Chapter

38 ANESTHESIA FOR PROCEDURES IN NON–OPERATING ROOM LOCATIONS

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Procedures performed outside the operating room fall under the term non–operating room anesthesia (NORA), which refers to providing anesthesia care at any location away from traditional operating room suites (Box 38.1). In response to the need for minimally invasive interventions as well as the rapid advancement in imaging and other technologies, the number of NORA procedures has markedly increased in many medical and surgical specialties. Even as more hybrid operating rooms are being built inside or close to the main operating rooms, NORA is increasingly becoming a significant part of anesthesia care.

Many patients treated in NORA locations are deemed "too sick" to undergo traditional surgical interventions. As with most anesthetics, both patient and procedure factors must be considered (Table 38.1). Anesthesia-related concerns include (1) maintenance of patient immobility and physiologic stability, (2) perioperative management of anticoagulation, (3) readiness for sudden unexpected complications during the procedure, (4) provision of smooth and rapid emergence from

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This chapter is dedicated to the memory of our esteemed colleague and mentor, Dr. William L. Young.

Box 38.1 NORA Locations That Commonly Require Anesthesia Services

Radiology and Nuclear Medicine
Diagnostic radiology and nuclear medicine
  Computed tomography
  Fluoroscopy
Therapeutic radiology
  Interventional body angiography (can involve embolization or stent placement)
  Interventional neuroangiography (can involve embolization or stent placement)
Magnetic resonance imaging
Positron emission tomography (PET) scan
Ultrasound imaging

Radiation Therapy
Standard x-ray therapy with collimated beams
Gamma Knife x-ray surgery for brain tumors and arteriovenous malformations
CyberKnife x-ray surgery for central nervous system, body tumors, and arteriovenous malformations
Electron beam radiation therapy (usually intraoperative)

Cardiology
Cardiac catheterization with or without electrophysiologic studies
Cardioversion
Structural cardiac intervention

Gastroenterology
Upper gastrointestinal endoscopy
Colonoscopy
Endoscopic retrograde cholangiopancreatography

Pulmonary Medicine
Tracheal and bronchial stent placement
Bronchoscopy
Pulmonary lavage

Psychiatry
Electroconvulsive therapy

Urology
Extracorporeal shock wave lithotripsy
Nephrostomy tube placement

General Dentistry and Oral and Maxillofacial Surgery
Dental surgery

Reproductive Health
In vitro fertilization procedures

NORA, Non-operating room anesthesia.

Table 38.1 Factors Considered for the Involvement of Anesthesia Services

Patient	Procedure
History of anxiety	Duration
Chronic opiate dependency	Nonsupine position
High oxygen requirement	Breath holding
Sleep apnea	Immobilization
Altered mental status	Degree of invasiveness
Inability to follow command	
Comorbid conditions	

anesthesia and sedation at appropriate times (which may even be required during the procedure), and (5) appropriate postprocedure monitoring and management during transport. A study of the National Anesthesia Clinical Outcomes Registry (NACOR) database has revealed that patients receiving NORA were older, and monitored anesthesia care was more commonly performed as compared to anesthesia given in the main operating room.[1] NACOR's report of complications in NORA locations also indicated that the most common major complications were serious hemodynamic instability and increased rates of death in cardiology and radiology locations. This chapter emphasizes the unique aspects of working in some of the common NORA locations, which often include special medical and procedure concerns and approaches.

CHARACTERISTICS OF NORA LOCATIONS

Importance of Communication

Remote locations are structured differently from the typical operating room, but clear communication is prudent for efficient and safe practice in either site. With clear communication, the actions of anesthesia personnel can be integrated with those of the procedural team involved in the NORA intervention. The anesthesia provider should have a detailed plan for communicating with more centrally located anesthesia colleagues and technicians, especially when help is required urgently. For instance, an unexpected difficult airway can be especially challenging because of the remote nature of many NORA locations. Additional anesthesia personnel and resources should be immediately available if needed. Sometimes the anesthesia providers in NORA locations feel isolated from the facilities available to operating room personnel. The lack of mutual experience and vocabulary presents challenges for anesthesia providers and other staff working in NORA locations. Anesthesia providers and proceduralists should have a mutual understanding of the specifics and challenges in the procedures as well as in medical care. Anesthesia providers working in an unfamiliar remote location must keep track of the identity and role of personnel participating in the interventional procedure or patient care. During times when the anesthesia provider may need experienced medical assistance (e.g., tracheal intubation, placement of an invasive monitor, or intravenous access), the availability of qualified staff members must be identified. Readily available preoperative documents for all patients in remote locations must include the attending proceduralist's patient history and physical examination. Patient arrival and check-in arrangements should be similar to those for patients undergoing procedures in a traditional operating room setting.

Standard of Care and Equipment

Anesthesia care provided in remote locations must adhere to the same standards as the operating room. The American Society of Anesthesiologists (ASA) has issued a Statement on Nonoperating Room Anesthetizing Locations that posts minimal guidelines for NORA procedures. In summary, these guidelines recommend adequate monitoring capabilities, the means to deliver supplemental oxygen via a face mask with positive-pressure ventilation, the availability of suction, the equipment for providing controlled mechanical ventilation, an adequate supply of anesthetic drugs and ancillary equipment, and supplemental lighting for procedures that involve darkness. Although portable anesthesia machines should be placed in close proximity to the patient to facilitate breathing circuit connections, this is not always possible owing to the presence of equipment such as fluoroscopy "C-arms."

If anesthetic gases are to be used, scavenging must be sufficient to ensure that trace amounts are below the upper limits set by the Occupational Safety and Health Administration (OSHA). Remote locations frequently involve additional hazards, such as exposure to radiation, loud sound levels, and heavy mechanical equipment. Advance preparation should be made to have all needed equipment available, such as lead aprons, portable lead-glass shields, and earplugs. At the end of the procedure one may often travel distances longer than the usual distance to the postanesthesia care unit or other patient units. So that patients can be safely and expeditiously transported to a recovery area, remote locations should always have available sufficient supplies of supplemental oxygen, transport monitors, and elevator and passageway keys. The anesthesia provider should always know the location of the nearest defibrillator, fire extinguisher, gas shutoff valves, and exits.

SAFETY AND CONCERNS IN RADIOLOGY SUITES

Imaging-related procedures for both diagnostic and interventional purposes have been presented as a major component in current NORA operations.

Radiation Safety Practices

Ionizing radiation and radiation safety issues are often encountered in these locations.[2] Radiation intensity and exposure decrease with the inverse square of the distance from the emitting source. Frequently, the anesthesia provider can be located immediately behind a movable lead-glass screen. Regardless of whether this is possible or not, the anesthesia provider should wear a lead apron and a lead thyroid shield and remain at least 1 to 2 m from the radiation source. A 2011 study also highlighted the importance of eye protection for anesthesia providers working for a significant time in the radiology suite.[3] Clear communication between the radiology and anesthesia teams is crucial for limiting radiation exposure.

