REVIEW ARTICLE

Anesthesia for interventional radiology

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Summary

Pediatric patients in the neurointerventional radiology setting pose the dual challenges of caring for relatively sick patients in the outfield environment. For safe and successful practice, the anesthesiologist must not only understand the nuances of pediatric anesthesia and the physiologic demands of the cerebral lesions. They must also help maintain a team-based approach to safe, compassionate care of the child in this challenging setting. In this review article, we summarize key aspects of success for several of these topics.

Introduction

The care of pediatric patients in interventional radiology (IR) exemplifies the credo that 'children are not small adults'. In the adult IR suite, an anesthesiologist is a rarity, and the vast majority of procedures are accomplished in patients who are awake or lightly sedated. This is not the case in the pediatric neurointerventional setting; many if not most procedures require the assistance of an anesthesiologist for safe and successful completion. As an essential part of the pediatric neurointerventional radiology environment, the anesthesiologist perforce plays many roles. The physiologic and developmental effects of anesthesia on children of all ages must be well understood. The anesthesiologist requires as well an understanding of the physiology of the cerebral lesions to be treated, the requirements for successful treatment and the potential effects of the proposed treatment. In addition to these obvious responsibilities, the anesthesiologist in this outfield environment has an important role to play in developing a collaborative approach to patient care and safety, as there is rarely a situation in which a 'one-size-fits-all' approach will suffice. In this article, we will review some of the procedures requiring anesthesia, both diagnostic and therapeutic, which are performed on the pediatric patient in the neurointerventional radiology suite.

Safety

Patient and provider safety must both be considered when working in the neurointerventional suite. Patient safety concerns in large part can be categorized under the greater rubric of safety for non-OR anesthesia (NORA). The NORA environment has long been recognized as presenting unique challenges to safe patient care (1). These challenges notwithstanding, there are many factors that can be modified to enhance patient safety in the outfield.

It is commonly recognized that older anesthesia equipment is to be found in the NORA milieu (2,3). Closed-claims data have demonstrated that patients in the NORA environment are more likely to suffer more serious harm, and inadequate monitoring is cited as a contributor (4,5). The neurointerventional suite, where lengthy complex cases are performed on sicker patients, should have anesthesia equipment that is standardized with that being used in the main operating room. This

promotes safety not only by allowing the use up-to-date technology for complex patients, but also by reducing the chance of operator unfamiliarity with infrequently used devices.

The distance between the interventional suite and the main operating room cannot be changed in the absence of a dedicated IR-operating room, which is in many cases prohibitively expensive. What can be accomplished is the institution of a culture of safety in the IR suite. Communication, particularly for emergencies, between the IR suite and the 'mother ship' should be standardized (6), so that anesthesia staff can be efficiently summoned when needed. However, it cannot be strongly enough emphasized that the staff in the IR suite are the closest resource in case of emergency. By inculcating a team-based approach to patient care, which includes simulation of emergency events, a well-coordinated group of nurses and technologists *in situ* can assist the anesthesiologist in the event of a crisis (7,8).

Intravenous contrast is almost invariably used in neurointerventional procedures, and thus the anesthesiologist must be well-versed in the recognition and treatment of contrast reaction. Reactions to contrast, whose mechanism is likely anaphylactoid (9), occur in 1–3% of cases (10), and most commonly occur within the first hour of administration. Reactions can range from rash to full-blown bronchospasm and cardiovascular collapse. Treatment is supportive and can include antihistamines, steroids, and hemodynamic and/or airway support when indicated (11). Patients at high risk of contrast reaction, such as those with a prior history of a reaction or a history of asthma or atopy, should be pretreated with steroid and antihistamine.

Patient safety is obviously at the forefront of the anesthesiologist's mind, but this should not be at the expense of personal safety. It is incumbent on every anesthesiologist to appropriately protect themselves from radiation. Radiation is particularly insidious, as there are no external indicators such as heat or light that potentially harmful exposure is occurring. There is no minimum acceptable dose of radiation, and the effects of exposure–increased incidence of cancer or cataracts–do not manifest themselves for decades (12,13). In the procedure room, anesthesiologists' exposure to radiation is threefold greater than that of radiologists' on the opposite side of the procedure table due to scatter radiation (14). To reduce exposure, anesthesiologists should wear lead aprons, preferably wrap-around, and protective eyewear. Portable lead shields should be placed between the radiation source and the anesthesiologist (Figure 1). If feasible, the anesthesiologist should leave the room during angiography 'runs' (15). Portable dosimeters should be worn and monitored in

Figure 1 Representative setup of room demonstrating appropriate protection for the anesthesiologist. Note wrap-around lead apron, lead glasses, portable shield between anesthesiologist and the two X-ray sources (anteroposterior and lateral in this case).

compliance with local regulations. As most neurointerventions are performed with biplane imaging, the dose to the anesthesiologist is increased, making these precautions even more necessary.

