Anesthesia for Diagnostic or Therapeutic Radiology

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Diagnostic radiology procedures are anatomic or functional, minimally to non-invasive, cause little pain or discomfort, and are most frequently performed without anesthesia services. When anesthesia care is requested, it is typically because of the patient’s unique physiological or psychological needs or desires. Therapeutic techniques are often more invasive and more likely to require an anesthesiologist because of the complexity of the procedure and the comorbidities and discomfort of the patient. All therapeutic procedures are to some degree interventional, but many diagnostic procedures are not, although an interventional radiologist may perform them. Conducting anesthetics in the radiology department can be challenging because of the patient’s comorbidities, the procedure, the anesthetic, the radiology equipment, and the environment.

Anesthetics can be one of three types: monitored anesthesia care (MAC), regional anesthesia, or general anesthesia. Selection depends on the procedure and the relative risks and benefits to the patient. Monitored anesthesia care, the least invasive anesthetic, is indicated when a procedure may nominally require deep sedation or increased monitoring. The anesthesiologist administers intravenous sedation and analgesia; the proceduralist may give an additional local anesthetic at the site. Monitored anesthesia care is a physician service that is distinct from moderate sedation because the anesthesia provider must be able to apply resources to support life and ensure patient comfort and safety during diagnosis or therapy.

Diagnostic Radiology

Iodinated contrast media is used in both diagnostic and interventional radiology and may cause adverse (anaphylactoid) reactions or renal dysfunction. Adverse reactions involve direct cellular effects, including enzyme induction and activation of the complement, fibrinolytic, kinin, and other systems. Manifestations range from relatively benign itching to life-threatening cardiovascular or ventilatory collapse. Prophylaxis and treatment for the former include antihistamines and steroids, while advanced cardiac life support measures may be needed for the latter. Anaphylaxis is quite rare and is probably not a result of the iodine in the contrast material.

Patient-specific risk factors for renal complications include chronic renal disease, diabetes mellitus, heart failure, older age, anemia, and left ventricular systolic dysfunction. Contrast-specific risk factors are high osmolarity, viscosity, volume, and ionic media. For patients with renal disease, diabetes, proteinuria, hypertension, gout, or congestive heart failure, serum creatinine levels should guide the radiologist’s administration of the contrast material. Adequate intravascular volume, bicarbonate, and low volumes of iso- or low-osmolar contrast are indicated. Diabetic patients with preexisting renal dysfunction who also take metformin have developed severe lactic acidosis after an iodinated contrast study. Thus, metformin should be discontinued at the time of or before the procedure, withheld for 48 hours subsequent to the procedure, and reinstituted only after renal function has been re-evaluated and found to be normal. Intravenous gadolinium for magnetic resonance imaging (MRI) contrast studies is not problematic during the anesthetic. Ultrasound contrast is achieved through the intravenous administration of echogenic microbubbles, which carry an FDA warning that patients with pulmonary hypertension or unstable cardiopulmonary conditions be closely monitored during and for at least 30 minutes after administration. Although barium is not an intravenous contrast, it should be mentioned because it may pose an aspiration risk after ingestion during deep sedation or general anesthesia.

Anatomic Imaging

The ASA has issued a specific practice advisory emphasizing a location or position for optimal patient observation and vigilance during delivery of anesthesia in the MRI. The American College of Radiologists and the Joint Commission on the Accreditation of Healthcare Organizations have also established standards, guidelines, and recommendations for the MRI suite.8-10 Anesthesia equipment must conform to the criteria of the American Society for Testing and Materials and the Food and Drug Administration.

Patient monitoring and the administration of an anesthetic in the MRI suite are difficult because the anesthesia provider is physically separated from the patient during the study. The patient must be observed continually, either through a window into the scanner room or with a camera trained on the patient and a video monitor in the control room.
booth. Vital signs must be monitored through a window or via a camera trained on a monitor in the scanner room or a slave monitor in the control room.

