Considerations on anesthesia for posterior fossa-surgery

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Abstract

Neuroanesthesia is a special chapter of anesthesia, referring to surgery that is performed right at the site of action of anesthetic drugs, namely the central nervous system (CNS).

Changes induced by general anesthesia on the CNS are accompanied by changes in brain physiology, including cerebral blood flow (CBF), cerebral metabolic rate of oxygen (CMRO2), cerebral perfusion pressure (CPP) and electrophysiological functions.

In neuroanesthesia, posterior fossa surgery faces difficult challenges due to the peculiarities observed from an anatomical and physiological point of view, which also requires the patient to be put in a specific position prior to surgery.

Therefore, we have considered useful and detailed aspects of general anesthesia in this type of surgery, presenting data both from specialized literature and from personal experience of over 25 years.

Fundamentals of anatomy and physiology

The Posterior Fossa contains vital nerve structures such as the brainstem, the cerebellum and the fourth ventricle.

The Brainstem is the most important area of the subtentorial space with a complex structure, representing the transitional area for the main ascending and descending nervous paths that cross each other belonging to the nervous system.

The Gray Matter of the brainstem is represented by its own nuclei and origin nuclei of the cranial nerves.

The brainstem contains numerous vital centers such as:
- The Respiratory center;
- The Cardiovascular center;
- The Swallowing center;
- The Center of vomiting, coughing, and/or hiccups;
- The Chewing center;
- The Salivary centers.

The Brainstem Reticular Substance plays an important role as it is involved in our sleep-wake state regulation, regulation of muscle tone, regulation of sensori-sensitive function and the regulation of our autonomic functions. Reticular formation is a vast neural mass stretched all along the brainstem as an unspecific, polysynaptic path also containing the majority of neural network points, somato- vegetative (respiratory, cardiovascular) and a series of extrapyramidal structures.

The Cerebellum is another important part of the posterior fossa, as it plays a essential role in regulation, coordination, and controlling voluntary and involuntary motor activity like balance and locomotion.

The IV Ventricle is a dilated region in the form of tent, located between the brain stem and cerebellum. It consists of the floor and ceiling. The fourth ventricle floor is the rhomboid fossa, posterior faces in

correspondence to the bulbo-pontine area. This floor designs the bulbo-protuberanţial locum for vital centers, and thus poses high risks during surgical practices.

The content skull consists of three components:
- Brain substance (80%);
- Blood volume (12%);
- Cerebrospinal fluid (CSF) - 8%;

These sections performed in a pressure skull called the intracranial pressure (ICP), with normal values between 8-15 mmHg. In pathological conditions, the volume of a compartment through various mechanisms (cerebral edema,

hydrocephalus) or the emergence of a new compartment represented by a pathological process (hematoma, tumor, cyst, abscess) determines the increase in intracranial pressure.

Intracranial hypertension (ICH) is accompanied by changes in blood circulation, drainage of CSF, and decreased brain compliance, which is defined as relation volume /pressure. The relationship between cerebral hemodynamics, CSF dynamics, cerebral perfusion pressure and mean blood pressure (TAM), plays an important role in ICP changes occurring in brain injury of any etiology.

The Cerebrospinal Fluid (CSF) is produced by the choroid plexus in the walls of the lateral ventricles and in the floor of the fourth and third ventricle; a small amount is produced in the perivascular spaces.

The Tissue Compartment is the largest intracranial compartment consisting of neurons, glial cells and extracellular space. The main cause of increase in brain volume is the cerebral edema, which causes intracranial hypertension .

The Vascular Compartment consists in arterial and venous blood and its volume changes as changes in cerebral blood flow by autoregulation (effect of $PaCO_2$ and $CMRO_2$) However, venous volume change if the superior vena cava syndrome, venous sinus thrombosis is present or mechanical ventilation with positive end expiratory pressure (PEEP) occurs. Cerebral vessels are anatomically (endothelial tight junctions) and physiological (mechanisms of self-regulation and chemo regulation) different from vessels outside the central nervous system.

Cerebral perfusion pressure is defined as the difference between MAP and ICP.

Auto-Regulation of Cerebral Blood Flow is defined as the ability of the

CBF to keep its constant values despite a wide variation of MAP(at normal value

of $Pa O_2$ şiPaCO2) so long as the lime MAP varies between 50-120 mmHg(13).

Influence of the Metabolic Rate of Oxygen. The brain is the organ with the highest metabolic rate, but its reserves in glucose and oxygen are limited. Increased neuronal activity leads to increased neuronal metabolic rate and of cerebral blood flow in order to provide oxygen and glucose requirements.