Cerebral angiogram

Diagnostic cerebral angiography is the most common and least physiologically deranging neurointerventional procedure performed on pediatric patients. While noninvasive imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI) have become increasingly useful in the elucidation of intracranial pathology, cerebral angiography is still considered the 'gold standard' for the diagnosis of neurovascular pathology (16). Some of the more common indications for cerebral angiography include hemorrhage, stroke (including that from vasculopathies such as Moyamoya disease) and postoperative evaluation of cerebrovascular interventions (17).

The requirements for a successful procedure are few: an immobile patient and the ability in most cases to provide intermittent moments of apnea. General endotracheal anesthesia is most commonly used in children to provide these conditions (17). While a more mature patient may be able to cooperate with this procedure with no adjunct or with light sedation to relieve anxiety, any deeper levels of sedation increase the risk that the patient will be unable to comply with breath holding. In situations where sedation is deemed to be the appropriate choice from an anesthetic perspective, it is essential to communicate with the neurointerventionalist and confirm that the image quality without apnea will be acceptable.

Considerations for anesthetic management of patients for this relatively quick procedure (generally less than 1 h) include blood pressure, fluid management, and postprocedure care. Care must be taken, particularly with induction of anesthesia, to avoid hypotension which can put patients with a vasculopathy such as Moyamoya at risk of cerebral hypoperfusion (18). On the other hand, acute hypertension, which could precipitate catastrophic bleeding in an unstable aneurysm or arteriovenous malformation (AVM), must also be avoided. An arterial line for this short procedure is generally unnecessary. Normocapnia is desirable in the vast majority of cases, and any proposed acute hypocapnia should be discussed with the proceduralist. While the risk of significant bleeding is extremely low, intravenous access, which is sufficient to allow for adequate hydration, is necessary. Normo- to slight hypervolemia can offset the diuretic effect of the nonionic contrast medium and reduce the slight chance of any contrast-induced nephropathy (19).

One of the challenges for a pediatric patient after a cerebral angiogram is that for hemostasis, they must lie flat for several hours after the femoral arterial sheath is removed (19,20). While behavioral techniques and the presence of parents can help reassure and distract an older or more cooperative child, medications have a role for younger or less cooperative children. Deep extubation when feasible and a period of quiet sleep in the recovery area with narcotics or α-2 agonists as adjuncts can be quite helpful (21).

Complications after cerebral angiography in pediatric patients are quite rare. Several series from busy pediatric centers have demonstrated rates less than 0.4% with experienced neuroradiologists (17,22,23). The most common of these rare problems is bleeding or hematoma at the site of femoral puncture (24). Neurologic or vascular problems as a result of catheterization are very rare, as are nephrologic consequences of contrast administration.

Therapeutic neurointerventions

Indications for neurointerventional procedures include embolization of intracranial vascular anomalies, such as arteriovenous malformations (AVM) (Figure 2), arteriovenous fistulae and aneurysms, targeted injection of intra-arterial chemotherapy for tumors, and presurgical embolization of both AVMs and tumors of the head and neck.

Therapeutic interventions in the neurointerventional suite stand in contrast to the relatively quick, minimally deranging diagnostic cerebral angiogram. These procedures can take many hours, with procedures over 8 h not being uncommon. Careful attention to patient positioning and padding is essential; once catheters are deployed in the cerebral vasculature, it may be impossible to reposition a patient. With very few exceptions, neurointerventions in children are performed on patients under general endotracheal anesthesia with consistent muscle relaxation (25,26). Patient motion could be dangerous, and frequent periods of apnea are generally required.

Good intravenous access is necessary, primarily for hydration and drug administration. The chance of significant blood loss is extremely small. Euvolemia to slight hypervolemia is again recommended to offset the osmotic diuretic effect of contrast (11). It is important to bear in mind that to reduce the risk of microemboli (27), a continuous infusion of heparinized saline is instilled via the femoral sheath through the guide catheter. This can result in a significant amount of fluid delivered to the patient by the neuroradiologist. Patients are often heparinized to an activated clotting time of 250–300 s (28).
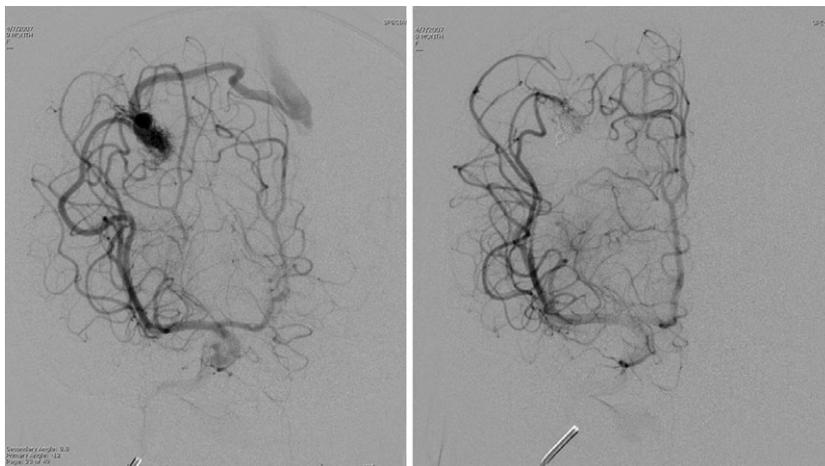
Figure 2 Angiography before (left) and after (right) embolization of frontal lobe AVM in a 9 month old.

