

REVIEW / DERLEME

SECRETS OF ANESTHESIA FOR INTERVENTIONAL NEURORADIOLOGY**GİRİŞİMSEL NÖRORADYOLOJİ İÇİN ANESTEZİNİN SIRLARI****Ayten SARAÇOĞLU, Kemal Tolga SARAÇOĞLU****Bilim University Faculty of Medicine, Department of Anesthesiology and Reanimation, Istanbul, Turkey**

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SUMMARY

Neuroradiology procedures are being applied more with increasing frequency both for diagnosis and treatment of extra- and intracranial pathologies. In this review, we aimed to determine the most important aspects of anesthesia during interventional neuroradiology. General anesthesia is advantageous in terms of assuring patients' immobility, hemodynamic and respiratory stability. However, nitrous oxide should be preferably avoided as it has the risk to enlarge the micro air bubbles that ingenerate during injection of contrast or irrigation fluid. Bradyarrhythmias may occur during balloon inflation for extracranial carotid angioplasty or stenting. As manipulation of airway may be difficult during the procedure, it is essential to assess the airway during the preoperative visit. Necessary precautions should be taken against seizures, postoperative pain, massive hemorrhage, hypothermia or contrast-induced nephropathy. Hyperactivity of the sympathetic system after subarachnoid hemorrhage and massive catecholamine release may cause critical ECG changes, arrhythmias, and left ventricular failure. Nausea and vomiting may be observed in patients as side-effects of the applied contrast agents and anesthetics. Patients requiring interventional neuroradiology may be transferred directly from the intensive care unit, and the safe transfer is crucial for such patients.

KEY WORDS: Neuroanesthesia, Neuroradiology**ÖZET**

Ekstra ve intrakraniyal patolojilerin teşhis ve tedavisi için nöroradyolojik girişimler artan sıklıkla daha çok uygulanır hale gelmiştir. Bu derlemede girişimsel nöroradyoloji sırasında anestezinin en önemli özelliklerini belirlemeyi amaçladık. Genel anestezi hastalara immobilizasyon, hemodinamik ve respiratuar stabilite sağlaması bakımından avantajlıdır. Ancak azot protoksit kullanımından, kontrast madde ya da irrigasyon sıvılarının enjeksiyonu sırasında oluşabilen mikro hava kabarcıklarını genişletme riskinden dolayı tercihen kaçınılmalıdır. Ekstrakraniyal karotid anjioplasti veya stentleme için uygulanan balon inflasyonu sırasında bradiaritmler oluşabilir. İşlem sırasında havayolu manipülasyonu zor olabileceği için preoperatif vizit sırasında havayolunun değerlendirilmesi önemlidir. Nöbetler, postoperatif ağrı, massif hemoraji, hipotermi veya kontrast ilişkili nefropatiye karşı gerekli önlemler alınmalıdır. Subaraknoid hemorajiyi takiben oluşan sempatik sistem hiperaktivitesi ve massif katekolamin salınımı kritik EKG değişikliklerine, aritmilere ve sol ventrikül yetmezliğine sebep olabilir. Uygulanan kontrast madde ve anesteziklerin yan etkilerine bağlı olarak hastalarda bulantı kusma gözlemlenebilir. Girişimsel nöroradyoloji gerektiren hastalar direkt olarak yoğun bakım ünitesinden transfer edilebilirler ve bu tür hastalarda güvenli transfer önemlidir.

ANAHTAR KELİMELER: Nöroanestezi, Nöroradyoloji**INTRODUCTION**

Interventional neuroradiological procedures can be examined in two different groups:

1. Closing or occluding procedures: Embolization of aneurysms, repair of arteriovenous malformations and other fistulas of brain and pinal cord. Preoperative embolization of vascular tumors like meningioma, temporary or permanent occlusion of intra- and extra-cranial arteries

2. Opening procedures: Treatment of stenosis or vasospasm through angioplasty or stenting. Application of chemical or mechanical thrombolysis in patients with stroke

General anesthesia may be preferred in neuroradiological procedures due to long duration of operation and patient-related factors or for assuring physiological control. The factors that necessitate general anesthesia in interventional neuroradiology procedures are as follows (1):

1. Long procedures
2. Conditions in which manipulation of blood pressure or ventilation is necessary
3. Cases with the risk to quickly develop complications
4. Conditions when better image quality is obtained as a result of patient immobilization

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General anesthesia is advantageous in terms of assuring patients' immobility, hemodynamic and respiratory stability. However, neurological assessment is not available during the intra-operative period and there is a risk of increased intra-cranial pressure resulting from hypertension or coughing caused by endotracheal intubation or extubation. Nitrous oxide should be preferably avoided as it has the risk to enlarge the micro air bubbles that generate during injection of contrast or irrigation fluid. Laryngeal mask may be used as an alternative to endotracheal intubation. In this way, airway can be managed with less hemodynamic stress and the patients experience a smooth emergence from anesthesia.

