

ANAESTHETIC MANAGEMENT OF SUPRATENTORIAL INTRACRANIAL TUMOURS

G.S. Umamaheswara Rao
Professor
Department of Neuroanaesthesia
National Institute of Mental Health and Neurosciences
Bangalore 560 029

Brain tumours constitute the majority of neurosurgical conditions that present for elective operations. The nature of the lesions varies from benign tumours like meningiomas and schwannomas to highly malignant tumours like glioblastomas. About 80% of the tumors are located in the supratentorial compartment and about 20% in the posterior fossa.

The anaesthetic and perioperative care of patients with brain tumours requires an understanding the following aspects:

1. Intracranial pathophysiology of the tumors
2. Effects of anaesthetics on brain
3. Measures to decrease the brain bulk at surgery
4. Intraoperative monitoring requirements
5. Implications of fluid therapy
6. Perioperative haemodynamic management
7. Implications of surgical position
8. Implications of concurrent medications

PATHOPHYSIOLOGIC CONSIDERATIONS

Intracranial Pressure

Normal intracranial pressure (ICP) is about 10-15 mmHg. Raised ICP is a common feature of intracranial tumours. Intracranial hypertension, in these cases, results from the mass lesion itself, oedema of the surrounding brain or hydrocephalus in case of III ventricular or infratentorial tumors. Natural mechanisms such as displacement of intracranial blood volume and cerebrospinal fluid (CSF) and increased reabsorption of CSF tend to limit the increase in ICP as the tumor increases in size. When these mechanisms are exhausted, ICP increases steeply. Such steep increase in ICP leads to rapid neurological deterioration. The important consequences of raised ICP are:

- a) Cerebral ischemia due to reduction of cerebral perfusion pressure (CPP) and
- b) Brain shifts. Significant gradients of ICP within various compartments of intracranial cavity lead to herniation of brain structures. The most common forms of herniation are herniation of the uncus of the temporal lobe through the hiatus in the tentorium cerebelli, herniation of the cingulate gyrus under the falx cerebri, and herniation of the cerebellar tonsils through foramen magnum.

Clinical Signs of Raised ICP

Headache vomiting and papilloedema are the three cardinal signs of raised ICP. Conscious patients with raised ICP complain of generalised or frontal headache. They may also have nausea and vomiting. Vomiting is generally projectile in nature. Impairment of consciousness occurs when the ICP is very high; it may vary from somnolence to stupor and deep coma. Hypertension and bradycardia represent an attempt at restoration cerebral blood flow (CBF) in the face of grossly elevated ICP. Presence of retinal haemorrhage, indicates very high ICP. A variety of abnormal breathing patterns have been observed in patients with severe increase in ICP. Periodic, irregular, deep, shallow or typical Cheyne-stokes patterns have been reported. Increase of respiratory rate is usually an initial sign of elevated ICP followed by irregularity or depression of the respiration and finally periods of apnoea and respiratory arrest.

Diagnostic studies for Raised ICP

Skull Radiography: Plain X-ray of the skull shows "beaten-silver" appearance and demineralisation of sella tursica in patients with chronic elevation of ICP.

Angiography: Slowing of the circulation may be evident on angiography. Angiography may also show diffuse narrowing of intracerebral arteries.

CT Scan: Focal or diffuse oedema is seen as hypodensity of brain parenchyma, usually in the white matter. Diffuse brain oedema is accompanied by obliteration of the basal cisterns and cerebral sulci and collapse of ventricles. Focal or perilesional oedema in cerebral hemispheres manifests with compression of ipsilateral ventricle and midline shift. Significant shift of brain structures may occur without increase in the measured global ICP. Most often, CT scan provides a better indication of the status of ICP dynamics than direct measurement of ICP.