Monitor placement and the length and routing of leads, wires, and tubing should be considered to prevent entanglement or traction as the MRI tables moves. Coiling monitor wires (e.g., pulse oximeter, electrocardiogram) should be avoided because this can cause patient burns.14 Patient temperature should be monitored because it may increase from the heat of radiofrequency radiation within the magnetic field,15 or it may decrease by radiation, conduction, convection, and evaporation. Monitoring temperature intermittently instead of continuously may avoid the possibility of burns from the thermistor during long sessions or in critically ill patients.16

Medical emergencies must be anticipated and a plan in place to treat them. Although advanced cardiac life support may be instituted on a patient still in the scanner, prompt relocation outside the scanner room gives better access to the patient and is safer for the staff. If an emergency requires the magnet to be shut down quickly, (quenching)17 the liquid cryogen boils off rapidly and releases enormous amounts of helium vapor, so an evacuation plan must be in place. The scanner is noisy and there have been reports of patient hearing loss following MRI scan, so some form of ear protection is advisable, even for unconscious patients.18

Airway management must be scrupulous and conservative because of the distance and barriers between the anesthesiologist and the patient. It may be best to secure the airway outside of the scanner room and then transport the patient into the room.

Electromagnetic waves (X-rays) have been incorporated into a number of different imaging modalities, including static two-dimensional X-rays, dynamic two-dimensional X-rays (fluoroscopy) and “three-dimensional” computed tomography (CT). Major issues include the anesthesia provider’s radiation exposure and distance from the patient. The former is addressed by distance, lead, and personal dosimetry; the latter, by following protocols for monitoring similar to those in the MRI suite. The U.S. Occupational Safety and Health Administration has established limits for the exposure of individuals to radiation in restricted areas,16 and institutional guidelines should adhere to these standards. Radiology equipment (e.g., C-arm or CT aperture) can make airway management and access to the patient difficult, and the anesthesia equipment often adds to the difficulty of maneuvering in the suite, as can the encumbrance of a lead apron. The configuration of the table and other equipment means that patient positioning, especially lateral or prone, can be problematic.

For diagnostic fluoroscopy procedures, the contrast material may be ingested (e.g., barium swallow), administered per rectum (e.g., barium enema), or injected intravenously (e.g., intravenous pyelogram) or intraroterially (e.g., aortogram). Many procedures can be performed without anesthesia support, unless a patient’s comfort, comorbidities, or cooperation requires it. For example, diagnostic angiography is often performed with no or only light to moderate sedation and analgesia by cardiologists; percutaneous transhepatic cholangiography may be performed by a radiologist using the same regimen.

Computed tomography is an easily tolerated procedure for most patients and is relatively safe for personnel since the X-ray beam is tightly focused. Although studies are performed in a few seconds or minutes, they require a still patient, so cooperation must be assured either through patient reassurance or medications. Like diagnostic X-rays, diagnostic ultrasound imaging is noninvasive and easily tolerated. In the absence of invasive techniques, anesthesia support is not warranted; if it is indicated, no encompassing techniques or precautions are necessary.

Functional (Brain) Imaging

Functional brain imaging reveals blood flow, metabolism, or electrical activity. Electrical activity is represented by the electroencephalogram (EEG), which directly measures the electrical potential between two scalp electrodes. The EEG is spatially limited by the number of electrodes, a limitation that has been improved by high-density arrays of over 120 electrodes.17 Magnetoencephalography is a more sensitive technology that records local magnetic fields produced by neuronal electrical activity in the brain via extremely sensitive instruments such as superconducting quantum interference devices.

Other functional brain imaging techniques rely on the remarkably consistent relationship between regional changes in the cellular activity of the brain and changes in the blood flow and metabolism of the region.18 Blood flow is revealed by functional MRI (fMRI), positron emission tomography (PET), and single-photon emission computed tomography (SPECT). A functional MRI distinguishes between the distinct magnetic resonance signals of
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A PET scan involves injecting a radionuclide molecule that emits positrons which annihilate electrons and
produce gamma rays that are then detected by the scanner. The amount of imaged tracer reflects blood flow and
concomitant brain activity. Regional metabolic activity can be seen if the radionuclide molecule contains [F]-2-
fluoro-deoxy-d-glucose (FDG), which concentrates in the more active areas. Positron emission tomography is
often combined with CT or MRI to correlate anatomy with function. Like PET, SPECT detects gamma rays but the
tracer material itself emits gamma radiation as it decays. More material indicates greater blood flow.

Metabolic activity also can be revealed through magnetic resonance spectroscopy, which detects signals
specifically from hydrogen or phosphorous to determine the concentration of brain metabolites in tissue; greater
levels indicate greater metabolic activity.