Sedation provides the advantages to easily perform repeated neurological tests and to prevent potential hemodynamic changes associated with intubation and emergence. Propofol or dexmedetomidine has been used successfully (2). However, unprotected airway is a disadvantage, because it has the risk of pulmonary aspiration, hypoxia and hypercapnia. Additionally, emergency neurological management may be delayed with a sudden movement of the patient.

Coiling of cerebral aneurysms, embolization of cerebral and dural arteriovenous malformation (AVM), thromboembolism of acute thrombolytic stroke and angioplasty of atherosclerotic lesions are the neuroradiology procedures that are relatively frequently applied. It is necessary to analyze the health status of the patients in detail so as to obtain optimal operative results. A quick transition may be necessary from deep sedation to recovery with analgesia which may result in severe complications (Table I).

Endovascular therapy may be used to treat many cerebral aneurysms. Patients may present for emergency repair after subarachnoid hemorrhage or for elective

treatment due to ruptured aneurysms. The patients with subarachnoid hemorrhage may be affected by rupture, hydrocephalus or cerebral vasospasm. In the course of endovascular therapy, practitioners must be always prepared for possible aneurysm rupture. In order to reduce the risk for development of rupture or recurrence of rupture after the procedure, blood pressure should be frequently checked.

Cerebral AVMs are other lesions that can be intervened using endovascular embolization. The complications of AVM embolization include foreign body embolization in undesired sites, intra-cranial hemorrhage and cerebral edema. Stenotic atherosclerotic lesions both in intra-cranial and extra-cranial vessels can be treated with balloon angioplasty. The use of extra-cranial carotid artery stenosis, carotid angioplasty/stenting has increased recently. In such operations, the operator should be on alert against bradyarrhythmias that may develop during balloon inflation.

Pre-anesthesia Assessment: Anesthesia practices to be performed outside the operating room are both challenging and risky (3). Therefore, it is essential to have a detailed route map prepared by an experienced anesthesiologist beforehand.

Interventional neuroradiology laboratories are generally located away from the operating room, maybe even on a different floor, in the hospital setting (Figure 1). The necessity of working environments with reduced light level and exposure to intense ionizing radiation are other drawbacks of non-OR neuroradiology.

In addition to a standard pre-anesthesia check-up, a careful neurological examination, which is focused on GCS, is required in neuroradiology procedures to identify existing and known deficits (4). Pupil size and reactivity should be measured and recorded. Patients' intensive care need, arterial blood pressure and other baseline parameters

Table I. Complications related to interventional neuroradiology procedures

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|------------------------------------------------------|
| Central Nervous System Complications: |
| 1. Hemorrhage |
| 2. Aneurysm perforation |
| 3. Intra-cranial vascular injury, dissection |
| Occlusive Complications: |
| 1. Thromboembolism |
| 2. Displacement or breakage of the coil |
| 3. Vasospasm |
| Non-Central Nervous System Complications: |
| 1. Contrast medium allergy |
| 2. Contrast medium-induced nephropathy |
| 3. Bleeding or hematoma at the site of the operation |



Figure 1. Neuroradiology intervention room

concerning cardiovascular and renal reserve and coagulation should be determined. Moreover, patients' history regarding previous angiography or allergy to any contrast agent and protamine should be recorded. Sedative premedication should not be applied.

