Anaesthetic Considerations in Intracranial Neurosurgical Patients

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Abstract

Rapid developments in the practice of neurosurgery pose significant new challenges for the attending anaesthetist. The neuroanaesthesiologist is faced with the task of modification of various anaesthetic techniques depending on the alterations in the neurophysiologic parameters present in the patient. A close cooperation between the anaesthesiologist and the neurosurgeon is mandatory for successful conduct of the procedure. A thorough preoperative preparation of the patient with careful intraoperative monitoring is required. The anaesthetic techniques should be tailored to avoid any alterations in the neurophysiologic parameters which may prove to be deleterious for the patient. With the advent of minimally invasive neurosurgical procedures, the anaesthesiologist has to be aware of different techniques used so that the use of anaesthetic drugs can be made accordingly.

Keywords

Intracranial neoplasms; Intracranial pressure; Neurosurgery; TIVA

Introduction

With the advances in Neuroimaging and neurosurgical techniques, besides neurosurgeon, the attending anaesthesiologist also has to face numerous challenges. The development of newer minimally invasive neurosurgical techniques has also modified the role of the anaesthesiologist has put an additional responsibility of providing optimal surgical conditions with preservation of neurocognitive functions, continuous electrophysiological monitoring and provision of awake and calm state of the patient postoperatively for neurological assessment. Patients may present with various types of intracranial tumours and pathologies which can possibly elicit different responses to various anaesthetic techniques and drugs as compared to normal population. The major goals in neurosurgery for an anaesthesiologist are to maintain the adequate tissue perfusion to brain to maintain the metabolic demands and to provide ideal surgical conditions for the neurosurgeon to operate. The different anaesthetic techniques can influence the intracranial pathology and if wrongly chosen can adversely affect the outcome in these patients.

Neuro-physiological principles

The entire monitoring standards are based upon certain basic neurophysiologic principles which are extremely important for the anaesthesiologist to be completely aware of while caring for the neurosurgical patients and can be summarized as:

Cerebral Perfusion Pressure (CPP): The CPP is defined as the difference of mean arterial pressure (MAP) and intracranial pressure (ICP) and can be given as:

\[ \text{CPP} = \text{MAP} - \text{ICP} \]

in rare patients with central venous pressure more than intracranial pressure, the CPP can be given as:

\[ \text{CPP} = \text{MAP} - \text{CVP} \]

Intravenous agents have beneficial effects on CBF and autoregulation which may prove to be deleterious for the patient. With the advent of minimally invasive neurosurgical procedures, the anaesthesiologist has to be aware of different techniques used so that the use of anaesthetic drugs can be made accordingly.

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Many of the anaesthetic drugs can influence CPP as they exert their effects directly and indirectly on MAP and ICP but it is usually necessary to keep the CPP more than 70 mmHg. Literary evidence has established that in head trauma patients CPP of less than 60 mmHg is associated with a poor neurological outcome [1].

Most of the inhalational anaesthetics cause dose-dependent vasodilatation which is counteracted by vasoconstriction due to reduced cerebral metabolic requirement of oxygen (CMRO₂). These effects occur maximally with desflurane and minimally with sevoflurane. The effects of sevoflurane are minimal on autoregulation even at higher concentrations while isoflurane maintains autoregulation in a concentration less than 1 MAC. Nitrous oxide has been found to increase cerebral blood flow, CMRO₂ and thus ICT and the effects are only partially mediated by its sympathetic hyperactivity. Nitrous oxide can also offset the beneficial effects of hypocapnia. Intravenous anaesthetics can influence the CPP by their effects on MAP but are considered to be safer than inhalational agents.