Posterior fossa neurosurgical disorders are classified by:
Etiology
- Tumor Pathology
- Traumatic Pathology
- Vascular Pathology
- Infectious Pathology
Location
- Median Line Syndrome
- Cerebellar Hemisphere-Syndrome
- Ponto-Cerebellar Angle Syndrome
- Brainstem Syndrome
Depending on the location of the disease process, there is a large variety of clinical

symptoms, due to intracranial hypertension syndrome, cerebellar and vestibular disorders, movement disorders and susceptibility to onset of autonomic disorders which is a sign of serious prognostic and damage of vital centers, respiratory and cardiovascular (1, 5).

ICH syndrome, in most cases, is among the first element of diagnosis of the posterior fossa neurological disorders. It is represented clinically by headache, vomiting, visual disturbances (due to papilledema).

This increase, even if slight, affects the brain function by two means:

- It lowers the CBF with secondary ischemia;

- It causes herniation of brain substance.

After exhaustion of compensatory mechanisms herniation of the cerebral mass will take place, especially cerebellar tonsils through the "foramen magnum" with compression, constriction and twisting of the blood vessels and nervous paths of the brainstem impairing the brainstem vital functions coordinated at this level.

Neural damage due to cerebral ischemia in neurosurgical infratentorial pathology provides critical clinical forms, due to the presence of vital and neurovegetative centers that are in this area. Appropriate means to avoid cerebral ischemia during surgery at this level is an important concern of the anesthetic and surgical team.

Anesthetic Peculiarities

The presence of vital nerve structures and limited space for surgical approach to the posterior fossa, explains the aforementioned challenges of surgery at this level, both for the surgeon and the anesthetist. Along with the pathological and surgical maneuvers, anesthesia interacts with brain structures and functions.

As a result, in addition to systemic hemodynamic stability in neuroanesthesia, the criteria for choosing the anesthetic technique is aiming to achieve the following:

- ICP stability avoiding its growth;

- CBF and CMRO2-reducing, maintaining physiological coupling;

- Maintaining of self-control/regulation of cerebral circulation;

- Maintaining cerebrovascular reactivity to changes in PaCO2;

- Ensuring optimum CPP;

- Possibility to monitor evoked potentials and electromyography;

- Protection of the brain;

- Rapid waking up for early postoperative neurological assessment.

In order to fulfill these criteria, the following are of particular importance:

-Use of modern methods for monitoring all the vital functions;

-Positioning the patient on the operating table;

-Choosing appropriate anesthetic technique.

In patient monitoring, both general and especially neuroanesthesia is inconceivable nowadays without modern methods of monitoring.

Patients undergoing surgery of the subtentorial area are subjects to blood loss, cardiac arrhythmias, blood pressure variations, air embolism, urinary losses, specific positioning causing difficult survey of the tracheal tube caused by difficult access also of the precordial area; therefore multimodally monitoring to assess appropriate the status of all vital organs is mandatory.

Taking into account the importance of systemic hemodynamic stability during

neurosurgical interventions to ensureCPP, and that the infratentorial region-based surgical maneuvers may affect cardiovascular centers of the brainstem, systemic hemodynamic invasive and non-invasive monitoring (ECG, MAP, poulse,central venous pressure, precordial Doppler) are mandatory.

Monitoring breathing for posterior fossa surgery requires a great amount of concentration in order to sustain the hemodynamic stability and ICP. Thus, inspiratory pressure should be as low as to not embarrass venous return and additional attention should be given to continuous monitoring of SpO2, ETCO2, tidal volume, minute volume, blood gas analyst.

Intraoperativ neurophysiological monitoring has become standard of care in many neurosurgical procedures. The main modalities are: somatosensory evoked potentials(SSEP),motor evoked potentials(MEP), and electromyography(EMG) (7).

Other monitored parameters are temperature, diuresis, blood glucose, hematocrit.

Patient positioning. A good surgical access, hemodynamic stability and optimal ICP, need optimal patient selection position in order to perform surgery in the infratentorial area. This topic has been controversial over time, giving up certain positions, then returning to them. Choosing one of the positions listed below is a decision taken by the anesthesiologist and neurosurgeon, taking into account:
• Neurosurgical pathology;
• Patient age;
• Preexisting diseases;
• Constitutional type;
• Method of surgical approach;
• Technical possibilities of monitoring;

• Proper operating facilities.
Main positions used in posterior l fossa surgery are:
• Ventral/prone position;
• Sitting position;
• Lateral position with her version of park bench position.