Arterial lines for close blood pressure monitoring are usually required. Blood pressure parameters should be agreed upon by the neurointerventionalist and anesthesiologist prior to the case. While deliberate hypotension and even induction of asystole have been described to facilitate injection of glue into high-flow lesions (25), these have not been well-described for pediatric patients. The technique of balloon-assisted glue embolization may render such radical measures unnecessary (29).

Some hemodynamic alterations may be observed during neurointerventions. Embolization with ethylene vinyl alcohol copolymer glue (Onyx, Covidien, Plymouth, MN) has been reported to induce bradycardia (30). Embolization of high-flow AVMs, which have already resulted in some degree of high-output heart failure, may result in immediate improvement in the patient's status (28).

Embolization of brain AVMs carries the risk that perfusion to surrounding normal brain tissue may be compromised, with a concomitant loss of function. Several groups describe the use of sedation rather than general anesthesia so that a patient's motor, language, or visual function can be assessed during test injections of agents such as amobarbital prior to definitive closure of a feeder vessel (31–33). However, in the vast majority of cases reported, this assessment was performed on adult patients, and some authors specifically note that children in their case series received general anesthesia and were monitored by other means, such as somatosensory-evoked potentials (31). Several factors have been identified as risk factors for failed provocative testing. These, unsurprisingly, include younger age (less than 10–13 years depending on the study) and developmental delay (34,35).

Alterations in flow dynamics within a cerebrovascular lesion peri-intervention may result in a period of increased hemorrhage risk (36–38), and this is particularly true of partial embolizations such as those before a surgical resection. Descriptions of postprocedure care of these patients have emphasized close control of blood pressure (39), avoiding abrupt increases in pressure. While there are few descriptions of techniques for achieving this goal, our group has had success with a continuous infusion of dexmedetomidine following extubation for the first night in the intensive care unit.

Embolization of an AVM or a tumor in preparation for surgical resection can occur either under a single anesthetic or in separate sessions. It is not uncommon for this to occur as separate anesthetics, as both the embolization and the resection can be quite long procedures. As mentioned above, close control of blood pressure after partial embolization of an AVM is extremely important. When a patient is going to be embolized and resected in one session, they are likely to require transport under anesthesia from the IR suite to the main operating room. While hybrid operating suites that incorporate high-quality angiography exist (40), they are not widespread. Transport should be performed with attention to support of the airway and control of hemodynamics, making sure that a patient's level of sedation does not decrease to the point where blood pressure spikes can occur.

Injection of intra-arterial chemotherapy carries some unique challenges for the anesthesiologist. Depending on the site of the tumor, the radiologist may require pharmacologic assistance to direct the dispersion of medication; in the treatment of retinoblastoma, oxymetazoline nasal spray to preferentially drive flow in the ophthalmic artery to the optic component is utilized (41). Injection of the chemotherapeutic drug in retinoblastoma has been associated with a not-insignificant risk of bronchospasm, and thus, agents such as albuterol are often given at the time of instillation (42). Nausea and vomiting can certainly be increased postoperatively in these patients, and aggressive prophylaxis may be necessary to prevent a child with a fresh femoral puncture from repeatedly retching and vomiting.

Conclusion

Anesthesiologists caring for pediatric patients in the neurointerventional suite have many tasks. As experts in the physiology of both anesthesia and the changes expected to occur during a proposed procedure, they are the final arbiter of whether a patient is medically prepared to undergo a procedure in an offsite location with potentially limited access to backup help. They are the coordinators of the care team in the procedure room, tasked with ensuring that every person is focused on the safety of the patient and success of the procedure (in that order), regardless of their role. They act as a psychological support to fearful patients and parents prior to the procedure, reassuring them that the child's safety and comfort are of equal importance to the entire team. Only by successfully integrating all of these tasks can a consistently safe and successful pediatric neurointerventional service be facilitated.

Acknowledgment

Conflict of interest

No conflict of interests declared.

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