ICP Monitoring: The indications for ICP monitoring in patients with brain tumours are not clearly defined. With easy accessibility to CT scanning, continuous ICP monitoring in patients with brain tumours has become less frequent. However, postoperative ICP monitoring may be employed in patients with massive intraoperative brain swelling requiring aggressive treatments such as mechanical ventilation, barbiturate therapy etc. ICP monitoring is also helpful in patients at enhanced risk of postoperative haematoma (e.g., intraventricular tumours).

Cerebral Blood Flow Changes

Normal CBF is 40-45 ml/100g/min. Cortical blood flow (70 mL/100g/min) is much higher than subcortical flow (20 ml/100g/min). In health, CBF is regulated by important mechanisms such as autoregulation and cerebral blood flow-metabolism coupling. Brain tumors may cause an increase or decrease in the CBF depending on the nature of the tumour. Changes in CBF autoregulation, vascular response to CO₂ and CBF-CMR coupling also occur in these patients.

Tolerance to arterial hypotension is reduced if the autoregulation is impaired. Loss of vascular response to CO₂ may limit the usefulness of hyperventilation in decreasing the ICP. Loss of CBF-CMR coupling may result in luxury perfusion in the peritumoral zones.

Implications of Cerebral Effects of Anaesthetics

Anaesthetics may exert their effects on various facets of cerebral function such as CMRO₂, CBF, cerebral blood flow-metabolism coupling, ICP, autoregulation, vascular response to CO₂ and brain electrical activity. The net result of all these effects of the anaesthetic agents combined with their systemic effects may prove beneficial or detrimental to an already diseased brain.

All anaesthetics, in general, decrease cerebral oxygen consumption (CMRO₂) in a dose-dependent manner, but their potency varies with individual agents. Intravenous induction agents (barbiturate, propofol) are the most potent depressants of cerebral metabolism (CMR) followed by inhalational agents (isoflurane, sevoflurane, desflurane), benzodiazepines (midazolam) and narcotics (fentanyl, alfentanil, sufentanil). All intravenous agents with the exception of ketamine decrease ICP. All inhalational agents increase ICP, though individual agents vary in the magnitude of this effect. Intravenous agents preserve autoregulation, while inhalational agents impair it to varying degrees. Agents that cause significant impairment of autoregulation are likely to cause higher degrees of reduction of cerebral perfusion in the event of perioperative hypotension. Anaesthetic agents that produce an isoelectric electroencephalogram in clinically useful concentrations (isoflurane, sevoflurane, desflurane) are likely to play a cerebral protective role in the intraoperative period though convincing clinical evidence is lacking.

Opioids have been the mainstay of neuroanaesthesia for a number of years. The earlier belief that synthetic short-acting opioids agents lack any significant effect on ICP and CPP was challenged by studies that documented a small increase in CSF pressure, significant decrease in mean arterial pressure (MAP) and thus a substantial change in CPP¹. Based on studies that reported EEG seizure activity with high doses of fentanyl in animals and humans^{2,3}, cerebral activation with corresponding increase in CBF has been proposed as the possible mechanism of this increase in ICP. A more plausible explanation came from a study in head injured patients⁴ that demonstrated a close relationship between opioid-induced hypotension and an increase in ICP. Effective prevention of such hypotension prevented the increase in ICP. This observation led to the hypothesis that the ICP increase is related to the autoregulatory cerebral vasodilation in response to the hypotension caused by the opioids.

Remifentanil seems to be particularly suitable for neurosurgery because of its rapid onset and rapid offset of action and minimal effect on ICP. In a human study of patients undergoing supratentorial craniotomy, remifentanil, alfentanil

and placebo caused similar changes in ICP⁵. Most of the later studies in neurosurgical patients showed an overall efficacy and safety profile that is similar to, if not better than, fentanyl. The important difference between remifentanyl and other opioids is its rapid offset of action that facilitates early response to verbal commands and rapid tracheal extubation. Patients receiving remifentanyl are more likely to have immediate postoperative pain and therefore, may require a transitional analgesia^{6,7}. Rapid titratability makes it a promising agent for awake craniotomy for brain tumors.

