The Evolving Role of Anesthetic Techniques in Neurosurgery: Tiva vs. Inhalational Agents

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Abstract—The treatment of anaesthesia in neurosurgery has changed dramatically, and because of its advantageous neurophysiological profile, total intravenous anaesthesia (TIVA) has become the method of choice. To maximise patient outcomes in various neurosurgical scenarios, a comparison of TIVA with inhalational drugs is necessary. The pharmacological, clinical, and procedural consequences of TIVA in comparison to inhalational anaesthesia are the main topics of this review, which examines the changing importance of anaesthetic methods in neurosurgery. To assess the effects of TIVA and inhalational drugs on intracranial pressure (ICP), brain relaxation, haemodynamic stability, neuromonitoring, and postoperative recovery, a narrative synthesis of current clinical investigations, randomised controlled trials, and meta-analyses was carried out. Research indicates that TIVA, which mostly uses propofol and remifentanil, improves brain relaxation, maintains neuromonitoring integrity, and offers better control over intracranial pressure. These factors make TIVA a good option for procedures involving the supratentorial and posterior fossa. Inhalational medications like desflurane and sevoflurane are useful in some situations, but their usage in high-risk neurosurgery situations is restricted because to their correlation with elevated intracranial pressure and postoperative nausea.

Index Terms— Total Intravenous Anaesthesia (TIVA), Inhalational Anaesthesia, Neurosurgery, Intracranial Pressure (ICP), Brain Relaxation, Hemodynamic Stability

INTRODUCTION

The neuro-anaesthesiology team has many difficulties when performing neurosurgery, which calls for careful preparation, accuracy, and flexibility. Anaesthesia care has evolved into a complicated interplay of many techniques and agents that are suited to the particular demands of each patient and operation due to the advancement of neurosurgical procedures, especially the move towards minimally invasive approaches. These days, epilepsy surgery, awake neurosurgery, minimally invasive neurosurgery, and adjuvant surgeries after endovascular procedures are all commonplace in addition to traditional procedures like tumour resections. In order to provide the best results for patients undergoing these complex procedures, this dynamic area necessitates ongoing learning and cooperation between surgical and anaesthesia teams.
In order to facilitate early neurological evaluations, anaesthesiologists must handle particular issues such preserving ideal cerebral perfusion, controlling intracranial pressure (ICP), and guaranteeing a speedy recovery. Maintaining haemodynamic stability, lowering intracranial pressure, increasing cerebral perfusion pressure, and encouraging brain relaxation to aid in the surgical process are the objectives of anaesthesia during neurosurgery procedures.[1]. There are a number of anaesthetic techniques accessible because to the variety of neurosurgical procedures. Among these methods are general anaesthesia [total intravenous regional techniques, sedation, and anaesthesia (TIVA, inhalation anaesthesia, or a mix of both) [2,3]

Regarding the best anaesthetic method (intravenous or inhalational) and the best anaesthetic drug, there are a number of debates, conflicting views, and procedures, especially when it comes to the surgical excision of supratentorial tumours. According to the majority of published data, TIVA ensures ideal surgical settings by improving haemodynamic stability, outcomes, ICP management, and brain relaxation.

TOTAL INTRAVENOUS ANAESTHESIA (TIVA)

Anaesthetic medications are only given intravenously during delivery in TIVA. Propofol's favourable pharmacokinetics and pharmacodynamics make it the cornerstone of TIVA. Ideal conditions for neurophysiological monitoring, rapid start and offset, and decreased intracranial pressure (ICP) are all offered. Benefits: Improved depth of anaesthesia control, decreased brain metabolic rate and ICP, reduced effect on neurophysiological monitoring (e.g., SSEPs, MEPs), Reduced frequency of nausea and vomiting following surgery (PONV). The risk of propofol infusion syndrome (PRIS), the requirement for infusion pumps and careful observation, and the higher expense in some situations are the limitations. Agents for Inhalation For many years, inhalational drugs have been a standard in general anaesthesia. Agents like desflurane and sevoflurane are prized for their dependability and simplicity of use. They need to be carefully titrated, nevertheless, because of their complicated effects on cerebral physiology. Benefits: Good muscle relaxation and forgetfulness, straightforward delivery methods and titratability, economical in a variety of medical contexts Restrictions: Possibility of elevated intracranial pressure, inhibition of neurophysiological impulses, and elevated risk of PONV