Monitoring the Radiation Dose

Anesthesia providers, like all other health care workers who are at risk for radiation exposure, can monitor their monthly dosage by wearing radiation exposure badges. The physics unit of measurement for a biologic radiation dose is the sievert (Sv): 100 rem = 1 Sv. Because some types of ionizing radiation are more injurious than others, the biologic radiation dose is a product of the type-specific radiation weighting factor (or "quality factor") and the ionizing energy absorbed per gram of tissue. Radiation exposure can be monitored with one or more film badges. In the United States, the average annual dose from cosmic rays and naturally occurring radioactive materials is about 3 mSv (300 mrem). Patients undergoing a chest radiograph receive a dose of 0.04 mSv, whereas those undergoing a computed tomography (CT) scan of the head receive 2 mSv. Federal guidelines set a limit of 50 mSv for the maximum annual occupational dose.

Adverse Reactions to Contrast Materials

Contrast materials are used in more than 10 million diagnostic radiology procedures performed each year. In 1990, fatal adverse reactions after the intravenous administration of contrast media were estimated to occur approximately once every 100,000 procedures, whereas serious adverse reactions were estimated to occur 0.2% of the time with ionic materials and 0.4% of the time with low osmolarity materials. Radiocontrast materials can produce anaphylactoid reactions in sensitive patients, and such reactions necessitate aggressive intervention, including the administration of oxygen, intravenous fluids, and epinephrine, with epinephrine being the essential component of therapy (also see Chapter 45).

Adverse drug reactions are more common after the injection of iodinated contrast agents (used for x-ray examinations such as CT) than after gadolinium contrast agents (used for magnetic resonance imaging [MRI]). The signs and symptoms of anaphylactoid reactions can be mild (nausea, pruritus, diaphoresis), moderate (faintness, emesis, urticaria, laryngeal edema, bronchospasm), or severe (seizures, hypotensive shock, laryngeal edema, respiratory distress, cardiac arrest) (also see Chapter 45). Prophylaxis against anaphylactoid reactions is directed against the massive vasodilation that results from mast cell and basophil release of inflammatory cytokines such as histamine, serotonin, and bradykinin. The main approach to prophylaxis is steroid and antihistamine administration on the night before and the morning of the procedure. A typical regimen for a 70-kg adult is 40 mg prednisone, 20 mg famotidine, and 50 mg diphenhydramine.[4] Patients undergoing contrast procedures usually have induced diuresis from the intravenous osmotic load presented by the contrast agent. In this regard, adequate hydration of these patients is important to prevent aggravation of coexisting hypovolemia or azotemia. Chemotoxic reactions to contrast media are typically dose-dependent (unlike anaphylactoid and anaphylactic reactions) and related to osmolarity and ionic strength of the contrast agent.

Intravenous contrast material is often administered for radiologic imaging. A serious adverse reaction called nephrogenic systemic fibrosis (NSF) can occur after exposure to gadolinium-based MRI contrast agents.[5] In NSF there is fibrosis of the skin, connective tissue, and sometimes internal organs. The severity of NSF can range from mild to severe and it can also be fatal. However, NSF apparently occurs only when severe renal impairment (e.g., dialysis-dependent renal failure) also exists. Anesthesia providers should not casually administer gadolinium-containing MRI contrast agent to patients with renal disease.

MAGNETIC RESONANCE IMAGING

MRI is a standard diagnostic tool and is likely to supplant or replace conventional x-ray techniques. However, MRI image quality is degraded significantly with patient movement, and scanning sequences can take an hour or more. The MRI "bore" where the patient is positioned is a tube with diameter of only 60 cm to 70 cm and length of approximately 120 cm. Thus, patient immobility is the primary indication for sedation or general anesthesia. Patients who routinely require anesthesia services for MRI include children, adults who are claustrophobic or in pain, and critical care patients.

MRI Safety Considerations

Although ionizing radiation is not a safety issue because no x-rays or radioactive substances are involved, other safety issues are prominent in the magnet suite. Hearing loss may occur from high sound levels during the scan. Electrical burns can occur if incompatible monitoring equipment is attached to the patient. Similarly, patients with incompatible implanted devices or ferromagnetic material should never be placed inside a large magnetic field as device heating and malfunction can result in patient injury. Finally, missile injury can occur if ferromagnetic objects are brought within the vicinity of the magnetic field.

Objects in the magnet room need to be both MRI safe and MRI compatible. The term "MR conditional" was defined by the American Society for Testing and Materials to describe an item that poses no known hazards in a specified MRI environment (with specifications that include the static magnetic field strength and spatial gradient field generated by a particular MRI model). Before an MRI scan is started, the anesthesia provider should ensure the patient has been screened and cleared by MRI technicians responsible for knowing that the patient's body does not contain susceptible metal objects such as incompatible orthopedic hardware, cardiac implantable electronic devices (CIEDs), wire-reinforced epidural catheters, or a pulmonary artery catheter with a temperature wire. Pulse oximetry is essential during MRI scans, and only an MRI-compatible fiberoptic pulse oximeter should be used. Patient burns can result at the point of attachment if one uses a standard pulse oximeter. Similar concerns pertain to any other monitoring or management devices that make actual or potential patient contact.

Missile injury in an MRI suite is a serious and life-threatening risk. The superconducting electrical currents that generate an MRI scanner's large magnetic field are always "on." Therefore, MRI scanners are always surrounded by large magnetic field gradients (up to 6 m away). Magnetic field gradients can pull metallic objects into the magnet with alarming speed and force. Certain metals such as nickel and cobalt are dangerous because they are magnetic, whereas other metals such as aluminum, titanium, copper, and silver do not pose a missile danger. These metals are used to make MRI-compatible intravenous poles, fixation devices, and nonmagnetic anesthesia machines. MRI-compatible intravenous infusion pumps are clinically available. If one must bring susceptible metal items such as infusion pumps into the MRI magnet room, they should be safely located and fixed, preferably bolted to a wall or floor. The additional equipment should be placed and verified as secure before the patient enters the MRI scanner. In the event that an object is pulled into the magnet causing patient injury and equipment damage, the superconducting magnet can be turned off immediately. This process, called *quenching*, should only be performed by MRI technicians. The superconducting magnet of an MRI operates at cryogenic temperatures near absolute zero and requires coolant (cryogen) such as liquid helium to maintain the low temperature. The quenching process involves a rise in temperature of the superconducting magnet with escape of cryogen into a venting system outside the MRI room. However, cryogen can escape into the MRI room and displace oxygen, which can cause cold injury and asphyxiation.

Monitoring Issues in MRI Suites

Many anesthesia providers prefer to be outside the magnet room during the scan. This practice is acceptable as long as the provider (1) has access to all vital sign monitor displays and (2) can view the patient through a window or video camera. Critically ill patients undergoing MRI may require an arterial line for blood pressure monitoring. If the pressure transducer is classified as “MR conditional” for the particular MRI scanner, then it may be used during the procedure along with an MRI-compatible pressure cable and monitoring system. Otherwise, long lengths of pressure tubing must be added so that pressure transducers and their electrical cables can be located far from the magnet, preferably outside the magnet room. The radiofrequency pulse from an MRI can cause a pressure transducer to generate artifactual spikes. This can lead to erroneously high arterial blood pressure readings that could mislead the anesthesia provider. Visual inspection of the waveform allows rapid detection of this artifact. All arterial and venous line stopcocks should be capped so that hemorrhage will not occur if the stopcock is inadvertently manipulated.

Compatible Equipment

The MRI-compatible equipment that goes into the magnet room functions as a second anesthesia workstation. Although suction, physiologic monitoring, and mechanical ventilation must be possible inside the magnet room, a primary anesthesia workstation must be located just outside the magnet room. If a potentially life-threatening problem arises, the patient must be promptly transferred from the scanner room to the primary anesthesia workstation so that optimal care and additional help can be provided.