During the maintenance phase of anaesthesia, rapid changes in the depth of anaesthesia can be effected with sevoflurane. Rapid emergence from sevoflurane anaesthesia facilitates early neurological examination. Smooth emergence without coughing prevents increase in cerebral venous pressure and the possibility of haematoma formation.

Propofol offers a number of pharmacological advantages for total intravenous anaesthesia (TIVA) in neurosurgical patients. It decreases CBF, and CMRO₂ and increases cerebrovascular resistance (CVR). Cerebral autoregulation and vascular response to carbon dioxide remain unaltered. Its effects on neuronal activity are similar to those of thiopentone. Therefore, it was proposed that, like thiopentone, it could offer cerebral protection. The protection offered by propofol seems to be a result of a decrease in CMRO₂, maintenance or redistribution of CBF and prevention of large increases in blood glucose, which generally accompanies and worsens cerebral ischemia⁸. Despite these theoretical considerations, till date, there is no convincing evidence to use propofol as a cerebral protective agent in clinical situations.

Management of Fluid and Electrolyte Balance

The volume and composition of the fluid transfused have major implications in patients with cerebral pathology. While hypervolemia increases brain oedema, excessive dehydration decreases CBF.

Plan of Intraoperative Fluid Management

Intraoperative fluid therapy in patients with brain tumors should take into account the maintenance requirements and excessive urine losses due to diuretics. Third space losses may be considered negligible in these patients. Fluid deficit due to preoperative fasting may be ignored in adult patients. The goal of intraoperative fluid management in adult patients is to achieve a mild negative balance of the order of 500-1000 mL. More meticulous calculations are required in children to ensure that there is neither a positive nor a negative balance at the end of surgery.

Glucose containing solutions are preferably avoided during the first four hours of surgery. In prolonged surgeries glucose containing solutions are administered in moderation. Our own approach in this regard has been to administer alternate units of glucose-containing and non-glucose containing

solutions for maintenance requirements. Faster infusion requirements caused by excessive diuresis or blood loss are met with by non-glucose containing solutions.

Composition of the Fluid: Maintenance of mild hyperosmolality of plasma is desirable in the intraoperative period. Therefore, hypotonic fluids like 5% Dextrose in water, 1/2 N saline, 1/5 N Saline, Isolyte-M must be avoided in the intraoperative period. Isotonic solutions such as 0.9% normal saline or Ringer's lactate are the fluids of choice. Depending on the necessity (children, diabetic patients), 5% dextrose may be added to these solutions. When there is a need for large volume of fluid infusion, even Ringer's lactate is not advisable as it is mildly hypotonic with reference to plasma. While these recommendations are applicable to patients without any major preoperative electrolyte disturbances, in patients with preoperative electrolyte disturbances, the choice of the fluid is determined by the nature of disturbance involved.

Mannitol: Mannitol is the commonest hypertonic solution used to provide lax brain at surgery. While causing cerebral dehydration and decreasing the ICP, mannitol has the potential to cause adverse effects such as dehydration, hyponatremia, hypokalemia, renal failure, transient increase in ICP before the diuresis sets in and exaggeration of brain shifts in patients with unilateral mass lesions. Dose recommendations for intraoperative use of mannitol vary from 0.25 - 2 g/kg as a bolus. Some centres use mannitol as a routine in all cases of cerebral tumors; the rationale for such practice is that mannitol, by reducing the brain bulk, provides easy access to the surgical lesion even when the ICP is not very high. In some centres mannitol is used only in situations where the brain is expected to be tense based on the preoperative CT scan. When indicated, it must be administered as a bolus over 15-20 min before opening the dura. Urine output, serum osmolality and serum electrolytes must be monitored to avoid complications related to intravascular volume and electrolyte disturbances.

