CURRENT OPINION

Anesthesia care in the interventional neuroradiology suite: an update

Corina Bello[a], Chanannait Paisansathan[b], Thomas Riva[a,c], Markus M. Luedi[a], and Lukas Andereggen[d]

Purpose of review

The scope of procedures conducted by neurointerventionalists is expanding quickly, with lacking consensus over the best anesthesia modality. Although the procedures involve all age groups, the interventions may be complex and lengthy and may be provided in hospitals currently not yet familiar with the field. Here we review current literature addressing elective outpatient neurointerventional procedures and aim to provide an update on the management of intervention-specific crises, address special patient populations, and provide key learning points for everyday use in the neurointerventional radiology suite.

Recent findings

Various studies have compared the use of different anesthesia modalities and preinterventional and postinterventional care. Monitored anesthesia care is generally recommended for elderly patients, whereas children are preferably treated with general anesthesia. Additional local anesthesia is beneficial for procedures, such as percutaneous kyphoplasty and vascular access.

Summary

Combining different anesthetic modalities is a valuable approach in the neurointerventional radiology suite. More interventional and patient population-specific studies are needed to improve evidence-based perioperative management.

Keywords

interventional neuroradiology, monitored anesthesia care, nonoperating room anesthesia

INTRODUCTION

Anesthesia service is not commonly requested for procedures in the interventional neuroradiology (INR) suite except during an emergency, such as endovascular treatment for stroke or aneurysmal subarachnoid hemorrhage (SAH). However, with the increasing complexity of procedures conducted by interventional neuroradiologists, adequate planning of sedation and peri-interventional management must be a multidisciplinary goal as practiced in other interventional specialties, such as cardiology [1]. Ongoing development in radiology and data science, such as preprocedural radiomic texture analysis mapping to predict functional activity, will likely further shape the complexity of INR in the near future [2]. In this review, we focus on elective peri-interventional anesthesia care in the INR suite for the less familiar anaesthesioligist.

SPECTRUM OF PROCEDURES IN THE INTERVENTIONAL NEURORADIOLOGY SUITE AND ORGANIZATIONAL CHALLENGES

The treatment of acute stroke with endovascular recanalization remains a key procedure handled in the INR that requires immediate intervention, with

[a]Department of Anaesthesiology and Pain Medicine, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland, [b]Department of Anesthesiology, University of Illinois at Chicago, Chicago, Illinois, USA, [c]Unit for Research & Innovation in Anaesthesia, Department of Paediatric Anaesthesia, Istituto Giannina Gaslini, Genova, Italy and [d]Department of Neurosurgery, Kantonsspital Aarau, Aarau, Switzerland, Faculty of Medicine, University of Bern, Bern, Switzerland

Correspondence to Lukas Andereggen, Department of Neurosurgery, Kantonsspital Aarau, Aarau, Switzerland.
E-mail: lukas.andereggen@ksa.ch

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KEY POINTS

- The scope of interventional neuroradiology is expanding rapidly, and a consensus over the best modality of anesthesia care for most procedures is still lacking.
- Standard preinterventional assessment, intraprocedural and postprocedural monitoring, and safety protocols are needed, particularly in the outpatient setting.
- Procedure-specific emergencies call for crisis-management algorithms that have to be composed by interdisciplinary teams.

even minimal delay having potentially fatal consequences [3]. With abundant data about the best peri-interventional care for stroke patients but a paucity of evidence for elective procedures [4▪▪,5▪▪], this review focuses on INR interventions in the later cohort.

Elective diagnostic and therapeutic procedures performed in the INR suite include but are not limited to interventions to treat arteriovenous malformations (AVMs) or dural arteriovenous fistulas, intracranial aneurysms, carotid artery stenosis (CAS), refractory cerebral vasospasms from SAH, venous angiomas, retinoblastoma, and Vein of Galen malformations. In addition, neuromodulation for the treatment of chronic back pain because of spinal cord lesions [6] or percutaneous kyphoplasty (PKP) for osteoporotic vertebral compression fractures is increasingly performed in the INR suite.