ICP AND ANAESTHETIC AGENTS

Controlling cerebral blood flow (CBF) and cerebral metabolic rate of oxygen (CMRO2) is essential in clinical neurasthenia because these variables have a direct impact on intracranial dynamics and neuronal health. Inhalational and intravenous anaesthetics have different physiological effects, and they are essential in regulating these parameters. By inhibiting neuronal activity and metabolic demand, intravenous hypnotics like propofol and barbiturates reduce CBF and CMRO2 in a dose-dependent manner. The flow-metabolism coupling principle governs this phenomenon, which causes a proportionate drop in CBF as CMRO2 declines. These medications improve surgical circumstances by promoting brain relaxation and lowering ICP through lowering CBF. They are especially useful in neurosurgical procedures because of their neuroprotective qualities, which also result from their capacity to reduce metabolic demand, restrict excitotoxicity, and lessen ischaemic injury.[4] Opioids, on the other hand, have the potential to cause vasoconstriction, which would decrease blood flow to already compromised areas and exacerbate perfusion in ischaemic regions. On the other hand, it is known that inhalational anaesthetics raise ICP in a dose-dependent manner, mostly because they cause cerebral vasodilation, which raises CBF. At dosages higher than 1 minimum alveolar concentration (MAC), when the vasodilatory response can significantly raise CBF and, in turn, ICP, this impact becomes particularly noteworthy. Nevertheless, inhalational drugs show a more balanced profile at sub-MAC dosages, with negligible increases in CBF and concurrent decreases in CMRO2. Dose titration is essential for maximising anaesthetic treatment in patients with intracranial disorders because of this dual impact, which may be advantageous at lower doses by reducing metabolic demand without unduly raising ICP.[5]

The risk of cerebral tissue ischaemia may rise if hyperventilation is used to reverse vasodilation, particularly when strong opioid dosages are present.

ANAESTHETIC TECHNIQUE AND OUTCOME AFTER NEUROSURGICAL PROCEDURES

By customising their anaesthetic technique to each case's unique requirements, anaesthesiologists play a crucial part in determining the results of neurosurgery. Their thorough knowledge of surgical techniques, including possible side effects and intraoperative difficulties, allows them to foresee and successfully handle crucial situations. Additionally, as specialised neuro-anaesthesiologists, they possess the knowledge and skills necessary to handle the particular neurological and physiological demands of these intricate procedures, particularly in paediatric neurosurgery, which greatly enhances patient safety, optimal recovery, and overall surgical success [6].
In their narrative review, Kannabiran and Bidkar [7] support TIVA as a good option because of its easy onset, quick recovery, lower risk of nausea and vomiting, and—above all—its capacity to produce superior brain relaxation, which enhances surgical outcomes. A retrospective analysis with 263 patients who had glioblastoma excision was carried out by

Kumaria et al. [8]. Of them, 184 procedures were carried out under inhalational anaesthesia, while 79 were carried out with TIVA. The scientists came to the conclusion that TIVA is superior to inhalational anaesthesia during the perioperative phase, mainly because it promotes better surgical circumstances and brain relaxation. In their comprehensive study, Zuleta-Alarcón et al. [9] came to the conclusion that volatile anaesthesia is a safe alternative, especially for patients who do not have excessive ICP and have normal intracranial compliance. . Ninety individuals with posttraumatic subdural haemorrhage were included in the study by other authors. Based on whether TIVA or inhalational anaesthesia was used during the craniotomy for the evacuation of the haemorrhage, the patients were split into two groups. According to their prospective trial, TIVA enhanced brain relaxation, reduced intracranial pressure, and improved the haemodynamic clinical profile of patients with severe traumatic brain injury. [10,11] The results of 111 patients who were randomly assigned to one of two groups—the desflurane group or the TIVA group—were published by Jiang et al. [12]. They discovered that while brain relaxation was similar in both groups, the desflurane group recovered more quickly but had higher incidence of nausea and vomiting. In their meta-analysis of randomised controlled trials comparing propofol versus volatile anaesthesia, specifically with regard to brain relaxation, Jonathan et al. [13] analysed 17 published papers including almost 2000 patients. Using a 4-point scale model, ICP, haemodynamic, and recovery following neurosurgery procedures, they compared brain relaxation. They came to the conclusion that brain relaxation was comparable to volatile-based anaesthesia, with the exception of a lower ICP in the propofol group.