Cerebral Blood Flow (CBF): The average CBF is about 40-50 ml/100gms/min with higher flow to the grey matter as compared to white matter. The cerebral blood flow is maintained over a wide range of perfusion pressure usually between 50-150 mmHg by the phenomenon of autoregulation. This protects the brain from ischemia at lower blood pressures and from hemorrhage at higher blood pressures. It is influenced by the arterial blood level of carbon dioxide (paCO₂) with an increase range of autoregulation at lower levels of paCO₂ and narrow range at higher levels of paCO₂.

Inhalational anaesthetics can reduce the CBF by their effect on cerebral metabolic rate while the most prominent effect is dose dependent increase in CBF due to vasodilation [2-4]. The studies indicate that this increase in cerebral blood flow is least with the use of sevoflurane [5-7]. The effects on autoregulation are least affected by sevoflurane and isoflurane while both halothane and desflurane can abolish autoregulation at higher concentrations [8,9].

Recently total intravenous anaesthesia (TIVA) has gained widespread popularity in managing patients undergoing neurosurgery for intracranial tumours, especially of short duration [10]. Intravenous agents have beneficial effects on CBF and autoregulation by decreasing the CBF by causing cerebral vasoconstriction as well as by reducing cerebral metabolic rate. This effect is seen most with propofol and barbiturates and least with etomidate [11,12].
Opioids have minimal effects on CBF

Cerebral Blood Volume (CBV): About 15% of the cerebral blood volume remains in the arterial cerebral circulation while about 15% is found within the venous sinuses. The changes in CBV are mostly similar to those in CBV except during the changes of head position when the CBV can change without changes in CBF.

Among inhalational agents, isoflurane increases CBV while sevoflurane has least effect on CBV. Intravenous agents like propofol have effects of decreasing the CBV and thus is more favourable [13, 14].

Intracranial Pressure (ICP): The normal ICP is about 10 mmHg and with the increase in ICP beyond 20 mmHg, regional ischemia of brain starts occurring and ultimately progresses to global cerebral ischemia if adequate control is not established. The increase in ICP follows the Munroe-Kelly doctrine which states that out of three components of intracranial cavity namely brain, cerebrospinal fluid and CBV, any increase in any of these components must be compensated with a subsequent decrease in other components so that ICP is not increased.

Intravenous agents also have minimal effects on ICP mainly results in decrease in ICP. Studies show that combined use of both inhalational as well as intravenous agents can have beneficial effects on ICP and better preservation of CPP [18]. However, cerebral vasocostriction may prove to be detrimental by causing cerebral hypoperfusion and ischemia especially if used for prolonged time. Opioids have minimal effects on ICP mainly by their effects on mean arterial pressure [19].

Cerebral Metabolic Oxygen Requirement (CMRO): This is an important factor in prevention of ischemic damage to the cerebral tissue. In the presence of increased CMRO, any decrease in CBF can markedly affect the perfusion of cerebral tissue and can lead to ischemic damage. Thus, reductions in CMRO may be an important step in prevention from ischemic damage.

Intravenous agents have an effect of reducing the CMRO but due to their direct dilating effects on cerebral blood vessels, they tend to increase the ICP.

Intravenous agents, on the other hand, reduce CMRO, and thus CBF with subsequent reductions in CBV and ICP making them useful in patients with raised ICP.

Carbon dioxide responsiveness: Hypercarbia causes vasodilation in cerebral vessels and thus increases CBF as well as ICP while hypocarbia, often induced by hyperventilation, results in reduction in CBF and ICP by vasoconstriction. However, decrease in CBF can lead to ischemia of cerebral tissue depending on the extent and duration of hypocarbia.

Isoflurane and sevoflurane maintain the CO2 reactivity upto 1.5 MAC while halothane can reduce it at higher concentrations [20].

Intravenous agents do not influence the carbon dioxide reactivity. A fine balance between all the above neurophysiological parameters is mandatory for the safe conduct of anaesthesia in the neurosurgical patients.