Implications of Surgical Position

Surgery on intracranial tumours may require various positions, which include supine, prone, lateral and sitting positions. Haemodynamic and respiratory complications and nerve injuries associated with these positions need to be taken into account while positioning the patients for surgery.

Sitting position has fallen to disrepute in recent years because of life threatening complications such as venous air-embolism and severe hypotension. Surgical access to the operative lesion may demand acute flexion of the neck that may cause airway obstruction and obstruction to cerebral venous outflow, resulting in intraoperative brain swelling. Elevation of the head above the heart level facilitates cerebral venous drainage; however, it may be fraught with the risk of venous air embolism from open veins if the gradient between the vein and the right atrium is sufficiently high.

Nociceptive stimulation during the three-pin holder application must be prevented by administration of additional doses of fentanyl or infiltration of the scalp with a local anesthetic agent.

Perioperative Haemodynamic Management

Optimal blood pressure management plays an important role in preventing major intraoperative and postoperative complications. In conditions associated with impaired autoregulation, CBF is pressure-dependent; hypotension decreases CBF and hypertension increases CBF and ICP. Intraoperatively, blood pressure must be maintained at preoperative values of the patient. Control of systemic hypertension prior to surgery or control of intraoperative episodes of hypertension requires consideration of the effect of such treatment on intracranial pathology and cardiovascular function. Acute normalisation of blood pressure in a patient with hypertension due to raised ICP may cause worsening of neurological deficits.

Induced hypotension, which was a popular technique for reduction of intraoperative blood loss, is not received with same enthusiasm at present. There is substantial evidence to show that neurological morbidity of induced hypotension is significantly high while the observed benefits are marginal.

Choice of antihypertensives to control hypertension - when indicated - depends on the effects of these agents on cerebral circulation and ICP. Direct vasodilators such as sodium nitroprusside, nitroglycerine and calcium antagonists are to be discouraged as they are likely to increase CBF and ICP. Beta-adrenergic blocking agents and angiotensin converting enzyme inhibitors are preferred.

Implications of Concurrent Medications

Anticonvulsants, and steroids are some of the common medications that these patients are likely to be receiving at the time of surgery. The patient's drug schedule should be noted so that the relevant drugs can be administered when the repeat doses are due in the intraoperative period. Drug interactions can occur between the preoperative and intraoperative medications. Anticonvulsant agent, phenytoin may decrease the duration of action of nondepolarising muscle relaxants. Adrenocortical suppression due to prolonged steroid therapy may cause unexpected hypotension intraoperatively.

ANAESTHETIC MANAGEMENT

Premedication

In patients with raised ICP, sedative premedication carries the risk of depression of consciousness, airway obstruction, hypoxia and hypercapnia and hence avoided. In patients without evidence of raised ICP, small doses of benzodiazepines may be given orally on the day of surgery to allay anxiety. Narcotics may be administered after establishment of IV access, during the

placement of monitoring devices. The patient must be carefully monitored and should not be left unattended. Other concurrent medications such as corticosteroids, anticonvulsants, antacids and medications for coincidental diseases must be continued up to the day of surgery.

Intraoperative Monitoring

Routine monitoring during brain tumour surgery should include ECG, invasive and noninvasive blood pressure, pulse oximetry, capnography, nasopharyngeal temperature and urine output.

Anaesthetic Technique

Patients who are symptomatic for raised ICP, tend to pose problems of “tight brain” or “massive intraoperative brain swelling” at surgery. The majority of these patients would have received steroids for sometime that might have brought the ICP under reasonable control when they present themselves for surgical intervention. Preoperative CT evidence of large tumour, excessive peritumoral oedema, gross midline shift, obliterated or effaced lateral ventricles and subarachnoid cisterns and obliterated cortical sulci suggests high ICP.