These procedures are often performed on awake individuals, although occasionally a patient’s psychological or
physical condition may require the use of sedation or general anesthesia. Administering anesthetic psychotropes may
result in artifacts that disrupt the “remarkably consistent relationship between regional changes in the cellular
activity of the brain and changes in its circulation and metabolism.” Isoflurane is associated with a relatively
global reduction in brain glucose metabolism during PET with FDG. Propofol causes a larger absolute metabolic
reduction, a greater suppression of cortical metabolism, and significantly less suppression of basal ganglia and
midbrain metabolism. Propofol preferentially decreased cerebral blood flow in brain regions previously implicated
in the regulation of arousal, performance of associative functions, and autonomic control and had more regional
impact. Using fMRI, morphine demonstrates a regional effect, decreasing the signal in cortical areas as do
propofol and midazolam, but activating endogenous analgesic regions such as the periaqueductal gray, the anterior
cingulate gyrus (decreased signal), and hypothalamus (increased signal). Midazolam impacts fMRI by significantly
altering the signal in the brain’s auditory and visual cortices. Mechanical maneuvers can also influence imaging
outcomes, such as an increased mean airway pressure (e.g., continuous positive airway pressure) reducing the fMRI
signal in the primary visual cortex.

There are no strong recommendations for anesthetic technique for these diagnostic procedures. Indeed,
functional brain imaging techniques such as PET and fMRI have been used to study the effects of general anesthesia
on the brain, and a systematic baseline response to anesthetics has not yet been developed. If an anesthetic is
required, the anesthesiologist should consider the anesthetic’s impact on cerebral blood flow, metabolism, and
electrical activity and choose agents with minimal effect, combine agents to minimize their effects, and maintain
steady-state anesthetic conditions during the study.

Therapeutic Radiology

Therapeutic radiology has grown from relatively simple percutaneous procedures for aspiration/drainage to complex
embolizations of arteriovenous malformations and the placement of arterial stents. It epitomizes the adage, “There is
no body structure that cannot be reached with a number 14 needle and a good strong arm,” especially now that
structures can be visualized in real time. Minor procedures such as biliary tube placement or exchange, tunneled
catheter placement, vascular interventions, and other catheter insertions have been performed using moderate
sedation, during which nurses, trained in critical care, monitor the patient and administer low-dose midazolam and
fentanyl. Adverse events are few and minor without clinical impact. Less rather than more sedation is the rule in
Europe, although general anesthesia is more common in Europe when anesthesia is utilized. In one East Coast
academic center, MAC or general anesthesia was used for only 10% of cases for interventional radiology.

As it increases in volume and complexity, interventional radiology is more often being performed in emergency
settings and also includes more high-risk patients who cannot tolerate a more invasive (e.g., surgical) intervention,
making an anesthesiologist necessary. The conditions for performing an anesthetic for therapeutic radiology
procedures include those for diagnostic radiology: monitoring from afar, avoiding radiation exposure, working with
radiology equipment and prohibiting ferrous materials in the MRI suites. The choice of anesthetic technique for
interventional radiology is procedure specific with wide variations, depending on the patient and the skill sets of the
interventionalist and associated personnel. The anesthetic presents more challenges because the procedure is
invasive and the patient may have several comorbidities. The goal of a completely still patient, both for the success of the procedure and the safety of the patient, can sometimes be attained by sedation and analgesia administered either by the proceduralist or an anesthesia provider. If a predictable ventilatory pattern in the patient is desired, it can be achieved by the judicious administration of medications to a cooperative patient or by general anesthesia with controlled ventilation. Some particularly painful procedures (e.g., radiofrequency ablation of osteoid osteomas) require a subarachnoid block or general endotracheal intubation by an anesthesiologist. Other procedures associated with extreme fluid shifts (e.g., drainage of ascites fluid or blood loss during a uterine artery embolization) benefit from the presence of someone who is well versed in intravenous access. Some procedures may require anticoagulation and the means to measure its effects (e.g., activated coagulation time).