**Peri-Operative Anaesthetic Management**

The most common types of neurosurgical procedures involve excision of intracranial mass, decompression during major haemorrhage, aneurysmal clipping surgery and minimally invasive neuro-endoscopic procedures for diagnostic and therapeutic procedures in intracranial neoplasms. Whatever the surgical procedure is going to be performed, anaesthetic administration requires a detailed assessment and examination pre-operatively.

**Preoperative assessment**

Preoperatively, a thorough assessment of the patient’s general condition should be performed with special considerations for the signs of raised intracranial pressure like headache, nausea, vomiting, blurred vision, altered mental status, altered breathing pattern, hypertension, bradycardia and papilloedema which are commonly associated with intracranial tumours. A complete neurological examination must be performed and pre-existing neurological deficits should be documented. The presence of other co-morbid conditions related to cardiac, respiratory, renal, musculoskeletal, hepatic and others and their ongoing therapy if any as well as present status should be documented.

A quick but thorough preoperative assessment is mandatory in the emergency situations of decompressive surgery for sudden deterioration due to rapidly enlarging brain tumours or traumatic brain injury and mostly involves assessment of mental status by Glasgow Coma Scale (GCS). The patients with intracranial tumours are frequently on medications like steroids and antiepileptics which can have effects on intraoperative glucose homeostasis and pharmacokinetics of anaesthetic drugs as most of these antiepileptics are liver enzyme inducers. Moreover, antiepileptic drugs can enhance the cerebral depression caused by anaesthesia inducing drugs so that the doses have to be reduced accordingly. Any sedative premedication should be avoided in these patients as it can affect the neurological assessment and any increase in paCO₂ due to hypoventilation can have deleterious effects on ICP.

**Essential Clinical Investigations**

All the baseline blood investigations should be asked preoperatively which includes complete blood count, renal function tests, serum electrolytes, coagulation parameters, chest radiographs and 12 lead electrocardiogram. Other special investigations may be asked depending on the presence of other co-morbid conditions.

The imaging studies involving computed tomography and magnetic resonance imaging should be reviewed to ascertain the type of tumor, its location, vascularity, presence of hydrocephalus and any midline shift. The location of tumour i.e. supratentorial or infratentorial is very important to modify the anaesthetic technique accordingly. The excision of supratentorial tumours may be accompanied with intraoperative raised intracranial pressure, for which necessary precautions should be taken. Also, supratentorial tumors may require specialised neuromonitoring in the form of SSEP, MEP, speech mapping etc. which require modifications in the anaesthetic techniques.

The infratentorial tumors also pose a threat of raised intracranial...
pressure and involvement of lower cranial nerves which may cause difficulty in extubation and these patients may require postoperative mechanical ventilation. Also, the sitting position may be used in these patients which have a high risk of venous air embolism (VAE) for which appropriate monitoring should be employed.

However, in emergent situations only the computed tomography of brain is required as these cases often require immediate decompression and evacuation of tumour and hematoma for a positive outcome.

**Intraoperative Monitoring**

The standard monitoring including five lead electrocardiogram, non-invasive blood pressure, pulse oximetry, end-tidal carbon dioxide and temperature should be instituted. Invasive blood pressure monitoring may be used in large tumors in posterior cranial fossa as well as intracranial aneurysms as minor fluctuations in blood pressure can have deleterious effects on neurological outcome. The core temperature should be kept within normal range throughout the surgery. The urine output should also be monitored by an indwelling foley’s catheter due to prolonged nature of such surgeries. Recently, use of intraoperative computed tomography (iCT) has been introduced in the neurosurgery for intraoperative imaging of blood vessels and for rapid information about critical impairment of brain perfusion. It has been found to feasible with short acquisition time and little interference with the surgical workflow [21]. However, anaesthetic concerns are limited access to the head end during the procedure with the possibility of disconnections of the anaesthetic circuit, so close monitoring is mandatory.

