Drug Choices For Neuroanesthesia

Adrian W. Gelb, MB, ChB, DA, FRCPC

The most appropriate choice of drugs for anesthesia in a patient undergoing an intracranial neurosurgical procedure is dependent on a clear understanding of the pharmacological effects of the drugs as well as the requirements for neuroanesthesia in general and the specific case. This lecture will review the characteristics of the ideal agents for neuroanesthesia and review how some of the newer anesthetics measure up.

Rapid Onset and Rapid Offset

Intracranial surgery is characterized by periods of intense stimulation alternating with periods of minimal pain. Manipulation of the brain itself is not painful to the patient, but the scalp, skull (periosteum), and meninges are well innervated with pain fibers. In addition, traction on cerebral arteries, as well as sensory cranial nerves, can be painful. It is therefore desirable that one's anesthetic/analgesic agents can be rapidly titrated according to responses.

Maintains Hemodynamic Stability

Cerebral perfusion is dependent on maintaining an adequate cerebral perfusion pressure, which is the mean arterial pressure minus intracranial pressure (ICP). In many patients some degree of modest hypotension is well tolerated, and in a small number of vascular patients it may even be desirable. However, ease of titratability and predictability of hemodynamic response are important.

Decreases Cerebral Blood Volume

Although the intracranial blood volume constitutes $<10\%$ of the total intracranial volume, it represents the component most easily manipulated by the anesthesiologist. Unfortunately, technological difficulties such as accessibility to a PET scanner have significantly limited the acquisition of knowledge regarding the effects of anesthetic agents. Newer techniques based on computed tomography or magnetic resonance imaging are now more available and allow for quantitative assessment of regional cerebral blood flow and cerebral blood volume (CBV) but have not been much exploited yet. We have used a computed tomography based approach and have studied propofol and isoflurane in the normal brain and in animals with brain tumors. Propofol, even at normocapnia, significantly reduces CBV relative to isoflurane. Hyperventilation reduces CBV in the presence of isoflurane, but CBV is still higher than with propofol.

Does Not Alter Cerebral Spinal Fluid Production or Reabsorption

The cerebral spinal fluid (CSF) constitutes approximately 15% of the intracranial volume. As it undergoes continuous production and reabsorption alterations in either of these variables could result in an increase in the CSF volume and, thereby, an increase in ICP. Enflurane has been shown both to increase CSF production and reduce reabsorption. All of the newer agents appear to have minimal effects on CSF dynamics.

Decreases Intracranial Pressure

Preventing increases in intracranial pressure is an important goal during neuroanesthesia. It is therefore important that the drugs chosen do not increase ICP. Ideally, they should decrease ICP, if already elevated. Sevoflurane is like isoflurane in that it does not appear to increase ICP if used with hyperventilation and at a concentration of 1 MAC or less. Although there has been controversy concerning the effects of opioids on ICP, the reported increases in ICP appear to be mainly related to the associated drop in blood pressure with compensatory cerebral vasodilatation. Propofol not only does not increase ICP but has also been shown to be effective in reducing elevated ICP. A study from my laboratory showed that propofol was more effective than hyperventilation in reducing acutely elevated ICP.

Maintains CO_2 Reactivity

All of the current commonly used anesthetic agents maintain the cerebral blood flow response to changes in $Paco_2$.

Maintains Cerebral Autoregulation

The full extent of the cerebral autoregulatory range has not been tested with the currently available anesthetic agents. However, within the clinical range of blood pressures, autoregulation has been shown to be intact during propofol and remifentanil anesthesia. Unlike the older inhalational anesthetics, autoregulation appears to be intact with sevoflurane up to 1.5 MAC.

Allows EEG/EP Monitoring for Ischemia and Seizures

The electroencephalogram (EEG) is unfortunately sensitive to all anesthetics and becomes markedly depressed at the upper end of the clinically relevant dosage range, hence its use in depth of anesthesia monitoring. Conversely, inhalational agents have a profound suppressive effect on somatosensory evoked potential monitoring, whereas most IV drugs have less suppressive effects. Opioids have the least effect on the EEG and evoked potentials, but this probably reflects the fact that they are inadequate or incomplete anesthetics.

Does Not Increase Cerebral Metabolic Rate

Intracranial neurosurgical procedures have the potential to reduce cerebral blood flow relative to metabolic requirements. Such compromise is usually focal, for example under the retractors or temporary vessel occlusion during aneurysm surgery. It is therefore important that the anesthetic agent not increase metabolic requirements, and it would be preferable that they are decreased. None of the current commonly used anesthetic agents increase cerebral oxygen consumption; the inhalational and IV anesthetic agents reduce it by up to 50%. Opioids at the usual clinical doses do not greatly influence metabolic rate.

Anticonvulsant

Neurosurgical disease and injury are associated with an increase in the likelihood of seizures. Anesthetic agents should not increase this potential. Anesthetics that may be used for sedation in the intensive care unit should be anticonvulsants, making them useful in the management of status epilepticus. Propofol is a very effective anticonvulsant and may be used in the management of seizures. The occasional reports of seizure-like movements with propofol are, in the vast majority of cases, not true seizures but rather reflect abnormal movements. There are, however, concerns (e.g., of cardiac failure and acidosis) with regard to the prolonged use of high-dose propofol infusions. Recent reports show that sevoflurane at 1.5 MAC or greater can induce spiking on the EEG. However, clinical manifestations of seizures do not accompany these electroencephalographic observations. Opioids are not anticonvulsant and within the usual dosage ranges do not produce EEG stimulation. However, at high dose they may produce spike activity. For example, we have found a bolus of remifentanil 10 $\mu g/kg$ to induce spiking in patients with known epilepsy.