The "Prone" position is the oldest and most commonly used in posterior fossa surgery. The patient is laid face down and has his head flexed on a special head holder, legs slightly bent to prevent slippage from the operating table.

Benefits of this position are:
• Surgical access pretty good, both midline and lateral;
• Low risk of air embolism;
• Better hemodynamic stability with a minimal risk of hypotension.

Disadvantages:
• Amount of blood loss is bigger than in sitting position;
• Difficult access to the airway, precordial area and tracheal tube;
• Ischemia and risk of retinal bleeding due to compression in the orbital area;
• Danger of necrotic lesions of the face areas and other points of support, which can be avoided by careful placement.

Sitting position for the posterior fossa surgery is controversial due to its great advantages over the contradiction between intracranial pressure values and serious incidents generated by this position.

Benefits of this position:
• Good surgical access, with good viewing of the pontin cerebellar angle;
• Good CSF and venous drainage with decreases of ICP and intraoperative bleeding;
• Easier access to the airways.
Disadvantages:
• Hemodynamic instability, concerning

patients especially at extreme ages and impaired cerebral circulation due to hypovolemia;

• Distribution volume change causes respiratory inflation pressure if small peaks in the expense base ventilation and perfusion lung damage reversed distribution under the influence of hydrostatic pressure, are bases shint and tops dead space. For this reason, optimal PEEP must be used carefully;

• Risk of air embolism;

• Quadriplegia with cervical spinal ischemia;

• Orthopedic and skin problems.

Choice of Anesthetic Technique

The preanesthetic checkup of the patient include the assessment of neurological and other organic systems disorders for establishing the right position on in the ASA scale / anesthetic risk.

The correct evaluation and possible treatment failures is of particular importance, given the undesirable effects of hemodynamic instability and hypercapnia on CBF and ICP.

Sensitivity to sedatives and narcotics in neurosurgical patients require special attention in their use preanesthetic stage. Danger of respiratory depression even at low doses of the substances mentioned above, the occurrence of hypoxia and hypercapnia, knowing the effects of hypoxia and hypercapnia if low brain compliance require keen surveillance

Induction of anesthesia is a critical time of any anesthesia because the period of apnea during intubation, risk of cough and hyperdynamic cardiovascular response to laryngoscopy and intubation maneuvers and the danger of hypotension and bradycardia when injecting certain drugs at this stage.

Danger of these shortcomings is much higher in patients with posterior fossa pathology due to low compliance with the ICH syndrome and cause cerebral ischemia or engaging tonsils with brainstem compression. We note the importance of selecting anesthetic drugs used, taking into account their effects on cerebral and systemic hemodynamics and fineness of maneuvers performed during this period (2). Exept ketamine, all drugs used in induction (thiopental, midazolam, propofol, etomidate) decrease more or lessCBF and CMRO 2 depending on the dose, resulting in decreased ICP and having cerebral protective effect (by decreasing cerebral oxygen consumption).

Maintenance of anesthesia.

Whilst selecting an anesthetic technique, we always wonder whether there is a perfect technique in order to perform modern neuroanesthesia and what the criteria is for choosing it.

Modern neuroanesthesia criteria are:

• Getting a relaxed brain;

• Systemic and cerebral hemodynamics monitoring, maintenance nomal levels of blood glucose and plasma osmolarity;

• Cerebral protection;

• Temperature control;

• Quick waking up.

Cerebral protection is achieved through the "state of anesthesia" itself. To protect from cerebral ischemia, propofol or thiopental avoid postoperative sequels. By following the above criteria we can say that all agents available today in certain combinations and doses may achieve a good neuroanesthesia, if used by a skilled anesthesiologist (Young WL 1998).

Criteria for choosing anesthetic techniques after Templehoff's scale (17)are

valid today:
- Easy use;
- Rapid induction and awakening;
- Maintenance PPC and self-regulation;
- Prevention of ICP growth;
- Maintenance of vascular reactivity to CO_2;
- Lack of systemic toxicity;
- Possibility of electrophysiological monitoring;
- Low cost.

To meet these criteria there are many possible combinations. The anesthesiologist will have to choose a technique based on knowledge of the pharmacological characteristics of the available agents.

A. Total Intravenous Anesthesia

Short-term effects of anesthetics (like propofol, alfentanyl, remifentanyl, rocuronium) and new pharmacokinetic and pharmacodynamics studies have increasingly started using "total intravenous anesthesia"(TIVA).