Due to the interplay of specialists from different backgrounds, basic institutional standards and procedural action plans are vital to ensuring effective collaboration [7]. By definition, procedures in the INR suite require real-time imaging. Thereby, patients must stay immobile to avoid procedural fatalities, facilitate imaging, prevent motion artifacts, and reduce radiation exposure. In addition, rapid recovery allowing for timely neurological examination after the procedures is important for assessing and treating sudden changes in the level of consciousness or neuromotor function, which otherwise can result in permanent damage [8]. The use of heparin during the procedures, and its reversal in certain emergency scenarios [8], complications, such as allergic reactions to contrast medium [9], intraprocedural thrombosis, or risk of bleeding [10] bring additional complexity to interventions in the INR suite. Safe and efficient management of such procedures is only possible with comprehensive preprocedural assessment, peri-interventional planning, and systematically organized postprocedural care.

PREINTERVENTIONAL ASSESSMENT

A preexisting hypertensive crisis, nausea-vomiting, epileptogenic state, agitation and anxiety, or a history of the difficult airway may complicate elective INR procedures even in otherwise healthy patients. Baseline blood pressure (BP), oxygen saturation (SO_2) at rest, and respiratory rate should be evaluated according to international standards.

Concomitant respiratory problems such as obstructive sleep apnea, chronic obstructive pulmonary disease, asthma, and other health conditions, such as advanced (above 80–85 years) or very young (below 6 years) age, preexisting cardiovascular or neurologic disease, bleeding history, BMI, and hepatic or renal function impairment need to be assessed [11]. There is still no consensus on preinterventional kidney protection from contrast media used in the INR [12,13]. Advice on fasting should be given according to international standards [14].

INTRAPROCEDURAL PHYSIOLOGY AND ANESTHESIA

Blood pressure management is to be personalized in close collaboration with the proceduralist. Although, for example, placement of material to occlude aberrant vessels may require the temporary induction of hypotension to decrease the risk of bleeding or material displacements [15], controlled hypertension is needed to alleviate vasospasms [16]. Autoregulation of intracerebral blood flow (CBF) within 50–150 mmHg of arterial BP [17] is not only often altered in patients with chronically high BP but also in certain AVM or SAH patients [18]. Also, hypercarbia significantly dilates brain vessels, thereby increasing brain perfusion [19]. In patients suffering from intracranial tumors, the blood–brain barrier and the autoregulatory processes can be disturbed in manners known from traumatic brain injury or bleeding to the extent that cerebral perfusion pressure (CPP) adapts to systemic BP [18].

Local anesthesia of the puncture sites is key in the INR suite [20], not only for patient comfort but also as autoregulation of CBF can be persevered. Yet, hypotension and bradycardia, for example, during placement of a carotid artery stent with simultaneous stimulation of the sinus carotid sinus, is frequent in patients undergoing procedures with local anesthesia only [20].

Monitored anesthesia care (MAC) with minimal sedation (patients remain responsive and cardiovascular and respiratory functions are unaffected) or moderate sedation/conscious sedation (a dissociative state with maintained response to verbal commands or soft tactile stimulation) [21] with local anesthesia of the puncture site is becoming a frequent modality in the INR suite [22,23▪]. Thereby, the aim is primarily to reduce consciousness while increasing the tolerance for painful stimuli (conscious sedation). Mandatory monitoring includes pulse oximeter (SO_2), noninvasive BP, ECG, and capnography, and adequate oxygen supply (nasal cannula/face mask) should be preinstalled [24,25▪▪].

Deep sedation, defined as a depression of consciousness with response to repeated or painful stimuli only [21], are accompanied by higher risks of life-threatening complications, such as a loss of a secured airway, hypoxemia, and cardiac arrest [21,24,25▪▪,26]. Simple measures to improve patient comfort, for example, convenient placement on the intervention table, can help reduce the need for anxiolytics and sedatives [9]. Furthermore, adequate vascular access with a large-bore cannula, extension tubing, and preinstalled medication to manage hypotension (norepinephrine infusion) needs to be established. Adequate airway equipment and rescue medication [25▪▪] have to be promptly available.