As manipulation of airway may be difficult during the procedure due to the head position in monitoring, it is essential to assess the airway. Airway safety should be carefully ensured. It is important to have patients' history regarding previous radiological procedures and reaction to contrast agents. As in other locations where anesthesia is administered outside of the operating room, the communication between the anesthesiologist and radiologist is crucial for optimal patient care. Awake neurological assessment is vital after some procedures. As it is required to perform neurological assessment in the shortest time possible, rapid recovery is important. There is not sufficient evidence to suggest that intravenous anesthesia or inhaled anesthesia has superiority over each other (1). Under clinical conditions, all volatile agents have the potential to increase cerebral blood flow, cerebral blood volume, and intra-cranial pressure (5). Nitrous oxide should be avoided as it increases the incidence of air embolism as well as causing elevated cerebral blood flow and intra-cranial pressure. In case that total intravenous anesthesia (TIVA) is employed, cerebral blood pressure, intra-cranial pressure and cerebral metabolic rate can be lessened with propofol and a short-acting opioid. However, sevoflurane has been reported to be associated with earlier recovery as compared to propofol in long interventional neuroradiology procedures (6). Since it does not have a significant influence on cerebral blood flow and intra-cranial pressure, sevoflurane can be an option as the inhalation agent. Besides, sevoflurane allows faster recovery than isoflurane which makes neurological assessment easier after the procedure.

Regardless of the preferred anesthesia technique, patients are monitored with standard anesthesia monitors. Anesthesia monitoring is expected to include pulse oximetry, ECG, and capnography. Measurement of mean blood pressure may be necessary in presence of medical comorbidities. It is recommended to place two intravenous catheters; one is for infusion of medication while the other is used for administration of liquids and bolus doses. Extension line can be applied in case that vascular access can not be achieved. Radial artery catheter should be used for monitoring in the procedures that necessitate blood pressure manipulation or when it is necessary to observe postoperative blood pressure. However, if there is no need to monitor the blood

pressure in the postoperative period, anesthesiologist and radiologist may share the same arterial line.

Many procedures require bladder catheterization. It is essential not only for liquid management but also for patient comfort. Significant amount of heparinized flush solutions and contrast agents are used intraoperatively. Furthermore, diuretics, including mannitol and furosemide, may be also required during the procedure. As a consequence, hypothermia may occur, and therefore, heating and temperature measurements should be routinely performed and heating blankets should be used.

In interventional procedures, patients are administered contrast agents in high volumes, i.e. 150-250 mL. Patients' plasma creatinine level and glomerular filtration rate should be evaluated in the preoperative period. The risk factors for development of contrast-induced nephropathy are listed in Table II.

Table II. The risk factors for development of contrast-induced nephropathy

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|--------------------------------------------------------------------------------------|
| 1. Reduced glomerular filtration rate |
| 2. Diabetes Mellitus (especially if the patients receives metformin) |
| 3. Dehydration |
| 4. Hypotension |
| 5. Age over 75 years |
| 6. Use of nephrotoxic drugs (aminoglycosides, nonsteroidal antiinflammatory drug) |

Thrombosis is a complication of endovascular procedures. Therefore heparin is commonly used in these cases. The aim is to keep the activated clotting time (ACT) 2-2.5-fold above the baseline levels. Generally, the baseline ACT is measured and recorded, and then, 70 IU kg⁻¹ heparin is given intravenously to make approximately a 2- to 3-fold increase in the baseline value. ACT should be checked at least once per hour and an additional dose of heparin should be given when needed. Although massive hemorrhage due to severe injuries to major vessels occur rarely, the risk should be always considered. Coagulation should be managed cautiously in order to prevent both intraoperative and postoperative thromboembolic complications.

Similar to some balloon occlusion procedures that is used to reduce blood flow in feeding arteries, induced hypotension is also frequently applied for embolization of AVMs. Agents, including esmolol, labetalol, and sodium nitroprusside are useful in such situations. Induced hypotension is performed to maximize collateral flow during cerebral ischemia. Phenylephrine is generally used both as a bolus and as an infusion titrated to increase systolic blood pressure 30%-40% above baseline values.

In these patients, close monitoring of ECG parameters for signs of myocardial ischemia is critical. Moreover, necessary precautions should be taken to avoid coughing and bucking. Intracranial pressure should be checked, and cerebral perfusion pressure should be appropriately maintained during anesthesia. Patients are exposed to high doses of ionizing radiation during the procedure. Therefore, it must be confirmed in female patients aged between 15 and 55 years that the patient is not pregnant. Patients with cerebral aneurysm may present with subarachnoid hemorrhage or cranial nerve palsies. Endovascular coiling is a procedure which can be safely performed in patients with aneurysm rupture. Nevertheless, radiologist should be warned in case of any hemodynamic instability during the procedure. Blood pressure should be decreased if aneurysm rupture develops.