**Induction and Maintenance of Anaesthesia**

Induction of anaesthesia is very critical in these patients as there are sudden fluctuations in blood pressure due to laryngoscopy and intubation and then again at the time of insertion of pins to position the head. All such fluctuations should be avoided. The use of intravenous induction agents like propofol and thiopentone is preferred due to their beneficial effects on ICP. The sudden increase in blood pressure can be attenuated by various techniques like use of intravenous lignocaine before intubation, use of short acting beta blockers like esmolol, additional boluses of short acting opioids and recently use of dexmedetomidine, a selective alfa 2 agonist, has been documented to blunt these effects [22,23].

The intubation is facilitated by use of non-depolizing muscle relaxants but the depolizing relaxants like succinylcholine can also be used if strongly indicated. The controversy of ability of succinylcholine in elevating the ICP is documented but is usually short lived and can be offset by additional doses of propofol or thiopentone or by a small defasciculating dose of non-depolizing muscle relaxant [24].

The techniques of maintenance of anaesthesia should take into account the balance between CPP and ICP with maintenance of adequate anaesthetic depth. Every attempt should be made to maintain the ICP at lower level till the dura is opened. Further maintenance techniques depend on the use of neuromonitoring intraoperatively which may involve recording motor evoked potentials (MEP) or somatosensory evoked potentials (SSEP). The most suitable technique is the use of total intravenous anaesthesia (TIVA) using propofol infusion and short acting opioids like fentanyl, sufentanil or remifentanyl which is found to have least effect on SSEP’s. [10] However, inhalational agents can also be used in a concentration of less than 0.75 MAC.

The use of nitrous oxide has been questioned due to its effects on CBF and CMRO2 postoperative nausea and vomiting, venous air embolism in sitting position, development of tension pneumocephalus and alteration of cerebral electrophysiological signals. However, studies show conflicting results for implication of nitrous oxide in development of delayed ischemic neurological deficit and the length of intensive care unit stay [25,26].

**Patient Positioning**

Different approaches to intracranial space for different tumours necessitate different positions for surgical access. However, the various positions used in the neurosurgical procedures can have numerous implications for the anaesthesiologist. The various positions commonly used in Intracranial neurosurgery and their possible implications include:

- **Supine position**: This position is used in patients with cerebellopontine tumors and cerebral aneurysms. The rotation of head used may cause stretching of jugular veins and brachial plexus. A 10 degree reverse Trendelenberg’s position has been tried in patients for cerebral aneurysm craniotomy surgery to decrease the ICP [27].

- **Prone position**: This position offers good surgical access to posterior fossa midline structures. The techniques used to reduce bleeding include head elevation but it increases chances of air embolism. The chest and pelvis should be supported with free abdomen for effective ventilation and all the bony prominences should be padded. The head should be well padded and every attempt should be made to protect eyes from undue pressure by use of horse-shoe or specially designed head stabilizers. It has been found that the rise of ICP is more in prone position as compared to the supine position [28].

- **Lateral position**: This position is utilised for accessing the cerebellopontine tumors more efficiently. A sufficient amount of padding should be done beneath the axilla to prevent damage to axillary nerves. Excessive flexion of neck should be avoided to prevent obstruction of internal jugular veins.

- **Sitting position**: This position is used to access the midline structures in posterior cranial fossa. Although used rarely, this position has shown to improve cerebrovascular and intracranial compliance [29]. However, this position is associated with many complications like venous air embolism, cord compression, macroglossia, pneumocephalus and peripheral nerve injuries.

**Peri-Operative Fluid Management**

Fluid management in neurosurgical patients is extremely important but numerous Controversies exist related to the volume and type of the fluids to be used. A good balance needs to be maintained between maintenance of adequate tissue perfusion and minimisation of cerebral edema. The use of normal saline (0.9% saline) is preferred over other solutions due to propensity of other solutions to increase total body water and ICP as normal saline is slightly hyperosmolar (308 mOsm/l) thus helps in attenuating cerebral edema. The use of hypertonic saline (3% or above) in neurosurgical patients have been documented to be favourable due to its ability to rapidly restore blood volume and to decrease the brain water [30]. But all these
effects are thought to occur with an intact blood brain barrier which is rarely present in neurosurgical patients especially with intracranial neoplasms. This makes it mandatory to aim for fluid management in neurosurgical patients so as to maintain normovolemia with normal serum osmolality.