Decrease Edema

The brain responds to injury with a loss of integrity of the blood-brain barrier and cell ion transport. This results in intracellular (cytotoxic) and extracellular (vasogenic) edema. The effects of anesthetic agents on edema in the brain have not been well studied.

Protect the Brain from Ischemia

As mentioned previously, neurosurgical procedures are associated with the potential for producing (focal) cerebral ischemia. The ideal anesthetic agent should reduce the probability or treat any injury if it occurred. This subject remains controversial but it is likely that the anesthetic state produces some modest protection relative to being awake but it is unlikely that anesthetic agents have a significant therapeutic role.

Selected References

1. Alkire MT, Haier RJ, Barker SJ, et al. Cerebral metabolism during propofol anesthesia in humans studied with positron emission tomography. Anesthesiology 1995;82:393–403.
2. Artu AA, Powers KM. Furosemide decreases crebrospinal fluid formation during desflurane anesthesia in rabbits. J Neurosurg Anesthesiol 1997;9:166–74.
3. Baker KZ, Ostapkovich N, Sisti MB, et al. Intact cerebral blood flow reactivity during remifentanil/nitrous oxide anesthesia. J Neurosurg Anesthesiol 1997;9:134–40.
4. Boisseau N, Madany M, Staccini P, et al. Comparison of the effects of sevoflurane and propofol on cortical somatosensory evoked potentials. Br J Anaesth. 2002;88:785–9.
5. Cenic A, Craen RA, Howard-Lech VL, et al. Cerebral blood volume and blood flow at varying arterial carbon dioxide tension levels in rabbits during propofol anesthesia. Anesth Analg 2000;90:1376–83.
6. Cremer OL, Moons KG, Bouman EA, et al. Long-term propofol infusion and cardiac failure in adult head-injured patients. Lancet 2001;357(9250):117–8.
7. From RP, Warner DS, Todd MM, Sokoll MD. Anesthesia for craniotomy: a double-blind comparison of alfentanil, fentanyl, and sufentanil. Anesthesiology 1990;73:896–904.
8. Gelb, AW, Cechetto D, Wilson, JX. Anesthetics and cerebral ischemia - should we continue to dream the impossible dream? Can J Anaesth 2001;48:727–31.
9. Guy J, Hindman BJ, Baker KZ, et al. Comparison of remifentanil and fentanyl in patients undergoing craniotomy for supratentorial space-occupying lesions. Anesthesiology 1997;86:514–24.
10. Herrick IA, Craen RA, Blume WT, et al. Sedative doses of remifentanil have minimal effect on EcoG spike activity during awake epilepsy surgery. J Neurosurg Anesthesiol 2002;14:55.

11. Herrick IA, Craen RA, Gelb AW, et al. Propofol sedation during awake craniotomy for seizures: electrocortographic and epileptogenic effects. Anesth Analg 1997;84:1280–4.
12. Nabavi DG, Cenic A, Henderson S, et al. Perfusion mapping using computed tomography allows accurate prediction of cerebral infarction in experimental brain ischemia. Stroke 2001;32:175–83.
13. Pinaud M, Lelausque J-N, Chetanneau A, et al. Effects of propofol on cerebral hemodynamics and metabolism in patients with brain trauma. Anesthesiology 1990;73:404–9.
14. Ravussin P, Guinard JP, Ralley F, Thorin D. Effect of propofol on cerebrospinal fluid pressure and cerebral perfusion pressure in patients undergoing craniotomy. Anaesthesia 1988;43S:37–41.
15. Strebel S, Lam AM, Matta B, et al. Dynamic and static cerebral autoregulation during isoflurane, desflurane, and propofol anesthesia. Anesthesiology 1995;83:66–76.
16. Todd MM, Warner DS, Sokoll MD, et al. A prospective, comparative trial of three anesthetics for elective supratentorial craniotomy: propofol/fentanyl, isoflurane/nitrous oxide, and fentanyl/nitrous oxide. Anesthesiology 1993;78:1005–20.
17. Todd MM, Weeks J. Comparative effects of propofol, pentobarbital, and isoflurane on cerebral blood flow and blood volume. J Neurosurg Anesthesiol 1996;8:296–303.
18. Watts ADJ, Eliasziw M, Gelb AW. Propofol and hyperventilation for the treatment of raised intracranial pressure in rabbits. Anesth Analg 1998;87:564–8.
19. Watts DJ, Herrick IA, McLachlan, R, et al. The effect of sevoflurane and isoflurane anesthesia on interictal spike activity among patients with refractory epilepsy. Anesth Analg 1999;89:1275–81.
20. Weeks JB, Todd MM, Warner DS, Katz JY. The influence of halothane, isoflurane, and pentobarbital on cerebral plasma volume in hypocapnic and normocapnic rats. Anesthesiology. 1990;73:461–6.
21. Werner C, Kochs E, Bause H, et al. Effects of sufentanil on cerebral hemodynamics and intracranial pressure in patients with brain injury. Anesthesiology. 1995;83:721–6.