In clinical practice, optimal conditions are obtained when the anesthetic agent concentration in the CNS (site of action) is stable, and it depends on stable concentration in blood stream, however maintaining such constant concentrations is not possible unless certain procedures are carried out:

- by bolus, when there is a sudden increase in blood concentration, and a decrease in distribution and elimination. The following CNS concentration remains longer in the blood compartment and maintenance of anesthesia will require an accurate titration of the drug.

- by manually controlled infusion, because you cannot get a steady blood concentration than hard as complex mathematical calculations required several times during anesthesia.

A computer included in an automatic injection pump can easily perform these calculations. This creates so-called technique of intravenous Target Controlled Infusion (TCI).

Maintenance dose of opioids are different in neuroanesthesia.

Painful events in neurosurgery are at the start and end point of the intervention, which are:
- Laryngoscopy, tracheal intubation;
- Fixing the head in the headrest;
- Skin, periosteum, and dura matter incision;
- Suture of Dura matter and scalp.

As a result, higher analgesic doses are required for dura mater incision and suture. Cerebral substance does not trigger pain when penetrated however.

So between these two intervals, the patient requires more hypnosis and muscle relaxants than analgesia. We can say that neuroanesthetical doses of anesthetics are more individualized.

B. Pivot Inhaled Anesthesia (balanced)

Balanced anesthesia is a more ancient than TCI and TIVA and more commonly used today. It involves maintenance of anesthesia with an inhaled agent, associations at or not nitrous oxide and repeated injection of small doses of opioid analgesic and muscle relaxants, depending on the need.

With increasing dose inhaled anesthetics decrease cerebral metabolism and causes cerebral vasodilation (8), so they have the potential to increase ICP, threatening maintaining optimal CPP (11).

However, inhaled agents react with the CO_2 in cerebral vessels, especially isoflurane (8), allowing their use in

neuroanesthesia by assigning a moderate hyperventilation to counter their effect of increasing the CBF(16). The CMRO2 decrease and circulation auto-regulation is impaired with an increase of inhaled agent's concentration.

Isoflurane protects brain through two mechanisms:

• reducing excitatory neurotransmitters release by presynaptic mechanism, an effect comparable to hypothermia (K Nakashima et al 1996);

• decreasing neuronal metabolism by nontoxic mechanism, and lowering glucose takeover in neurons, an effect comparable to thiopental (4); it can induce an EEG isoelectric line at non-toxic concentrations (2MAC).

Isoflurane can be an attractive opportunity to compete with the new trend of using TIVA, TCI.

Sevoflurane has a lower solubility coefficient than Isoflurane, which makes it attractive for neuroanesthesy. Cerebral effects (onCBF,CMRO2, self, reactivity to PaCO2)are similar to isoflurane, but not irritating to the airways, and that lend itself to mask induction agent used mostly in young children and infants. Sevoflurane is improving hemodynamic stability and decrease opioid and muscle relaxants dose as well, allowing a faster awakening and decreasing more the incidence of postoperative nausea and shivering.

Inhaled agents do not provide adequate analgesia and as a result require analgesic supplements especially to painful moments in neurosurgery. This is achieved with low doses of synthetic opioids injected during induction, the start of surgery, during surgery. Opioids can be administered on continuous pace with automatic pump.

The use of nitrous oxide is the most controversial in posterior fossa interventions. Studies have shown its effect of increasing the CBF and even cerebral oxygen consumption (14). Has also demonstrated its excitatory effect on the brain. It is advisable not to use nitrous oxide when somatic sensory evoked potentials are monitored.

Introduction using TIVA was an important step in improving anesthetic technique for this type of surgery. Using TCI technology allows precise dosing of anesthetic drugs, necessary medication use is much lower, also the incidence of postoperative vomiting and shivering, quick awakening affording early postoperative neurological assessment (15).

Using sitting position allows a relaxed brain, does not require depletion treatment, offers minimal intraoperative bleeding and good surgical approach and reduces the risk of damage of the nerves structures. I have not met incidents of air embolism or hemodynamic instability problems. Say that I have not used this position for small children, the elderly and cardiac patients with GCS less than 15 points.

Management of intraoperative fluids must take into account the maintenance of normovolemia primarily. It is allowed using intraoperative glucose solutions as glucose worsen cerebral edema and ischemic brain damage. Mannitol remains diuretic of choice in reducing intraoperative brain edema and obtaining a convenient ICP. It can lead to a transient increase in cerebral blood volume (vasodilator effect of hiperosmolality) and increased ICP. This phenomenon does not occur when administered slowly, at least 20'-30'. Manitol may accumulate in repeated doses. The rebound effect must be taken into account as doses that are used are 0.5-1g /

kg (18).