ANESTHESIA FOR NONINVASIVE IMAGING PROCEDURES

Because noninvasive imaging procedures do not cause pain, most adult patients do not need sedation or general anesthesia. The ASA has described a continuum of depth of sedation that includes progressive levels of sedation, including minimal sedation (anxiolysis), moderate sedation (so-called “conscious sedation”), deep sedation, and general anesthesia (also see Chapter 14, Table 14.1). For those adult patients who require sedation, anxiolysis (pharmacologic or nonpharmacologic) may be all that is required. In many medical centers, minimal sedation and moderate sedation can be provided by appropriately trained nonanesthesia personnel, whereas deep sedation and general anesthesia must be administered by anesthesia providers. For pediatric patients, deep sedation or general anesthesia is often required to facilitate the imaging procedure. In addition to the requirements for sedation, patient comorbid conditions such as airway compromise, severe cardiac or respiratory disease, or morbid obesity may require an anesthesia provider to assure patient immobility, maintenance of adequate oxygenation, hemodynamic stability, and minimization of pain and anxiety during the radiology procedure.

Physiologic Monitoring

The ASA Standards of Basic Anesthetic Monitoring (also see Chapter 20) are applicable to all noninvasive imaging procedures. Anesthesia providers commonly use specially constructed nasal cannulas that have an integrated CO_2 sampling line. Capnography can provide the respiratory rate and pattern, as well as the end-tidal CO_2 concentration, although readings are more prone to artifacts in a nonintubated patient. If capnography is not possible, ventilation must be assessed by continuous visual inspection, auscultation, or both.

Oxygen Administration

Supplemental oxygen via a nasal cannula should come from a dedicated flowmeter instead of the anesthesia machine common gas outlet. This approach permits more rapid deployment of the anesthesia machine breathing circuit for delivering face mask oxygen or positive-pressure ventilation if the patient develops hypoventilation, hypoxemia, or apnea. For procedures of long duration, humidified oxygen should be given via nasal cannula to promote patient comfort by minimizing drying of the nasal and pharyngeal passages. Certain patients, including infants and small children, will not tolerate a nasal cannula but can receive oxygen with a “blow-by” technique.

Pharmacologically Induced Sedation

Many medications can be used to provide sedation for imaging procedures (also see Chapters 8, 9, and 14). For example, sedation can usually be managed successfully with a continuous propofol infusion, with or without supplemental intravenous opioids or benzodiazepines (or both). For brief procedures, a small dose of a rapid-onset, short-acting opioid such as remifentanil or alfentanil is often an appropriate selection. Dexmedetomidine is another useful drug, primarily in procedures lasting more than an hour. Because dexmedetomidine has less frequent risk of respiratory depression compared to propofol, it is especially useful for patients with severe pulmonary hypertension, or those who require frequent assessment of mental status. Because dexmedetomidine tends to decrease systemic arterial blood pressure and has relatively long lasting duration, its use might require intravenous vasopressor support. Dexmedetomidine should be used cautiously in patients undergoing procedures that require arterial blood pressure to remain at baseline values or that require induced hypertension. Patients with atherosclerotic lesions in cerebral, cardiac, or renal arteries, as well as patients with brain or spinal cord compression from tumors, are particularly vulnerable.

Management of Anesthesia for Computed Tomography

CT is often used for intracranial imaging and for studies of the thorax and abdomen. Because CT is painless, noninvasive, and generally of short duration, adult patients undergoing elective diagnostic scans rarely require more than emotional support. In addition, the bore of the CT scan is much more open than an MRI, so claustrophobia is rarely an issue. CT scanning is a crucial diagnostic tool in several acute settings, including traumatic injury (head and abdominal), acute stroke, and acute altered mental status of unknown cause. CT scanning is also used for urgent assessments of gastrointestinal integrity in critically ill patients in the intensive care unit (ICU), who may require complex care during ICU transport. Sedation or general anesthesia is often essential for such patients, as well as for children and adults who have difficulty remaining motionless.

Unlike MRI, the concerns about magnetic fields are not present for CT scanning; however, the anesthesia provider is at risk for exposure to ionizing radiation. During the CT scan, the anesthesia provider should remain behind radiation shielding while the mechanized table moves the patient through the scanner. In addition to patient medical issues, complications during a CT scan could include disconnection of oxygen tubing or breathing circuits, inadvertent removal of intravenous catheters, and disconnection of monitors.

Management of Anesthesia for MRI

For pediatric patients (also see Chapter 34), a common technique consists of (1) inhaled induction of anesthesia with sevoflurane, (2) placement of intravenous catheter, (3) intravenous infusion of propofol, and (4) either nasal cannula, laryngeal mask airway, or endotracheal tube for airway management, based on patient comorbid conditions. For adults who require general anesthesia for MRI, the location of planned imaging may influence airway management choice. For example, a patient with a laryngeal mask airway may still have slight airway obstruction resulting in unacceptable motion artifact during brain MRI scan, which would not occur with an endotracheal tube.

Certain MRI image sequences (e.g., fluid-attenuated inversion recovery [FLAIR]) are influenced by the patient's oxygenation, which is managed by the anesthesia provider. Hyperoxia can increase signal intensity in brain cerebrospinal fluid, so the radiologist may request a decrease in the inspired oxygen concentration and must interpret the MRI scan accordingly.[6]

INTERVENTIONAL RADIOLOGY

Interventional radiology (IR) is a rapidly changing field as a result of continuing improvement in imaging quality and technological advances. The ability to combine real-time, noninvasive imaging with minimally invasive, often catheter-based, interventions offers great benefits to patients who otherwise have to experience the stress of an open surgery and possibly lengthier recovery. Interventional neuroradiology (INR), also called endovascular neurosurgery, mixes traditional neurosurgery with neuroradiology while also including certain aspects of head and neck surgery. Body IR mixes general surgery with general radiology. In angiographic procedures, the relevant blood vessel trees are imaged, after which a decision is made to advance to one or more therapeutic interventions via drugs, devices, or both. The list of IR procedures is extensive and continues to grow.

Interventional Neuroradiology

Anesthesia Choice

Most medical centers routinely use general endotracheal anesthesia for complex procedures or those of long duration, but there is no clearly superior anesthetic technique.[7] The specific choice of anesthesia may be guided primarily by the procedure needs as well as cardiovascular and cerebrovascular considerations.[8] Advantages of general anesthesia include control of ventilation and immobility, which improves image quality. Intermittent apnea may be requested by the interventional team to even further reduce motion artifact during digital subtraction angiography. Mechanical ventilation goals include maintenance of normocapnia or slight hypocapnia as long as intracranial pressure is normal. A patient with increased intracranial pressure may benefit from mild hyperventilation prior to anesthesia induction as well as during maintenance of anesthesia, in order to counteract inhaled anesthetic-induced cerebral vasodilation (also see Chapter 30). As an alternative to general anesthesia, minimal or moderate sedation has the advantage of allowing assessment of neurologic function during the procedure. A variety of medications can be used for sedation based on the experience of the provider and the goals of anesthetic management.