For INR procedures, general anesthesia (defined by a loss of consciousness without response to painful stimuli) requires smooth induction and quick but calm emergence, which is particularly important in patients with intravascular disorders. A combination of propofol and fentanyl or ketamine can provide hemodynamic stability [27]. High sympathetic surge during airway manipulation might cause hypertensive reactions [16], leading to fatal outcomes in particular in the anticoagulated patient. Given that the patient is usually not accessible during the procedures, airway management with tracheal intubation appears advisable. Maintenance of anesthesia is achieved with totally intravenous anesthesia (TIVA) for intracranial procedures or with volatile anesthetics, for example, for kyphoplasty procedures. Patients treated with sevoflurane emerge faster as compared with propofol infusion [28]. Desflurane, compared with sevoflurane and isoflurane, increases CBF and leads to loss of cerebral autoregulation more frequently; however, this difference was less evident when patients were hyperventilated in an attempt to decrease CBF [29].

Which agent is best for general anaesthesia in the INR suite remains unclear. There is a general consensus to avoid nitrous oxide because of the risk of intravascular microbubbles during contrast injection [16]. It is desirable to assess the depth of anesthesia with cerebral neuromonitoring [30], but it is often not practical because of significantly disturbing imaging quality for the interventionalist. In addition, intraprocedural, INR patients are at high risk of hypothermia, and forced warming is needed [16].

There is still no consensus on calcium channel blockers (CCB) or calcium channel reuptake inhibitors (CRI) for prophylactic cerebral protection. Some evidence suggested that oral nimodipine taken prophylactically before a planned intervention decreases catheter-induced vasospasms [9]. For smooth emergence, administering lidocaine 1.5 mg/kg can help prevent coughing [31].

Specific procedure-related considerations

Although a general algorithm (Fig. 1) can help to reduce stress in any type of INR emergency, procedure-specific considerations remain. Hereafter, we discuss some common intervention-specific challenges and management strategies.

INTRACRANIAL ANEURYSMS

An increased share of patients presenting with intracranial aneurysms is treated with interventional coil embolization or flow diverters [32]. A decision to use a preemptive therapeutic approach for unruptured aneurysms should be weighed against the odds of developing spontaneous bleeding, and the decision should be made by a multidisciplinary team [33]. It is common to administer anticoagulation preprocedural to combat the high risk of arterial thrombosis [34]. Still, increased ICP, SAH-dependent decreased intracranial compliance, and parenchymal injury from ischemia or hydrocephalus can occur at any time. An anesthesia provider can detect sudden bradycardia and hypertension from the Cushing reflex in response to increased ICP [35] and sometimes extravasation of contrast [10]. In addition, patients suffering from refractory cerebral vasospasms secondary to aneurysmal SAH may undergo intra-arterial CCBs or CRIs or balloon angioplasty for more proximal vasospasms [36,37]. CCBs and CRIs have vasodilatory effects on the pulmonary circulation, and potentially worsening arterial oxygenation because of an inhibition of hypoxic pulmonary vasoconstriction.

Following interventional treatment of unruptured intracranial aneurysms, close postinterventional monitoring is needed. Most postprocedural complications occur within the first 4–6 h [38,39] or latest on the first postinterventional day [38]. Same-day discharge might be considered on an individual basis. It is advised to monitor patients for at least 6 h in a location where invasive monitoring capabilities exist, and complications can be identified and managed rapidly [38]. Provided that highly skilled staff is available, admission to a ‘normal’ recovery unit instead of an ICU postprocedurally is possible and saves up to 57% of costs [40]. Early discharge could