**Intraoperative Glycemic Control**

It has been shown by various studies that hyperglycemia is associated with poorer outcomes in patients with ischemic stroke [31-33], subarachnoid hemorrhage [34] and meningitis [35]. However, the studies with strict control of glucose yield conflicting results [36]. So, it is generally held that glycemic control is highly desirable in neurosurgical patients but the technique of glycemic control is still controversial but the occurrence of hypoglycemic episodes should always be avoided as it can cause deleterious effects on already diseased brain.

**Intraoperative Concerns and Challenges**

The main intraoperative difficulties encountered during a neurosurgical procedure may include but are not limited to:

**Raised intracranial pressure**

Raised ICP is a dreaded complication encountered intraoperatively with swelling of brain tissue and poses significant problems for the surgeon. The anaesthesiologist plays a vital role in management of such raised ICP. The various treatment modalities are depicted in Table 1.

In addition to the above mentioned measures to reduce ICP, other precautions which should be taken to prevent any increase in ICP are maintenance of profound neuromuscular blockade and avoidance of sudden increase in peak airway pressures by preventing any bucking or coughing.

All these challenges are accentuated in patients with diabetes mellitus, cardiac diseases and other systemic co-morbidities [43].

**Hemorrhage:** Bleeding from venous sinuses during the Onco-neurosurgery is also a dreaded but controllable complication. Preoperative discussion with the neurosurgeon is very important in deciding the intraoperative plan and adequate cross-matched blood and blood products should be readily available.

**Recovery from anaesthesia:** The goal is to have a comfortable and pain free patient at the end of surgery with avoidance of coughing to reduce the sudden fluctuations in blood pressure and ICP. The intraoperative infusion of opioids if used should be tapered accordingly and additional boluses of short acting opioids may be required for a smooth extubation. If the preoperative condition of the patient demands continuation of mechanical ventilation postoperatively, the patient should remain deeply sedated and paralysed to maintain ICP.

**Postoperative care:** The degree of postoperative care is usually dictated by the complexity of surgical procedure and occurrence of intraoperative complications. These patients are usually nursed in an intensive care unit or atleast in a high dependency unit. If patients are extubated after surgery, post-operative nausea and vomiting prophylaxis can be exercised by administration of long acting 5HT3 antagonists like palonosetron [44]. The pain after craniotomy is usually not severe and can easily be managed with non-steroidal anti-inflammatory drugs. A close monitoring of vital parameters as well as neurological status is mandatory in postoperative period.

**Anaesthetic concerns for neuroendoscopic procedures:** With the advent of technological advancement in the endoscopic instruments, a large number of neuroendoscopic procedures are gaining popularity. Neuroendoscopy has been used for procedures like third ventriculostomy, tumor biopsy or resection, cyst fenestration, evacuation of intraventricular hemorrhage and plexus coagulation. The anaesthetic goals remain same as for other neurosurgical procedures with an emphasis on complete immobilisation of the patient, maintenance of cardiovascular stability, detection and treatment of sharp increases in ICT and rapid emergence for early neurological assessment.

**Conclusion**

In conclusion, the technical advances in various neurosurgical techniques causes appropriate changes in the anaesthetic techniques for a favourable outcome in these patients. A close cooperation between a neurosurgeon and neuroanaesthetist is vital to achieve such goals. A thorough preoperative preparation of these patients with minimal changes in hemodynamics and neurophysiological variables intraoperatively can result in better outcome. The provision of minimally invasive neurosurgical procedures requires newer anaesthetic management strategies for successful management of such cases.

**References**


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