Access and Monitoring

The INR suite requires multiple imaging screens and a large fluoroscopy C-arm device that is capable of extensive movement around the patient. As a result, the distance from the intravenous catheter to the intravenous fluid bag can be twice as long as normal. The tubing extensions must be securely connected and of sufficient length to prevent accidental dislodgement. Infusions of intravenous anesthetics or vasoactive drugs should be connected as close to the intravenous catheter as possible to minimize tubing dead space. For procedures involving the blood supply to the central nervous system (CNS), arterial line placement for continuous blood pressure monitoring is prudent. A significant volume of fluid (e.g., heparinized flush solution and radiographic contrast agent) can be administered through catheters placed by the interventional team, in addition to the fluid administered by the anesthesia provider. Foley catheter placement will facilitate assessment of urine output and assist in fluid management decisions, and will promote patient comfort by avoiding bladder distention.

Arterial Blood Pressure Management

Baseline arterial blood pressure and cardiovascular reserve should be assessed carefully because blood pressure manipulation is commonly required during INR procedures and treatment-related perturbations regularly occur. Maintenance of arterial blood pressure within a predetermined range is particularly important in patients with cerebrovascular disease. Arterial blood pressure targets should always be discussed preoperatively with the interventional team. Deliberate hypertension, that is, maintaining a higher than normal arterial blood pressure, is used in INR patients with occlusive cerebrovascular disease to promote collateral cerebral blood flow. Such cases include patients undergoing emergency thrombolysis[9,10] and patients with aneurysmal subarachnoid hemorrhage in whom vasospasm has developed. Maintaining normal or supranormal arterial pressure is also important in patients with tumors that compromise blood flow to the spinal cord, kidneys, and other organs. Conversely, prevention of arterial hypertension may be critical in certain patients, including those with recently ruptured intracranial aneurysms or recently obliterated intracranial arteriovenous malformation. Patients who have undergone cerebrovascular angioplasty and stent placement in extracranial conductance vessels such as the carotid artery are susceptible to posttreatment cerebral hyperperfusion injury and require careful control of systemic blood pressure after the procedure[11] (also see Chapter 30).

Management of Neurologic and Procedural Crises

Crisis management during an INR procedure requires a well-thought-out plan coupled with rapid and effective communication between the anesthesia and radiology teams. The initial responsibility of the anesthesia provider is to assure that airway patency, gas exchange, and hemodynamic status remain intact. Then the anesthesia provider should communicate with the procedural team and determine whether the INR problem is hemorrhagic or occlusive.

In the setting of vascular occlusion, the goal is to increase distal perfusion by augmentation of arterial blood pressure with or without direct thrombolysis. This may require preparation and administration of a vasopressor infusion.

If the problem is hemorrhage, the anesthesia provider should discuss with the interventional team whether to immediately cease heparin administration and administer reversal with protamine. Complications of protamine administration include hypotension, anaphylaxis, and pulmonary hypertension. Most cases of vascular rupture can be managed in the angiography suite. The INR team can attempt to seal the rupture site via endovascular approach and may abort the originally planned procedure. In addition, a ventriculostomy catheter may be placed emergently in the angiography suite if elevated intracranial pressure is suspected. Patients with suspected rupture will require emergent head CT scan, but emergent craniotomy may not be needed.

Body Interventional Radiology

Interventional radiologists use x-rays, CT, ultrasound, MRI, and other imaging modalities to perform image-guided procedures throughout the body. These procedures are usually performed using needles and catheters, which are regarded as minimally invasive compared to traditional surgery. This section highlights the general approaches and challenges of anesthesia management for the most common image-guided procedures, such as diagnostic procedures, catheter drainage, stent placement, tumor ablation, vascular angioplasty and embolization treatment, and site-specific delivery of therapeutic agents (Table 38.2). Transjugular intrahepatic portosystemic shunt (TIPS) procedure deserves special recognition because of the severity of illness in its patient population.[12]

Anesthesia Evaluation and Management

The anesthesia requirements of patients undergoing IR procedures can vary greatly. Because of the minimally invasive nature, many procedures in the IR suites are performed with minimal sedation without an anesthesia provider present. However, a number of factors can prompt the involvement of the anesthesia provider (see Table 38.1). The presence of an anesthesia provider allows the proceduralists to focus their complete attention on the intervention at hand. A clear and detailed discussion should take place among the team members, so the proceduralists can specify their intraprocedural needs and the anesthesia provider can express any anesthetic concerns.

The preprocedure evaluation by the anesthesia provider follows the same approach as with any other anesthetic (also see Chapter 13). The choice of anesthetic technique follows the same principles outlined earlier in this chapter (also see Chapter 14). Patients who have altered mental status, or cognitive dysfunction—dementia, delirium, encephalopathy, or developmental delay—may not be candidates for sedation if they will be expected to cooperate and breath-hold during the procedure. The

Table 38.2 List of Common Interventional Radiology Procedures

Vascular	Liver/Biliary	Cancer	Miscellaneous
Angiography	Biliary drainage and stenting	Percutaneous (needle) biopsy	Abscess drainage
Balloon angioplasty	Transjugular liver biopsy	Chemoembolization	Chest tube
Embolization	Transjugular intrahepatic portosystemic shunt	Radiofrequency ablation	Percutaneous nephrostomy tube
Central venous/hemodialysis access			Gastrostomy tube
Thrombolysis			
Vena cava filter			

medication list should be reviewed. Special concerns for body interventional procedures include therapy with the oral antihyperglycemic metformin, which may cause lactic acidosis if administered with intravenous contrast agent in the setting of renal failure. Lactic acidosis is extremely rare when a patient with normal renal function receives both metformin and intravenous contrast agent. ASA Practice Guidelines for Preoperative Fasting should be followed as with any other elective procedure.

If general anesthesia is not the initial anesthetic choice, the anesthesia provider should be prepared to escalate the level of sedation as needed, up to and including general anesthesia. Therefore, all necessary equipment, monitors, and medications should be available.

Transjugular Intrahepatic Portosystemic Shunt

Patients who are scheduled to undergo the TIPS procedure have significant liver disease and complications of portal hypertension, which can include variceal bleeding, ascites, and hepatorenal syndrome. The Model for End-Stage Liver Disease (MELD) score serves as a marker of liver disease severity and is a predictor of short-term mortality risk in these patients, some of whom may be candidates for liver transplantation. Anesthetic evaluation should focus on the multisystem effects of liver failure, including cardiovascular, pulmonary, neurologic, renal, and hematologic manifestations (also see Chapter 28). Hepatic encephalopathy is a common finding in this patient population and is a contraindication for TIPS. Coagulopathy and thrombocytopenia may increase bleeding risk and require correction prior to the procedure.

The anesthetic management of a patient undergoing TIPS procedure can be quite challenging. Because of the presence of cardiopulmonary comorbid conditions, coagulopathy, and the unpredictable length of the procedure, most proceduralists prefer general anesthesia. Medications that have significant liver metabolism and biliary clearance should be avoided or minimized. The presence of tense ascites and gastroesophageal reflux are obvious risk factors for pulmonary aspiration of gastric contents. An endotracheal tube is preferred for airway management (as opposed to a laryngeal mask airway) because the neck must be rotated to provide internal jugular venous access. Lastly, the anesthesia provider must be aware of several important post-TIPS complications: altered mental status because of post-TIPS encephalopathy, massive hemorrhage from intrahepatic bleeding or vascular injury, and worsening liver failure from decreased portal vein blood flow.

