to elevate the occiput. The tip of the curved MacIntosh blade is in the vallecula. The lips are pulled back to prevent injury during intubation.
Laryngeal mask airway

The correct placement of the LMA is shown.