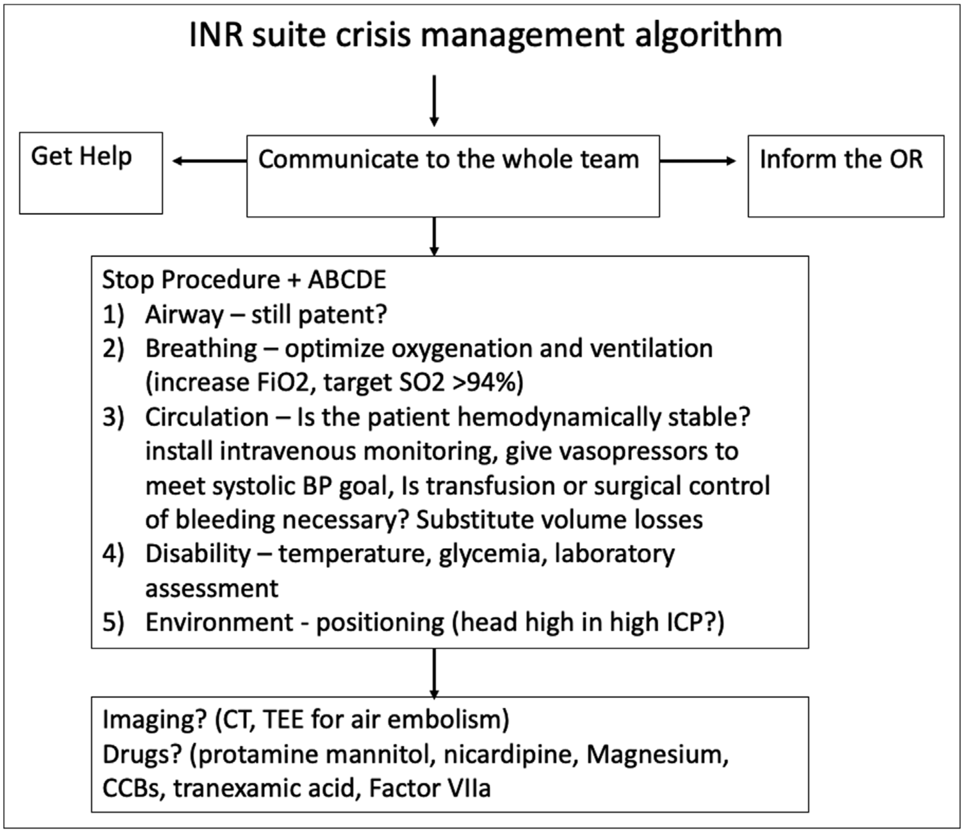

FIGURE 1. Interventional neuroradiology suite crisis management algorithm. Crisis management algorithm in the INR suite to provide general treatment strategies in any type of upcoming INR emergency. ABCDE, Airway, Breathing, Circulation, Disability, Exposure; BP, blood pressure; CCBs, calcium channel blockers; CT, computed tomography; FiO_2, fraction of inspired oxygen; ICP, intracranial pressure; INR, interventional neuroradiology; OR, operating room; SO_2, partial oxygen saturation (%); TEE, transesophageal echocardiography.

improve the financial burden [41]. Even patients on dual antiplatelet and heparin regimes undergoing coil embolization of an unruptured intracranial aneurysm under general anesthesia showed low neurologic complication rates despite discontinued the treatment. In this study, postoperative complication rates were higher in women and in patients with preexisting hypercoagulable states, larger aneurysms (>2 cm), and intraprocedural aneurysm rupture [40]. Addressing the potential ongoing antiplatelet therapy after treating an intracranial aneurysm (life-long aspirin 75 mg and clopidogrel 75 mg for 3–6 months) remains important when deciding on same-day discharge [20].