Challenges: Hemostasis and Anticoagulation

Many IR procedures involve access of the arterial tree with large-diameter catheters. To minimize the risk of thromboembolic complication, the anesthesia provider is often asked to maintain intraprocedural anticoagulation. This is usually achieved with intravenous heparin, and monitored with whole blood activated clotting time (ACT). Heparin has the advantage of a short half-life and reliable reversal with protamine. For patients with heparin or protamine allergy or heparin-induced thrombocytopenia, direct thrombin inhibitors are alternatives. However, there is no reliable reversal for these drugs.

On the other hand, IR embolization is frequently performed as urgent therapy for acute hemorrhage. Common applications include gastrointestinal or uterine bleeding. Diagnostic angiography is performed to identify the site and mechanism of bleeding. Often, coils and thrombotic agents can be injected to stop the bleeding. To safely induce anesthesia and to rapidly secure the airway in a bleeding patient can be challenging. In addition, the patient's vital signs may further deteriorate after induction of anesthesia and require resuscitation with fluids and blood transfusion (also see Chapters 23 and 24). In addition to acute anemia, coagulopathy and thrombocytopenia are common, either as the cause of the initial hemorrhage or as the result of dilution from fluid replacement or factor consumption. The correction of coagulopathy should ideally be guided by laboratory data and a treatment algorithm. Because data may not be available during an emergency, the decision whether to transfuse will need to rely on the patient's medical history (e.g., presence of hematologic and hepatic diseases), medications (e.g., anticoagulant or antiplatelet therapy), physical findings (e.g., of disseminated intravascular coagulopathy), and the clinician's judgment. In addition to platelets, plasma, and cryoprecipitate, recombinant factors and factor concentrates may offer similar benefit of correcting factor deficiency without the risk of transfusion-related complications (see Chapters 22 and 24).

ENDOSCOPY AND ENDOSCOPIC RETROGRADE CHOLANGIOPANCREATOGRAPHY

Endoscopy is frequently performed for the diagnosis and screening of gastrointestinal conditions. Indications for upper endoscopy (esophagogastroduodenoscopy, EGD) include gastroesophageal reflux, bleeding, dysphagia, protracted pain or nausea, accidental ingestion, and abnormal imaging. Additionally, therapeutic interventions such as treatment of bleeding source, ablation of Barrett esophagus, biopsy and removal of abnormal growth, dilation and stenting of stricture, and feeding tube placement can be performed. The development of high-frequency endoscopic ultrasound (EUS) using a small-caliber catheter through the biopsy channel of the endoscope can provide high-resolution images of benign and neoplastic lesions in the gastrointestinal tract.

For EGD, the patient is typically placed in a left lateral position with the neck flexed. The usual sequence of events includes (1) application of topical anesthesia to the patient's pharynx with either lidocaine or benzocaine, (2) placement of a plastic mouth guard to minimize risk of damage to teeth or endoscope, (3) administration of medications to achieve minimal to moderate sedation, (4) insertion of endoscope through mouth into esophagus, (5) examination of esophagus, gastroesophageal junction, stomach, pylorus, and duodenum as required, and (5) performance of therapeutic maneuvers when necessary.

Endoscopic retrograde cholangiopancreatography (ERCP) is often performed for the diagnosis and possible treatment of bile duct and pancreatic duct diseases. ERCP requires specialized equipment including a dedicated fluoroscopy machine. Common indications include jaundice, acute biliary pancreatitis, chronic pancreatitis of unknown cause, pancreatic pseudocyst, suspected biliary or pancreatic malignancy, sphincter of Oddi disorders, duct stricture, and postoperative bile leak. Often, intervention such as sphincterotomy, dilation and stenting of biliary duct, stenting of fistulas, stricture or postoperative bile leak, drain placement, and tissue biopsy is also performed. The patient is typically placed in a left lateral or prone position with the head turned toward the endoscopist. The first portion of the procedure is similar to EGD whereby the endoscope is advanced past the pharynx and is inserted into the esophagus. Once the endoscope is in the duodenum, it is rotated to face the papilla. A cannula is inserted into the papilla, contrast agent is injected, and the duct is visualized under fluoroscopy. Excessive intestinal motility can impede endoscopic examination and can be inhibited by the administration of either anticholinergic drugs or glucagon.

Anesthesia Evaluation and Management

Anesthesia providers are often asked to care for patients requiring procedures in the gastrointestinal endoscopy suites. The standard approach to preprocedure evaluation (also see Chapter 13) and anesthetic choice (also see Chapter 14) applies in this setting. Simple EGD and ERCP in otherwise healthy patients can be performed with minimal or moderate sedation administered by a trained nonanesthesia provider. However, anesthesia service (whether monitored anesthesia care or general anesthesia) may be requested if the procedure is expected to be challenging or prolonged, patient immobility is desired, or the patient's history suggests airway difficulty or other comorbid conditions. Hepatobiliary dysfunction is common in patients who require ERCP. These patients may have coagulopathy because of decreased synthesis of coagulation factors and thrombocytopenia (also see Chapter 28). Blood product transfusion may be necessary prior to the endoscopy, especially for the more invasive ERCP.[13]

The choice of anesthetic techniques requires clear communication between the patient, endoscopist, and the anesthesia provider. Although minimal or moderate sedation is the most common technique for uncomplicated EGD, deep sedation or general anesthesia may be necessary for EGD based on patient comorbid conditions or severity of clinical status (e.g., critically ill patient with massive hematemesis).

ERCP is considered to be a riskier procedure compared to EGD, based on the nature of the procedure and the typical patient population. The patient is most often in the prone position and the anesthesia provider has limited access to the patient's airway because the endoscopist stands next to the patient's head. Finally, the room is darkened to allow better viewing of the fluoroscopy screen, and the provider must wear protective lead shields to minimize exposure to ionizing radiation. Many patients undergo repeat ERCP and have developed a preference for monitored anesthesia care versus general anesthesia based on their experience.

Challenges and Complications

Complications of EGD or ERCP can generally be grouped by sedation and airway, procedure, and patient-related factors (Table 38.3). Topical benzocaine administration can lead to methemoglobinemia (also see Chapter 10). Procedure-related

Table 38.3 Complications of Esophagogastroduodenoscopy or Endoscopic Retrograde Cholangiopancreatography

Sedation and Airway	Procedure	Patient-Related
Hypoxemia	Bleeding	Bleeding
Excessive secretion	Perforation	Coagulopathy
Aspiration	Pancreatitis (ERCP)	Thrombocytopenia
Laryngospasm	Air embolism (insufflation)	Cardiac arrhythmia
Bronchospasm	Hypercarbia (CO_2 insufflation)	
Methemoglobinemia	Contrast agent allergy	

ERCP, endoscopic retrograde cholangiopancreatography.

complications, such as esophageal perforation, are rare but can be life threatening.[14] Esophageal perforation is more likely to occur in someone who has a history of stricture, previous perforation, previous surgery, or other anatomic abnormalities. Symptoms may include neck, chest, or abdominal pain. Clinical signs are often nonspecific (i.e., tachycardia, tachypnea, hypotension, abdominal distention, and even sepsis). Clinical suspicion should be intense especially if the symptoms do not resolve or are self-limited. The diagnosis of perforation is usually made radiographically, often with the use of water-soluble contrast material. Depending on the lesion, some perforations can be managed medically whereas others constitute surgical emergencies.