5% to 10% of arteriovenous malformations develop following subarachnoid hemorrhage, whereas most AVMs present with seizures, headache and focal neurologic findings. Anesthesia should be terminated smoothly and avoiding from coughing and hypertension. Otherwise, cerebral edema may develop. As in many other radiological interventions, patients may suffer from minimal postoperative pain. Severe postoperative headache, on the other hand, may be a sign of intra-cranial hemorrhage. When interventional techniques are employed for management of carotid occlusive diseases, there is a risk for development of bradycardia or asystolia as a result of carotid body stimulation during angioplasty. Even though it is challenging to prevent them in advance, glycopyrrolate or atropine may be useful. Postoperative hypertension should be avoided to prevent cerebral reperfusion injury.

Patients with aneurysmal subarachnoid hemorrhage should be monitored considering increased intra-cranial pressure, cerebral ischemia and hydrocephalus. As patients' stability reduces the incidence of perforation, general anesthesia is preferred in treatment of cerebral aneurysms by coiling. Thrombus may develop on the catheter, guide wire or coil during or after placement of the coil. The overall incidence of thromboembolic complication is 2.5–5% (7).

Hyperactivity of the sympathetic system after subarachnoid hemorrhage and massive catecholamine release may cause critical ECG changes, arrhythmias, and left ventricular failure. Neurogenic pulmonary edema may develop following subarachnoid hemorrhage (SAH) both in cardiac and non-cardiac mechanisms. Due to syndrome of inappropriate antidiuretic hormone (ADH) or cerebral salt-wasting syndrome, the prevalence

of hyponatremia is 10–34% among individuals with SAH (8). Blood pressure should be carefully monitored because BP > 160 mmHg may lead to aneurysm rupture. Vasodilators including hydralazine, glyceryl trinitrate and sodium nitroprusside increase intra-cranial pressure and cerebral blood volume and can cause ischemia by impairing cerebral perfusion. Calcium channel blockers, on the other side, reduce the incidence of vasospasm. Vasospasm needs to be treated triple-H therapy: hypertension, hypervolemia, and hemodilution. In case of AVMs, blood pressure should be decreased to reduce blood flow in the feeding artery before the injection of glue (9).

Preoperative embolization is applied for vascular tumors including meningiomas, glomus tumor, and juvenile nasopharyngeal angiofibroma. The target of embolization is to minimize blood loss and facilitate dissection by diminishing tumor vascularity.

Moderate hypotension is recommended to prevent cerebral edema and hemorrhage after AVM embolization. The mean arterial pressure should be kept 15-20% below the baseline value within the first 24 hours. Antihypertensive agents, such as labetalol or esmolol, can be used to control blood pressure as they have minimal effect on cerebral physiology. Furthermore, the mean arterial pressure should be kept 20-30% above the baseline value to maintain cerebral perfusion pressure in patients with occlusive conditions or vasospasm. Phenylephrine or norepinephrine may be used to achieve that level. Nimodipine administration continues up to 3 weeks in patients with aneurysmal subarachnoid hemorrhage. Most patients maintain aspirin treatment (75 mg) during 3 months. Nausea and vomiting may be observed in patients as postoperative side-effects of the applied contrast agents and anesthetics.

Patients requiring interventional neuroradiology may be transferred directly from the intensive care unit, and the safety of the transfer is crucial for such patients. Maintenance of the external ventricular drainage catheter or intra-cranial pressure monitoring device are fundamental elements of a safe transfer.

Conclusion

In conclusion, anesthesia in interventional neuroradiology involves optimal maintenance of hemodynamic and respiratory stability, together with the avoidance and management of perioperative complications. It is essential for taking the risks of patients outside the operating rooms.

Secrets of anesthesia should include:

1. Cooperation within the team.
2. Precautions against thromboembolic complications

using compression stockings and administering heparin in the preoperative period.

3. Precaution against massive bleeding.

4. Precaution against bradyarrhythmias and/or asistolia that may occur during balloon inflation for extra-cranial carotid angioplasty or stenting.

5. Moderate hypotension to prevent cerebral edema and hemorrhage after AVM embolization.

6. Optimization of hemodynamic and respiratory stability.

7. Optimization of the head position during the procedure and decision for airway management in case of emergency.

7. Anesthesia monitoring including pulse oximetry, ECG, and capnography. Measurement of mean arterial pressure in presence of medical comorbidities.

8. Avoidance of nitrous oxide.

9. Being aware of postoperative complications including inadequate postoperative pain relief.

10. Planning safe transfer of patients.

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