Induction and intubation may aggravate intracranial hypertension. Liberal doses of thiopentone or propofol combined with narcotics to achieve adequate depth of anaesthesia, mild to moderate hyperventilation with mask before intubation, intravenous lignocaine bolus and avoidance of nitrous oxide and inhalational anaesthetics until such time as moderate hypocapnia is established, are some of the measures that prevent dangerous increases in ICP. Total intravenous anaesthesia may provide better operating conditions than inhalational anaesthesia; this issue however, remains controversial in the light of a few studies that showed no significant difference between inhalational and intravenous anaesthesia in terms of short-term outcome measures. There are no studies on the impact of anaesthetic technique on the long-term neurological outcome of the patients.

Intraoperative ICP Reduction

Slack brain facilitates easy surgical access and adequate excision of the tumour. Inability to achieve adequate brain laxity is fraught with serious complications such as herniation of brain through craniotomy and excessive retractor pressure leading to retractor anaemia.

Prevention of tense brain at surgery requires attention to a number of details. These include smooth and unhurried induction, mild head elevation, and avoiding neck kink and pressure on the neck veins. Intubation in light planes of anaesthesia must be avoided. This would require higher than normal doses of induction agents, adequate muscle relaxation and administration of IV lignocaine prior to intubation. A small bolus of the IV induction agent may be repeated prior to intubation.

Definitive measures used for decreasing the brain bulk include hyperventilation, mannitol, continuous infusion of anaesthetic agents like thiopentone or propofol, and CSF diversion through a ventriculostomy catheter in patients with hydrocephalus. Moderate hypothermia may be employed in extreme conditions of massive brain swelling resistant to conventional measures.

Role of Hyperventilation

Hyperventilation, which has been in clinical use for many years for reduction of ICP, has been subjected to more critical analysis in the recent years. Hypocapnia decreases CBF by 2-3% for each mmHg fall in PaCO₂ upto 20 mmHg. Normal cerebral blood volume (CBV), which is 3-4 ml/100g, is reduced by 0.049 ml/100g/mmHg change in PaCO₂. If hyperventilation is sustained, CBF and CBV return to baseline over about 4 h.

For many decades, it has been a practice to lower PaCO₂ to improve operating conditions during craniotomy. Recently, there is some evidence to suggest that preoperative signs of raised ICP and condition of brain at craniotomy are poorly correlated and the value of routine hyperventilation to improve operating conditions remains questionable⁹. Secondly, the value of hyperventilation in decreasing the brain volume seems to depend on the background anaesthetic. A recent study demonstrated diminished responsiveness of CBF and CBV to hypocapnia during propofol anaesthesia¹⁰. Benefit of hyperventilation is probably limited to reversal of inhalational anaesthetic induced cerebral vasodilation and consequent increase in CBV.

Emergence from Anaesthesia

Aims during emergence from anaesthesia are maintenance of stable blood pressure and ICP, thereby adequate CPP, optimal oxygenation, normal PaCO₂, and normothermia. Hypertension, coughing, and asynchrony with the ventilator increase the chances of postoperative haematoma and oedema. The patient must be fully awake at the time of extubation so that neurological examination can be performed. The advantages of early versus delayed extubation are a subject of debate. The potential benefits of early awakening are feasibility of early neurological examination, and low cost. Advantages of delaying the extubation by a few hours have been reported recently. The potential benefits of delaying extubation are reduced risk of hypoxemia, better respiratory and haemodynamic control, and lower incidence of postoperative haematoma formation. Obtunded consciousness and inadequate airway preoperatively, intraoperative brain swelling, problems with haemostasis during surgery, and major postoperative homeostatic disturbances warrant delaying extubation.

Causes of delayed emergence: Unplanned delayed emergence is not an infrequent event after surgery for brain tumors. Some of the potential causes for such delay are seizure, intracranial haematoma, brain oedema or swelling, and tension pneumocephalus. Hypothermia, metabolic acidosis and hyponatremia

are some of the systemic causes of delayed emergence. A CT or MRI and serum biochemistry including blood gas analysis will help the differential diagnosis.

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