BRAIN ARTERIOVENOUS MALFORMATIONS

Brain AVMs harbor a risk of bleeding because of arteriovenous shunting [9]. Adhesive, solidifying, glue-like solutions can be introduced to embolize aberrant vessels. Deliberate hypotension during the placement of the adhesive material might help increase safety [15]. There may also be a significant number of 'silent' ischemic lesions (at least 22%) [42] because of abrupt changes in BP in the previously hypotensive areas within the 'nidus.' Severe postprocedural headaches might be the only sign of such 'silent' lesions. As cerebral autoregulation can be compromised, MAP should be kept to 20% less than the baseline during and after the procedure to avoid AVM hemorrhage [43]. Steroids may help prevent edema formation around the nidus [44] but its effect is controversial. A specific problem during the AVMs treatment is the high amount of physiological solution at a pressure of up to 300 mmHg that is administered by the interventional neuroradiologist via the various catheters. This volume must be taken into account for appropriate volume management.

CAROTID ARTERY STENOSIS AND CAROTID ARTERY BALLOON-TEST OCCLUSION

High-risk CAS patients can undergo endovascular treatment under local anesthesia with minimal sedation, provided that cerebral autoregulation is preserved and continuous evaluation of neurological function is possible [45]. However, vagal stimulation during the stent placement might cause bradycardia and hypotension. In addition, the previously inadequately perfused areas can be hyperperfused after placement of the stents; thus, carefully planned hemodynamic management is needed [46]. Similarly, thromboembolism, vessel occlusion, perforation, and bleeding can occur just as in managing the aneurysmal disease [20].

Just as for CAS management, anesthesia provider experts, who can manage sudden hypotension, sudden loss of consciousness, and all risks associated with highly heparinized patients, are needed in CA balloon occlusion test procedures [9].

KYPHOPLASTY

In general, endovascular procedures are not very painful [20]; however, patients may present with chronic opioid prescriptions or long-term pain medication that further complicates early discharge. A solid preprocedural pain assessment and an approach combining MAC with local anesthesia are recommended. Performance of a facet-joint block with ropivacaine combined with administration of prednisolone and vitamin B12 improved the short-term outcome (1 year) after PKP. The local anti-inflammatory and analgesic effects on the facet joints resulted in higher intraprocedural satisfaction and lower pain visual analogue scale (VAS) scores and disability scores for the first postinterventional month [22]. The use of preemptive analgesia (the application of celecoxib the night before surgery and 40 mg parecoxib sodium immediately before surgery) combining local anesthesia with 0.5% lidocaine and continuous intravenous 0.5 μg/kg/h dexmedetomidine intraprocedurally showed more stable BP and heart rate (HR) intrainterventionally and postinterventionally regardless of anesthesia modality. SO_2, however, remained unchanged both intraprocedurally and postprocedurally. VAS scores were better during the procedure but equal postprocedurally [23▪].

In a comparison of local ropivacaine applications to MAC with dexmedetomidine infusion or general anesthesia with sufentanyl/propofol/sevoflurane, MAC led to less anesthesia-related adverse events and lowered VAS and intervention times than general anesthesia. However, MAP and HR were significantly lower in MAC. Overall, MAC had the highest periprocedural satisfaction and lowest VAS 2 h after the procedure, with improved patient cooperation and a decreased risk of adverse events during PKP. The MAP and HR in the MAC group should be closely observed postprocedurally [47▪].

RETINOBLASTOMA

Mostly present in children, the procedure to treat retinoblastomas includes an intra-atrial application of chemotherapy via the ophthalmic artery. Also, reflex hypotension and bradycardia (trigeminal-cardiac reflex) can be expected during the ophthalmic artery catheter placement or intra-arterial chemotherapy.

Special patient populations in interventional neuroradiology

Children

There is a clear consensus for general anesthesia in the pediatric population, even for diagnostic imaging [48▪▪]. Knowledge of the presence of cardiovascular disease and its impact on daily life and upper/lower respiratory tract infections is essential [49▪]. Renal function testing, blood grouping, and cross-matching need to be conducted. Generally, there is a lower incidence of complications (neurologic and cardiovascular) in children compared with adults [50].