Fluoroscopy is the imaging modality typically used for endovascular stent placement. There is a significant procedural potential for complications and the patient may have been considered “too sick for open surgery.” Among the anesthetic techniques used for endovascular aortic repair are general, epidural, combined epidural/spinal, spinal, and continuous spinal. Even when performed under MAC, one must be prepared for significant blood loss and invasive monitoring. Mild hypotension, and an immobile patient are important when deploying the stent. Spinal cord injury may be decreased by limiting hypotension, monitoring evoked potentials and cerebrospinal fluid (CSF) pressure, and measuring CSF proteins (S100β) during thoracic aneurysm stenting. An intrathecal drain may be beneficial for thoracic aneurysm procedures, but it may also lead to catheter-related complications. Carotid artery stenting may be superior to traditional carotid endarterectomy in patients who are at overall increased surgical risk. Aspirin and clopidogrel are often administered before the procedure and heparin is given intraoperatively while activated clotting time is monitored. Stenting may be performed in a patient under MAC, with close attention paid to central nervous system changes and bradycardia, or under general anesthesia. General anesthesia depresses baroreceptor reflex sensitivity and induces hemodynamic stability, potentially decreasing complications.

Stenting to improve blood flow through iliac, popliteal, subclavian, or renal arteries does not mandate the presence of an anesthesiologist unless the patient’s comorbidities require it. Stenting of venous outflow has been used for chronic nonmalignant or malignant obstruction of the femoropopliteal vein, and patients with neoplastic superior vena cava syndrome have received palliative stents without sedation. A transjugular intrahepatic portosystemic shunt relieves portal hypertension by using an expandable metallic stent to create an artificial channel between the branches of the portal and hepatic veins. It is typically performed under MAC or general anesthesia, with the patient’s mental status, ability to tolerate the procedure without moving, overall hemodynamic status, and ease of airway management dictating the type of anesthesia. Significant comorbidities can include pathological shunting in vascular beds, leading to increased cardiac output and heart failure. Ascites, pleural effusions, intrapulmonary shunting, pulmonary hypertension, hepatorenal syndrome, encephalopathy, and coagulopathies are common in these patients. Because of hepatic insufficiency, the anesthetic agents selected should not depend on the liver for clearance. A cirrhotic cardiomyopathy is prone to a prolonged Q-Tc interval, which may deteriorate into a torsades de pointes arrhythmia.

Thrombolysis results from the local infusion of tissue plasminogen activators that create plasmin with ensuing fibrinolysis. Common agents include streptokinase, urokinase, and recombinant formulations. Thrombolysis is used in patients with myocardial infarction, ischemic stroke, pulmonary embolism, thrombosed dialysis access, portal vein thrombosis, and acute limb ischemia. Anesthesia is seldom required, but if it is, the anesthetic depends on the patient’s comorbidities and avoiding trauma during airway maneuvers. Neuaxial regional anesthesia is contraindicated.

Inferior vena cava filters are placed in patients who have a history of or who are at risk for deep vein thromboses in the lower extremities. Access is obtained through the right internal jugular vein or a femoral vein. The procedure may be performed without sedation, although anxiolysis or moderate sedation may be administered by the interventional radiologist. General anesthesia or MAC is occasionally necessary.

In balloon angioplasty, a narrowed or obstructed blood vessel is widened with a balloon-tipped catheter. Carotid angioplasty has been performed with deep cervical plexus blockade, MAC, or general anesthesia. The same concerns apply as for carotid stenting, which is often preceded by balloon angioplasty. Relatively minor procedures,
such as percutaneous transluminal angioplasty of the infrarenal aorta, can be safely performed with only local anesthesia by the interventionalist. A catheter is inserted into the femoral artery and guided under fluoroscopy into the hepatic artery. Contrast material is then injected to identify the arterial supply to the tumor. A chemotherapeutic agent such as doxorubicin is then injected, followed by an embolic agent such as iodized poppy seed oil, which both limits the tumor’s blood supply and traps the agent in close proximity to the tumor. Combination therapy with cisplatin, doxorubicin, and mitomycin C often enhances the tumor-specific toxicity. The procedure is typically performed without an anesthesiologist. If anesthesia is requested, the primary anesthetic concerns are patient comorbidities, coagulopathies, and hepatic insufficiency.

Vascular access is the placement of catheters in large veins for the infusion of medications (e.g., chemotherapy, parenteral feedings, antibiotics), dialysis, or blood sampling. Adults seldom require an anesthetic for catheter placement, but if anesthesia is needed, special attention is given to the patient’s coexisting diseases and to the risk of air emboli through an open, large-bore catheter during spontaneous ventilation.