The anesthetic management of a patient with upper gastrointestinal bleeding can be especially challenging. Tracheal intubation may be complicated by ongoing hematemesis. Large-bore, possibly central, venous access is required to continue resuscitation with fluid, blood, and vasopressors. Often the patient may have an underlying cause of coagulopathy, or the hemorrhage can cause a coagulopathy. A typical example is a patient who has end-stage liver disease with deficiency in coagulation factors, thrombocytopenia, portal hypertension, and variceal bleeding. For anesthesia providers caring for such critically ill patients, anesthesia management is further complicated by the location outside the operating room, where resources and help are often far way.

CATHETER-BASED CARDIOLOGY PROCEDURES

Adult Cardiac Catheterization

Patients needing coronary artery or peripheral artery angiography usually show evidence of coronary ischemia on noninvasive cardiac stress tests, or other clinical evidence of atherosclerosis. Preprocedural assessment and preparation should be focused on their cardiopulmonary functional status, airway, relevant medications, and other common comorbid conditions such as diabetes mellitus and renal insufficiency.

The procedure usually involves the cannulation of one or more peripheral arteries, such as the radial, brachial, or femoral. A noninvasive arterial blood pressure monitor should be placed on an extremity that is not involved with the procedure. The cardiologist will inject local anesthetic at the site of cannulation in addition to sedation using intravenous midazolam and fentanyl. The procedure itself is usually well tolerated by the patient. Anesthesia care is requested when the patient has a history of severe anxiety, because sedation by an anesthesia provider may be safer. Sometimes, high-risk coronary angioplasty is planned and may require mechanical extracorporeal circulatory life support (ECLS), in which case the anesthesia provider should be readily available so that if hemodynamic instability occurs the airway can be secured rapidly. General anesthesia is rarely indicated unless a surgical exposure for ECLS cannulation is planned. The risk of hemodynamic instability during general anesthesia is clearly high. Because the procedure is usually short, an opiate-dominated induction of anesthesia is not desirable. Small-dose propofol, etomidate, ketamine, or an inhaled induction of anesthesia may be appropriate. Either a small concentration of inhaled anesthetic or small dose of propofol via an infusion is usually sufficient to maintain anesthesia. The use of vasoconstrictors may be needed to maintain systemic vascular resistance, and inotropic drugs such as dobutamine, epinephrine, or dopamine can be given to those patients with severely depressed left ventricular ejection fraction. Finally, as with any non–operating room location, the anesthesia provider may be called to the catheterization suite emergently to help resuscitate a patient including securing a patent airway, and possibly organizing the transport to the ICU or operating room.

Electrophysiology Studies

Catheter-Based Ablation

Electrophysiology (EP) covers the diagnosis of cardiac dysrhythmias, detailed mapping of their circuitry, and treatment with catheter-based ablation.[15] With rapid advancements in cardiac monitors, computer tomography, MRI, and catheter technologies, a wide variety of dysrhythmia—atrial fibrillation, supraventricular tachyarrhythmias (SVTs), and ventricular tachycardia—are amendable to EP study and treatment. Patients undergoing EP studies and ablation can vary greatly, ranging from healthy young adults with isolated dysrhythmia to patients with end-stage heart failure with left ventricular assist devices. Preprocedural evaluation of these patients should focus on their cardiopulmonary reserve (particularly signs and symptoms when arrhythmias occur), airway, comorbid conditions, and relevant medications, especially anticoagulants such as heparin, warfarin and the newer direct factor Xa inhibitors, and direct thrombin inhibitors.

The intracardiac catheters are usually placed via the femoral and internal jugular veins, unless a retrograde approach to the left side of the heart via the femoral artery is planned. Endocardial mapping studies are performed with stimulation and recording from the internal and external electrodes, followed by catheter ablation of the endocardium (usually with radiofrequency energy) to produce a scar that disrupts dysrhythmia generation or propagation. Generous subcutaneous injection of local anesthetics and intravenous sedation administered drugs (also see Chapters 8, 9, and 10) during cannulation is sufficient for most patients. In fact, many electrophysiologists believe that excessive sedation or general anesthesia during the study can suppress dysrhythmia and negatively affect the success of mapping. The anesthetic plan and monitoring should be determined by the patient's overall clinical picture.[16] A history of syncope or angina during a tachycardic episode may suggest depressed cardiac output and significant hypotension, and an invasive arterial pressure monitor may be warranted as the study can induce or elicit periods of rapid heart rates. The anesthetic plan usually involves more profound sedation (often deep sedation) and analgesia during the initial cannulation and catheter insertion, and minimal sedation thereafter. One exception is atrial fibrillation ablation, which involves endocardial ablation that isolates pulmonary vein ostia from the rest of the left atrium. General anesthesia with endotracheal intubation may be helpful for this procedure. It allows predictable respiratory movement during ablation, monitoring of esophageal temperature to avoid left atrial perforation, and detection of any phrenic nerve stimulation. For procedures involving catheters in the left side of the heart, anticoagulation is usually achieved with intravenous heparin to avoid thromboembolic complications.[17] Finally, EP catheters are irrigated with fluid, and because the amount can be substantial over a long procedure, patients with a history of congestive heart failure may require a diuretic to avoid excessive intravascular volume.

Cardiac Implantable Electronic Devices

Another common group of procedures performed in the EP suite is the placement of CIEDs, such as implantable cardioverter-defibrillators (ICDs) and pacemakers (PMs). The anesthesia provider should understand the indication of the device, whether it is heart block, primary prevention for sudden cardiac death in cardiomyopathy, secondary prevention for a history of ventricular tachycardia, or biventricular pacing for cardiac resynchronization therapy. Transcutaneous pacing and defibrillator devices should be attached to the patient, and the anesthesia provider should understand how to operate these devices to institute emergency pacing or defibrillation. Again, the procedure can be performed successfully with subcutaneous local anesthetic injection and intravenous sedation and analgesia medications. However, the anesthesia provider may decide that general anesthesia may be safer, for example, in someone with altered mental status. The cardiologist may choose to perform a defibrillation threshold test, in which fibrillation is intentionally induced and the device's ability to sense and terminate fibrillation is confirmed. In some patients such as those with severe systolic left ventricular dysfunction (e.g., ischemic cardiomyopathy), the brief loss of cardiac output and perfusion, even for seconds, may be poorly tolerated. Invasive pressure monitoring is advisable to facilitate timely treatment of hypotension. Prior to the test, administration of oxygen and a small intravenous dose of a short-acting anesthetic to produce amnesia is appropriate.

Cardioversion

The anesthesia provider is frequently involved in caring for patients who are undergoing cardioversion for atrial fibrillation or atrial flutter. Because of the risk of thromboembolic disease in these patients, cardioversion is often immediately preceded by a transesophageal echocardiogram (TEE) to examine the left atrium for thrombus. TEE may be bypassed if the patient has been on therapeutic anticoagulation. The echocardiographer may choose to topicalize the upper airway with local anesthetics to suppress gag reflex during probe insertion. The drawback with topicalization is that the loss of airway reflex may linger beyond the procedure and have a potentially negative effect on the patient's ability to handle excessive secretions. A good choice is the use of a short-acting sedative such as propofol. Before TEE probe insertion, the patient should have standard monitors attached and have been breathing supplemental oxygen. Sedation with propofol is then titrated to accommodate the passage of the probe and should be maintained during the examination. Maneuvers such as jaw thrust, chin lift, or pharyngeal suctioning may be necessary to avoid obstruction or clear secretions. For cardioversion without TEE, small doses of propofol after preoxygenation to render the patient amnestic should be sufficient. After cardioversion, the anesthesia provider should continue to monitor the patient, relieve any airway obstruction, and provide additional oxygen until recovery of mentation and airway reflex is satisfactory before transferring patient care to the recovery room.