Loop diuretics administered before mannitol may reduce cellular edema, but without affecting the extracellular fluid volume. The two diuretics work better together, but attention to urinary losses and electrolyte disorders.

Intraoperative problems

Posterior fossa surgery, concerning vital nerve centers during surgical manipulation provides the worst risk, which is represented by cardiovascular disorders. Fourth ventricle floor stimulation can cause hypertension, bradycardia, tachycardia, and arrhythmia. If these problems required surgical maneuvers off, leading to normalize hemodynamic situation. Pharmacological treatment is necessary in rare cases.

The incidence of cardiovascular disorders is higher in patients with high ICP. Ventriculo-peritoneal drainage performed 1-2 weeks before surgical cure of the tumor decreases this risk.

Due to the patient position ventilation problems can arise (by sliding the tracheal tube).

Air embolism may be another intraoperative complication in sitting position.

Intraoperative bleeding requires monitoring losses and volume replacement with crystalloids and colloids, then blood transfusion (over 20% volume of blood loss).

Awakening allows immediate postoperative neurological assessing; clinical neurological examination is the best existing neuro-monitoring. Immediate awakening is associated with lower cardiovascular and catecholamine changes, but there is a risk (sometimes quite small)

the occurrence of hypoxia and hypercapnia (6).

Delayed awakening allows better control of oxygenation and CO2 removal, but can be associated with delayed neurological examination and a stronger incentive to extubation (hypersympaticotone reaction).

Shivering increases O2 consumption and CO2 production. All this is more serious in neurosurgical patient population, due to increased danger of ICP occurrence and cerebral bleeding and ischemia. As a result, awakening in posterior fossa neuroanesthesia will be gentle, avoiding cough and shivering.

The reversal of muscle relaxants and opioids will be after covering the patient. Low doses of hypnotics, helps us to control the situation

Some studies shown that the primary extubation is generally feasible, except patients with highes ASA score and a longer length of surgery. Also, the patients not extubated in the operating room have a longer stay in the hospital (3).

In conclusion, when consciousness is intact in the preoperative phase, surgery runs without any difficulties,it is recommended that the patient is awakened in the operating room. If consciousness is impaired preoperatively, if the operation time is prolonged if peroperative problems occur (cerebral edema, hemodynamic instability), delayed awakening is recommended. These recommendations of Bracco D et al (1998) are confirmed by randomized trials with significant differences in mortality and morbidity of immediate or delayed awakening.

Postoperative complications

Since the posterior l fossa surgery that is performed with surgical maneuvers around

key vital centers monitoring of cardiovascular, respiratory, neurological, renal functions are particularly important in the postoperative period.

Risk of respiratory disorders, swallowing disorders, cardiovascular disorders, requires careful and continuous monitoring in the ICU of these subjects.

In the postoperative period, sedation, analgesia and cerebral protection are key elements to prevent growth of ICP. Choices of substances that produce lower of CBFand CMRO 2 for sedation also provide cerebral protection (Thiopental, Midazolam, Propofol). Sedation will perform with blood gas monitoring, due to danger of respiratory depression.

In most cases, these patients do not require analgesia; postoperative headache is usually caused by increased ICP. Therefore, prevention of ICH prevents the headache. In case of cerebral edema, this is treated with depletion, sedation, adequate oxygenation and possibly minor analgesics.

Acute postoperative hematoma andhydrocephaluses are serious complications that require early detection and emergency surgery. To this end, close monitoring and repeated neurological examination every hour are tracking patient postoperatively.

Conclusions

Preserving neural function is a priority in neurosurgical interventions and especially in the posterior fossa level.

Current trends in neurosurgery using intraoperative microscope allows performance to the deepest and most sensitive areas of the brain structures. The safest way for reaching them without causing damage by mechanical traction through spreaders means to obtain a"

relaxed brain" and compliant with the so-called "chemical methods", which actually represent the key to success by means of a modern anesthetic technique.

Hence the question:

"What is the best anesthetic technique for this type of neurosurgical intervention?"

From the above, we can conclude that the techniques described can be used to access the posterior fossa surgical pathology but only provided with appropriate multimodal monitoring.

It should be noted that the choice of anesthetic technique depends on both the equipment and anesthetic team experience. In case of insufficient or inappropriate equipment it should be better to avoid this area of neurosurgical activity.

The TCI technique, using pharmacokinetic models, with control over blood concentrations of anesthetic substances might be preferred because it avoids the risks of over-or under dosing the anesthetic drugs, offering a rapid awakening that allows immediate neurological evaluation which is of extreme importance in this pathology.

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