Uterine fibroids, varicoceles, esophageal varices, and arteriovenous malformations can be embolized under fluoroscopy. A catheter is inserted through a large artery or vein with the tip positioned near the structure to be embolized. Particles (e.g., gelfoam or particulate agents such as gelatin-impregnated acrylic polymer spheres), sclerosing agents (e.g., alcohols), metal coils, or liquid glue are used. The procedure is typically performed without an anesthesiologist.

For uterine artery balloon occlusion in parturients at risk for hemorrhage, both general and epidural anesthesia have been utilized. An epidural catheter is placed before the balloon catheter is inserted to avoid displacement of the balloon when the patient is positioned and to provide analgesia should the patient undergo a cesarean section. Preparations should be in place for adequate intravenous access and invasive monitoring.

In percutaneous nephrolithotomy, medium-sized or larger kidney stones are removed from the urinary tract with a nephroscope. The patient is placed prone and a track is created through a small incision above the kidney, through which dilators and finally the nephroscope are inserted. If the stones are small, they may be removed directly. For larger stones, percutaneous nephrolithotripsy can break up the calculi into manageable pieces; this procedure typically requires a neuraxial block or general anesthesia. Risks include excessive fluid absorption, dilutional anemia, hypothermia, the potential for significant blood loss, and renal insufficiency. Potential complications are many and include pneumothorax or hydrothorax, pneumonia/atelectasis, paralytic ileus, nephroscopy tube dislodgment, urine drainage from the flank lasting more than 1 week, infection, urinoma formation, renal pelvic laceration, ureteral avulsion, ureteropelvic or ureteral stricture, bowel injury, or escape of stone fragments into the retroperitoneum.

Percutaneous biliary drainage may be performed with local anesthesia at the site of the drain tube and with supplemental intravenous sedation and analgesia. When pain is anticipated from large drainage catheters or dilatation of the transhepatic tracts, epidural or general anesthesia is recommended. Hepatic insufficiency and the potential for blood loss should be considered.

Ablative therapies demand cross-sectional images for accurate needle, probe, or catheter placement, which is accomplished with CT, MRI or ultrasound imaging. The same general imaging-specific caveats apply as for other therapeutic and diagnostic procedures. Thus, radiation exposure in the CT suite is monitored, and precautions against ferrous materials are taken in the MRI suite. The preanesthesia evaluation focuses on patient comorbidities. Hyperthermic ablation includes radiofrequency (RFA), microwave, or laser ablation. In RFA, the most common procedure, electrical currents in the radiofrequency range heat an electrode that has been percutaneously or directly placed within a tumor, with kidney, lung, breast, bone, and liver being common targets. Because healthy tissue is better able to withstand heat, radiofrequency energy preferentially destroys the tumor and only a small edge of normal tissue around its edge. The heat also “cauterizes” small blood vessels, potentially reducing hemorrhage. Moderate sedation is often adequate for the percutaneous approach. General and epidural anesthesia are often used for RFA of renal cell tumors. Since the ablation process produces heat, precautions must be taken when the electrode is adjacent to critical structures. For example, during RFA for a mediastinal lymph node, a temperature probe was applied to the endotracheal tube cuff to monitor the tracheal temperature. When temperature rose, chilled saline was substituted for air in the cuff to prevent tracheal trauma.
Cryoa b lation is used for tumors in the lung, liver, breast, kidney, or prostate. Liquid nitrogen or gaseous argon destroys tissue by direct freezing, denaturation of cellular proteins, cell rupture, cell dehydration, and ischemia. Patient comfort and safety have been provided with local or general anesthesia. In lung cryoablation, inflammation may result from the thawing phase of the ablated tissue. Cracking of a cryoablated liver may cause significant hemorrhage.

Interventional Neuroradiology

Interventional neuroradiologists use imaging techniques combined with catheters and other devices to treat vascular lesions in the central nervous system (CNS) and surrounding tissues. They either occlude blood flow through abnormal vessels or increase blood flow in occluded vessels. Cross-sectional imaging techniques assist in diagnosis, and the procedures are performed under fluoroscopy. Anesthesiologists are often needed because of the complexity of the procedure, the medical status of the patient, or the need for immobility. The preanesthesia assessment focuses on the patient's neurologic status and comorbidities. An anesthetic plan must consider the potential for disease progression or iatrogenic complications. Consultation with a neuroradiologist determines whether the patient must be responsive for continuous CNS evaluation or whether rapid emergence from general anesthesia is preferred. Anesthetic medications for a responsive (MAC) patient include propofol, dexmedetomidine, and fentanyl; for general anesthesia, propofol, sevoflurane, and desflurane. Nitrous oxide should be avoided because of the potential for enlarging emboli. Laryngeal mask airways may be considered for airway management.