Structural Heart Disease Intervention

Similar to EP, catheter-based intervention for the treatment of structural heart diseases is a rapidly evolving field. Balloon valvuloplasty or even valve replacement can be performed on all of the intracardiac valves. Atrial septal defect (ASD), patent foramen ovale (PFO), ventricular septal defect (VSD), and coronary fistula can be closed with expandable devices. These procedures are performed using fluoroscopy with additional guidance from echocardiography. Because a large portion of this patient population has had previous sternotomy for cardiac intervention, the transcatheter approach avoids the morbidity and risk of repeat sternotomy and inadvertent cardiac injury. General anesthesia has a number of advantages: an immobile patient, controlled ventilatory movement, ease of continuous TEE examination, and a secured airway in the case of hemodynamic instability or when open surgery is needed. The induction of anesthesia may be challenging, however, given the existent severe cardiac defect. Pediatric patients with cyanotic heart lesions or adult patients with palliative treatment of congenital heart diseases may be especially challenging. A thorough preprocedural discussion between the anesthesia provider, congenital cardiologist, interventional cardiologist, and cardiac surgeon regarding the cardiac anatomy and surgical history and its implication is invaluable.

Pediatric Studies

Caring for neonates, infants, and children who are undergoing invasive cardiac studies and procedures is one of the most challenging tasks faced by the anesthesia provider (also see Chapters 26 and 34). To safely anesthetize these patients requires a mastery of the neonatal cardiopulmonary physiology, complex anatomy of cardiac lesions, pharmacology, pediatric airway, and other coexisting congenital diseases. Because of their age and cognitive development, most pediatric patients require either general anesthesia or deep sedation for these procedures. Special attention must be paid to the possibility of a difficult airway, the rapidity of ventilation problems adversely affecting cardiovascular stability, the pharmacodynamic and pharmacokinetic properties of anesthetic drugs, and the avoidance of hypothermia in the smaller patient. The onset of intravenous and inhaled anesthetics will be significantly altered owing to the presence of intra- or extracardiac shunts. Similarly, the onset of medication effect can be delayed as a result of congestive heart failure and low cardiac output. Hypoxia, hypercapnia, excessive positive airway pressure, metabolic acidosis, hypothermia, and painful stimulation can lead to increases in pulmonary vascular resistance and right-sided heart failure and should be avoided. However, in patients with intracardiac shunts, hyperoxia and resulting pulmonary vasodilation may promote excessive left-to-right shunt and cause systemic hypotension. Also, cyanotic patients become polycythemic to compensate for chronic oxygen deprivation. This places them at a higher risk of thrombotic complications during the procedures. The rule of thumb is to have the cyanotic patient remain at preanesthetic hemodynamic and oxygenation baseline, which can be a considerable challenge during anesthesia.

Challenges and Complications

Providing anesthetic care in interventional cardiology locations can be challenging. The typical arrangement of a room designed for the interventional cardiologist frequently places the anesthesia provider far away from the patient, with other equipment serving as obstacles. Despite the infrequent use of general anesthesia in many cases, the anesthesia provider should always be prepared to escalate the depth of anesthesia, secure the airway, and provide resuscitation in case of emergency. The most common complications with interventional cardiology procedures are related to vascular access and include bleeding, hematoma, pneumothorax, and vascular injury. In addition, intracardiac catheters can trigger arrhythmia and heart blocks, which may cause significant cardiovascular changes.

Rarely, cardiac perforation can occur, resulting in pericardial effusion and tamponade. Clinical signs include persistent hemodynamic instability unrelated to the induced arrhythmia and refractory to routine administration of vasoconstrictors and intravenous fluids. The procedural team should be informed if perforation is suspected. The diagnosis can be confirmed with echocardiography. Blood products should be ordered immediately. Perhaps anticoagulation should be reversed after a consultation with the proceduralist. One or more of the venous sheaths can be used for intravascular volume resuscitation. The options for managing a new pericardial effusion in this setting could include the following: (1) “wait-and-watch” approach if the effusion is small and self-limiting; (2) emergent pericardial drain placement; or (3) rapid mobilization for surgical decompression of tamponade. Thus, communication and understanding of the procedural plan between the anesthesia provider and the cardiologist are crucial. The cardiologist’s specialty expertise can be an asset during a cardiovascular emergency. In addition, vascular access placed by the cardiologist can be used for invasive monitoring (arterial line) and fluid resuscitation (central venous line).

ELECTROCONVULSIVE THERAPY

Electroconvulsive therapy (ECT) is an effective treatment for patients suffering from severe depression (both unipolar and bipolar types), psychotic depression, and schizophrenia.[18] For severe depression, ECT, compared with antidepressants, produces faster remission, reduces acute suicidal risk, and lowers relapse rate. Most guidelines recommend ECT as a treatment reserved for those who have failed medical therapy with antidepressants, or those with severe psychotic features (catatonia) or at risk of suicide in need of rapid, definitive response. The American Psychiatric Association (APA) also recommends its use as maintenance therapy. ECT exerts its therapeutic effect by inducing generalized seizures, and its efficacy on depression is affected by techniques, such as electrode placement and length of convulsion, and by the length of ECT treatment. It is thought that grand mal seizure changes the neurobiology of depression by increasing CNS γ-aminobutyric acid (GABA) concentration, normalizing serotonin function, and suppressing hypothalamic-pituitary-adrenal axis hyperactivity.[19]

Electrically Induced Seizures

A trained ECT physician produces generalized seizure by placing two electrodes in bifrontotemporal (bilateral), right unilateral, or bifrontal positions on the patient's head. Right unilateral or bifrontal position is chosen in order to minimize the side effects of ECT, especially short-term cognitive dysfunction. On the other hand, bilateral position has the advantages of ease of use, lower energy, and higher efficacy for remission. A brief (0.5-2 ms) or an ultra-brief (<0.5 ms) pulse of electrical charge, usually 100 to 600 μC (microcoulombs) is applied with the goal to trigger a seizure of sufficient duration (>15 seconds). Seizure threshold can either be determined empirically during the initial ECT treatment or based on the patient's age (for bilateral position). Threshold can be affected by a number of factors, including medication and blood pH, and may also increase over the course of the treatment series. The duration of seizure is monitored with single-channel electroencephalography (EEG). Motor seizure activity can also be followed; however, motor activity typically stops before the electrical activity. Seizures shorter than 15 seconds or a complete lack of seizure may be subtherapeutic, whereas prolonged seizures (>120 seconds) may be harmful to the patient. Adjustment by the ECT physician and possible intervention by the anesthesia provider may be necessary. A typical course may involve 3 treatments per week and a total of 6 to 20 treatments.