A preprocedural checklist of materials and information is critical in the pediatric outpatient setting for diagnostic procedures [51]:

(1) Equipment – emergency cart age-appropriate for resuscitation
(2) Monitoring devices – ECG, pulse oximeter, capnometer, noninvasive BP (all size-appropriate), temperature probe (for cerebral aneurysm: beat-to-beat BP via radial/femoral line)

Local anesthesia is needed for angiography as the femoral artery is small [48▪▪]. The stress response following induction is aggravated in children; hence there is a need for sufficient depth of anesthesia (fentanyl 2–3 μg/kg + propofol 2.5–3.5 mg/kg or thiopentone 5–7 mg/kg). During embolizations, neuromuscular relaxation should be administered with rocuronium 0.6–1.2 mg/kg. However, complete relaxation is not necessary for imaging studies [26]. Background and bolus application of muscular relaxation agents are equivalent [52]. Hypothermia is likely, and monitoring of body temperature is mandatory. Deep extubation may be considered to avoid coughing [26]. First-time exposure to contrast medium adds to the high risk of severe allergic reactions.

The anesthesia providers must ensure the post-procedure observation with immediate access to

Table 1. Additional preinterventional assessment in the elderly

	Systems	Tools
History	Respiratory	Lung function testing
	Cardiovascular	ECG, echocardiography, PET-CT
	Renal	Urea, glomerular filtration rate, electrolytes
	Endocrinologic, hematologic	Blood glucose, HbA1c, full blood count
	Nutrition status	BMI, albumin
Medication	Anticoagulation	Coagulation screen
Functional assessment	Cognitive	Mental test score, auditory system, vision
	Functional	Mobility, self-sufficiency skills, Clinical Frailty Scale

HbA1c, hemoglobin-A1c; PET-CT, PET-computed tomography.

oxygen supply and resuscitation equipment nearby and bed rest of 2–6 h. The presence of family members are encouraged but younger or less cooperative patients might benefit from narcotics or alpha-2 agonists in case of agitation [53,54].

Geriatric population

In the geriatric population, the most common neurointerventional brain disorders encountered include stroke, CAS, intracranial neoplasms or AVMs, intracranial aneurysms, and subsequent SAH [55]. Physiologically lowered cerebrovascular reserve increases the risk of postprocedural delirium, cognitive dysfunction, delayed awakening, and secondary intracranial brain insult [56]. Presence of dementia or frailty can mask acute neurologic changes and further complicate neurologic examination, in addition to contributing to slower pupillary reaction and reduced tactile sensation (pain) [57,58▪]. Elderly patients are highly susceptible to hypothermia because of redistribution because of general anesthetics and room temperatures and, in addition, aging of the hypothalamus [59]. Chronic arterial hypertension is common and might affect cerebral autoregulation [18]. Ischemia can occur at higher MAPs than in healthy young normotensive patients [60]. Cardiac output is altered. The presence of increased afterload and myocardial hypertrophy combined with elevated BP leads to an increased risk of ischemia during states of high metabolic demand, such as intraprocedurally. Decreased cardiovascular responsiveness to stress because of beta-blockade further complicates the maintenance of adequate circulating volume [61]. Altered pharmacokinetic effects are, to a considerable extent, because of a reduction in glomerular filtration rate by 55% at the age of 80 [62]. Therefore, additional assessment tools are necessary for preinterventional evaluation (Table 1).

Optimizing modifiable risks preinterventionally, stable hemodynamic, respiratory, and intracranial conditions during all stages of anesthesia, and careful fluid management are important. Higher risks for postinterventional deterioration might require the use of transcranial Doppler ultrasound to detect vasospasms, especially after treatments of SAH, close monitoring of postprocedural respiratory complications, and screening for, as well as prevention of, delirium [63].

CONCLUSION

In INR, a consensus on optimal anesthesia care to safely conduct the rapidly expanding scope of procedures, especially in the outpatient setting, is lacking. A combination of different anesthetic modalities is a valuable approach and crisis management algorithms adaptable to each setting and by all care-takers involved in the interdisciplinary team help mitigate associated risks. Still, not only pathophysiologic considerations but also the spectrum of patients from all age groups should be considered for interventional and patient-population-specific studies to improve evidence-based perioperative management.

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Conflicts of interest

There are no conflicts of interest.

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