Intraprocedural concerns include elevated intracranial pressure, hemorrhage, blood pressure, and cerebrovascular occlusion. Control of carbon dioxide may be necessary for certain procedures. Hypercapnia has been used to vasodilate cerebral vessels for catheter entry, to enhance catheter propagation during superselective cerebral catheterization, and to increase cerebral venous outflow, thereby favoring movement of an embolizing agent away from intracranial drainage pathways. Hypocapnia may be used to decrease cerebral blood flow and lower intracranial pressure. Patient considerations include temperature, either warm for comfort or cool for cerebral protection. Bladder distention may be a concern because these are often lengthy procedures and intravascular volume/renal perfusion must be maintained in the presence of a dye load.

In addition to routine monitors, an arterial line may be helpful if the procedure requires hypertension or hypotension. An arterial line also enables the anesthesiologist to maintain the delicate balance between intracranial pressure and cerebral perfusion pressure and to better diagnose and treat hemorrhage. If arterial monitoring will be needed after the procedure, a peripheral site (e.g., radial artery) may be preferred to the side port of the introducer sheath. Intravenous access should always be adequate and blood products should be available as indicated.

Vertebroplasty and kyphoplasty are typically used to treat vertebral compression fractures. Patients are typically elderly with significant comorbidities, including diminished pulmonary function associated with the vertebral fracture. The procedures may be performed with general anesthesia or local anesthesia with sedation and analgesia. After the patient is placed prone, trocars are inserted on each side of the involved vertebral body under fluoroscopic or CT guidance. Polymethylmethacrylate (PMMA) is injected via a trocar into the medulla of the vertebral body under direct visualization. In kyphoplasty, a balloon is inserted through the trocar to restore the intervertebral distance before PMMA is injected. If PMMA leaks into perivertebral veins, it can cause radiculopathy, embolization, or interference with pulse oximetry readings. The most severe complication of PMMA leakage is spinal cord compression that requires immediate surgical decompression. Other complications associated with PMMA leaks are hypotension, hypoxemia, cardiac arrhythmias, and pulmonary embolism.

Anesthesia for the endovascular coiling of cerebral aneurysms ranges from none to general anesthesia. Many radiologists prefer general anesthesia for patient comfort and safety and to obtain optimal conditions for imaging, even though general anesthesia may mask the clinical signs that guide the progress of the procedure. Patients with a subarachnoid hemorrhage because of a leaking or ruptured aneurysm are at risk for increased intracranial pressure, cerebral ischemia, and hydrocephalus. Patients with a ventricular drain are at risk for transmural pressure changes and re-bleeding with elevated arterial pressure.

Patients with an arteriovenous malformation (AVM), a steal phenomenon that may lead to the loss of autoregulation in the surrounding brain tissue as chronic vasodilation compensates for the steal, may suffer
spontaneous hemorrhage and have seizures or other neurological symptoms because of ischemia or venous hypertension. 68

General anesthesia is often preferred for embolization of an AVM because it facilitates visualization of structures and prevents patient movement. Hypertension is controlled by reducing the anesthetic or administering vasoactive agents that may help “float” a flow-directed catheter into the desired vessels. The most common AVM embolic agent is the fast-polymerizing liquid adhesive n-butyl cyanoacrylate (n-BCA); a new liquid agent, Onyx, has recently been introduced. 69 During injection, Valsalva maneuvers and controlled hypotension may reduce the gradient across the AVM and diminish the amount of distal adhesive embolization. 69 When the AVM is embolized and steal ceases, the surrounding brain may suffer hyperperfusion injury unless the cerebral blood flow is aggressively controlled with nitroprusside or other agents.