Anesthesia Evaluation

Before starting ECT, a patient should undergo a full medical evaluation by the ECT physician and the anesthesia provider (also see Chapter 13). Any interval change in health and side effects from previous treatments should be elicited during subsequent visits. Special attention should be given to any cardiopulmonary comorbid conditions, CNS disease, surgical (e.g., orthopedic) history, and relevant medications. Patients are often older and common concerns include cardiovascular diseases (e.g., hypertension, coronary artery disease, valvulopathy, cardiomyopathy, arrhythmia, or aortic aneurysm) and CNS diseases (e.g., cerebrovascular diseases and intracranial hypertension). Patients who are symptomatic or have unstable cardiac disease, such as malignant hypertension, decompensated heart failure, or hemodynamic significant arrhythmia, should be evaluated and optimized by a cardiologist. Those with CIEDs and pregnant women can undergo ECT safely. Patients with unstable fractures may be at risk owing to motor seizure. Standard nil per os or nothing by mouth (NPO) guidelines should be followed. Chronic medication for cardiovascular or pulmonary diseases usually should be continued. One exception is the bronchodilator drug theophylline, which can increase the risk of status epilepticus. Chronic anticoagulation (e.g., warfarin) should be continued as the risk of bleeding is minimal. Chronic medication for treatment of gastroesophageal reflux disease should be taken, but there is no evidence for routine prophylactic use of antacid, H_2 antagonist, or proton-pump inhibitor in an asymptomatic patient.

Psychotropic Medications

Many ECT patients are receiving psychotropic medications. Lithium, anticonvulsants, and benzodiazepines, which may shorten seizure duration, may be tapered under the direction of the ECT physician. However, many psychotropic medications (e.g., monoamine oxidase inhibitors, serotonin reuptake inhibitors, tricyclic antidepressants, lithium, and benzodiazepines) have sympathomimetic, anticholinergic, and CNS effects and can cause serious drug-drug interactions with commonly used perioperative medications.

Induction of Anesthesia and Seizure

Preparation for ECT treatment is similar to that of induction for general anesthesia.[20] Standard monitors are applied and vital signs are continually checked. Invasive pressure monitoring is rarely necessary, but may be useful for someone with unstable or severe cardiovascular disease. Oxygen should be given via face mask, and the patient is encouraged to breathe deeply to maximize oxygen content of the functional residual capacity (FRC) before induction of anesthesia. A second blood pressure cuff is placed on a distal limb. A peripheral nerve stimulator placed distal to the cuff is useful to determine the onset of neuromuscular paralysis by succinylcholine or any evidence of prolonged blockade likely because of pseudocholinesterase deficiency. If the patient has an ICD, the defibrillation function should be temporarily deactivated so that the device does not misinterpret the ECT electrical stimulus as an arrhythmia. Depending on the ICD programming, a magnet placed over the ICD can deactivate the defibrillator function. Similarly, for a patient with a PM who is PM-dependent, a magnet placed over the PM should convert it to an asynchronous mode. Otherwise, the electrical artifact from the ECT stimulus and resulting motor movement can cause PM inhibition leading to severe bradycardia. An external defibrillator machine with PM capabilities should be immediately available for those patients with CIEDs.

The most common induction drug is intravenous methohexital (0.5 to 1 mg/kg), a short-acting barbiturate that is superior to propofol, a potent anticonvulsant that may increase seizure threshold and shorten seizure duration. An alternative is intravenous etomidate (0.2 to 0.3 mg/kg),[21] which has the advantage of maintaining hemodynamic stability and can decrease seizure threshold and augment seizure duration in some patients; however, it can induce nonepileptic myoclonic activity and can cause adrenal insufficiency with just a single dose. Ketamine is another alternative, but its use is controversial as it may cause posttreatment confusion. If a patient has undergone prior ECT, the anesthesia provider should determine what induction drug and dose were administered, the resulting seizure duration, and the presence of any adverse effects. Subtherapeutic seizure may prompt a dose adjustment or a change of drug to induce anesthesia. In consultation with the ECT physician, an appropriate drug and dose can be selected.

Once the patient loses consciousness, the cuff on the distal limb is inflated. A fast-acting neuromuscular blocker, usually succinylcholine (0.5 to 1 mg/kg), is then injected to produce paralysis. For those patients with contraindications for succinylcholine, rocuronium can be substituted, which can be rapidly reversed with sugammadex (see Chapter 11). The distal tourniquet allows the monitoring of isolated motor activity. A bite guard is placed in the patient's mouth. The anesthesia provider continues to support the patient's breathing with bag-mask ventilation and may be asked to provide hyperventilation, as hypocarbia can decrease the seizure threshold. Once fasciculation stops, electrodes are applied and the electrical stimulus is delivered. The seizure activity can be followed on EEG with visual confirmation of the motor activity of the injured limb. A prolonged seizure (>2 minutes) can be terminated by a small propofol bolus. As the neuromuscular paralysis subsides, maneuvers to relieve airway obstruction such as jaw thrust or chin lift may be necessary. Endotracheal intubation is rarely necessary. Laryngeal mask airway may be useful for airway management in patients with risk factors for difficult face mask ventilation or history of obstructive sleep apnea.

Physiologic Responses to Seizure and Treatment

The electrically induced seizure can have profound effects on the patient's vital signs. The first (tonic) phase is characterized by profound parasympathetic discharge that can lead to bradycardia, atrioventricular block, atrial arrhythmia, premature atrial or ventricular contraction, or even asystole. Hypotension may occur. Intervention with atropine or glycopyrrolate may be necessary. This is rapidly followed by the second (clonic) phase of sympathetic overstimulation characterized by tachycardia and hypertension, which can also be profound. This may be exacerbated by hypoventilation and the resultant hypercarbia. Although the hemodynamic response usually subsides quickly after seizure termination, persistent hypertension and tachycardia, especially in those with significant cardiovascular diseases at risk for ischemia, may require treatment such as β-adrenergic antagonists (e.g., esmolol or labetalol) and other antihypertensives (e.g., hydralazine).

As discussed, these patients undergo a series of ECT treatments over time. The anesthesia provider should review the prior anesthesia record to determine the intraoperative hemodynamic response as well as post-ECT experience of the patient. If the patient had an excessive sympathetic response during past treatments, the anesthesia provider may choose to administer prophylactic β-adrenergic antagonists before seizure induction. Severe post-ECT complaints such as headache, muscle pain, or nausea suggest that small doses of opiates, acetaminophen, nonsteroidal antiinflammatory drugs, or antiemetics should be considered in future treatments.

QUESTIONS OF THE DAY

1. How can the anesthesia provider minimize exposure to ionizing radiation from C-arm fluoroscopy?
2. What is meant by the term *MR conditional* in the context of magnetic resonance imaging (MRI) and the safety of monitoring equipment?
3. A patient requires anesthesia for ablation of a renal mass in the CT scanner. What are the specific anesthetic considerations for this procedure?
4. A patient with an intracranial aneurysm is receiving general anesthesia for interventional neuroradiology coil embolization. The radiologist announces that the aneurysm suddenly ruptured during manipulation. What are the most important next steps in the management of this patient?
5. A patient with hepatic cirrhosis and upper gastrointestinal bleeding is scheduled for urgent esophagogastroduodenoscopy (EGD). What are the anesthetic priorities in caring for a patient in this situation?
6. A patient with history of ventricular fibrillation requires placement of an implantable cardioverter-defibrillator (ICD). What intraoperative complications related to this procedure should be anticipated?
7. A patient is about to undergo electroconvulsive therapy (ECT) for severe depression. What are the expected cardiovascular responses to the induced seizure? How can these responses be attenuated?

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