Pial and dural arteriovenous fistulas (AVFs) are direct shunts between an artery and a vein and may be associated with extremely high blood flow. Clinical characteristics include bruit, neurologic symptoms or intracranial hemorrhage. Children may have concomitant high-output cardiac failure. 70 Transarterial embolization for high-flow, single-hole fistulas is performed with balloons, coils, stents, or n-BCA. 62

Cerebral thrombolytic procedures are most often performed on awake individuals, but their tenuous medical status may mandate an anesthesiologist’s presence. Anesthesia concerns include altered mental status, airway protection, control of patient movement, and management of intracranial pressure.

Embolization of cerebral tumors also may be associated with the consequences of a steal phenomenon because of the hypervascular nature of these tumors. Hypotension should be avoided before embolization and hypertension should be avoided after it. Other concerns include greater intracranial pressure from brain edema, which may be treated with steroids.

Neurophysiologic monitoring helps gauge the progress of an intervention. In a patient under general anesthesia, it signals impairment so that the insult may be reversed promptly. The EEG, somatosensory evoked potentials (SSEPs), and brainstem auditory evoked potentials can be critical for the successful endovascular treatment of cerebral aneurysms under general anesthesia. 71 Muscle motor evoked potentials can indicate spinal cord perfusion in the anterior spinal artery during endovascular procedures and complement SSEPs. 72 Transcranial Doppler ultrasonography directly measures regional cerebral blood flow (rCBF) in arteriovenous malformations, aneurysms, and arterial stenoses. 65 Other direct measures of rCBF include radionuclide CBF (e.g., technetium) studies and xenon CT. 71 Since anesthetics often have an effect on measurements, the anesthesiologist must be in close communication with monitoring personnel to distinguish between an anesthetic artifact and a new neurologic deficit.

Two devastating complications of interventional neuroradiology procedures are intracranial hemorrhage and thromboembolic stroke. 73 The incidence of these two complications during coiling of cerebral aneurysms is 2.4% and 3.5%, respectively; during embolization of arteriovenous malformation it is 1%–8%. 74 Arterial pressure can increase suddenly with acute intracranial hemorrhage and should be controlled immediately. Heparin reversal may be necessary along with a decrease in arterial pressure. Hyperventilation and mannitol should be considered to reduce intracranial pressure. Hemorrhage due to perforation can often be treated with coiling, although emergency craniotomy and clipping may be required if coiling fails.

Occulsive events can be thrombotic, embolic, or vasospastic. For all, the arterial pressure should be raised to increase collateral blood flow while normocarbia is maintained. Thrombi may be treated by mechanical lysis with a guidewire, normal saline, or thrombolytics. Misplaced coils may be retrieved endovascularly or via craniotomy. Vasospasm may be treated with papaverine or nicardipine, 75 cerebral angioplasty 76 or by increasing arterial pressure and volume while decreasing blood viscosity through hemodilution. 63 Maintaining hypotension with antihypertensive agents such as labetolol or esmolor may be beneficial after AVM embolization to prevent cerebral edema and hemorrhage. Using phenylephrine or norepinephrine, a mean arterial pressure 20%–30% above normal can maintain cerebral perfusion in patients with occlusion or vasospasm. 62

Recovery

Recovery of any anesthetized patient is governed by the ASA standards for postoperative care. 4 Ideally, nursing care should conform to the Standards of the American Society of PeriAnesthesia Nurses, and the facilities and equipment for recovery should be commensurate with the complexity of the patient. Medically stable patients who have undergone innocuous procedures under MAC (MRI, inferior vena cava filter) can often recover en suite.
provided that the nurses are trained and an anesthesiologist is available. Patients who have received regional or general anesthesia or who are at risk for pain (e.g., radiofrequency ablation for hepatocellular carcinoma) or procedural complications (e.g., aortic stent graft) recover in a dedicated postanesthesia care unit or an intensive care unit. Resuscitation equipment, oxygen, and monitors should be available for transport from the radiology suite.

Summary

As radiologic interventions become more common, the need for anesthesia care will increase. While a patient’s comorbidities are addressed and other concerns are similar to those in a surgical setting, the additional requirements and constraints of the imaging environment and the procedure call for specific approaches and techniques. Just as in the operating room, there is frequently no single best anesthetic technique for a given procedure. The technique is designed and implemented according to the demands of the procedure and the skill sets of the providers. Patient safety always takes precedence, and a location should never be permitted to compromise care. In any case, the patient deserves care that is consistent with the parameters, guidelines, and standards established by the various accrediting agencies and professional societies.

REFERENCES


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