The literature contains a variety of information about various neurosurgical techniques. The results of endoscopic transsphenoidal pituitary surgery patients were reported by Kim et al. [14]. They recruited 82 patients for their randomised controlled study, and they were randomised to either the TIVA group or the sevoflurane–remifentanil group. The 40-item Quality of Recovery scale served as the main outcome measure. They came to the conclusion that both anaesthesia methods worked, but that patients in the sevoflurane group recovered from anaesthesia faster than those in the TIVA group. A retrospective investigation at Heidelberg University Hospital produced some intriguing findings. The primary outcome of the trial, which included 576 glioblastoma patients, was survival. According to the authors, postoperative survival was not significantly impacted by the anaesthesia technique, namely TIVA as opposed to volatile anaesthesia.[15]

Supratentorial and infratentorial are the two general classifications for intracranial cancers; the latter category includes lesions that are located in the posterior fossa. There are not many published studies that compare neurosurgery of the posterior fossa and supratentorial regions. Nonetheless, the goal of intraoperative care in both situations is to maintain ideal brain relaxation and control ICP [16]. Potential haemodynamic abnormalities brought on by brainstem manipulation, the possibility of venous air embolism, a greater incidence of postoperative nausea and vomiting (PONV), and elevated postoperative pain scores are some of the unique difficulties associated with posterior fossa tumour surgery. [17] Propofol and remifentanil used with TIVA is linked to decreased PONV and maybe improved postoperative pain management. Several authors have pointed out that there is ongoing discussion on the use of opioids in neurosurgery. Six randomised controlled studies were included in a meta-analysis by Sriganesh et al. [18]. Their results highlighted the need for more research by demonstrating no superiority of non-opioid intraoperative analgesia over opioid-based analgesia in craniotomies for brain tumour excision.

According to recent reports, TIVA may lower sepsis rates because of propofol's immunomodulatory properties. Additionally, by preventing the synthesis of cytokines and nitric oxide, propofol may lower the risk of pulmonary problems. [19, 20] Data on 144,506 individuals who had neurosurgical procedures, such as decompressive craniectomy, tumour removal, open cerebrovascular surgery, skull base surgery, correction of craniosynostosis, and treatment of brain abscesses, have been reported by other authors. Based on the maintenance of anaesthesia, patients were split into two groups: those receiving inhalational drugs or TIVA. Although there were no statistically significant differences between the groups, the authors did note that the TIVA group experienced less postoperative problems. [21]

Optimal anaesthesia for endovascular thrombectomy is another important topic of discussion. Despite the large number of published research on the subject, intravenous general anaesthesia is generally thought to be linked to better recanalization rates and good results. [22, 23]

DISCUSSION

As surgical and neuromonitoring technology have advanced, so too has the choice of anaesthetic approach in neurosurgery. Inhalational agents and total intravenous anaesthesia (TIVA) are two main strategies, each with unique pharmacologic profiles, advantages, and disadvantages. While acknowledging the continuous usefulness of volatile anaesthetics in some situations, this article summarises the most recent data comparing both modalities and emphasises the rising preference for TIVA in neurosurgical settings.

TIVA, which mostly uses drugs like remifentanil and propofol, has a number of benefits that closely match the physiological requirements of neurosurgery operations. It is especially appropriate for situations demanding the best possible brain relaxation and neuromonitoring because of its capacity to maintain cerebral autoregulation, lower intracranial pressure (ICP), and give accurate depth control. Faster cognitive recovery and a lower incidence of postoperative nausea and vomiting (PONV) have also been linked to TIVA; these outcomes are important for early postoperative neurological evaluation. Furthermore, the immunomodulatory and anti-inflammatory properties of propofol may help lower the risk of sepsis and other postoperative problems such pulmonary sequelae.

However, inhalational anaesthetics like desflurane and sevoflurane are still often employed because of their accessibility, affordability, and simplicity of titration, especially in environments with limited resources. These substances have been demonstrated to raise cerebral blood flow and intracranial pressure, especially at higher doses, which may jeopardise surgical outcomes in individuals with inadequate intracranial compliance. However, they also give sufficient amnesia and muscular relaxation. Volatile drugs, on the other hand, exhibit a more balanced impact when taken at sub-MAC levels, with less metabolic effort and no increase in ICP. Because of its greater intraoperative haemodynamic stability and brain relaxation, TIVA is preferred in recent investigations, such as those conducted by Kannabiran and Bidkar and Kumaria et al. Nevertheless, contradictory results, like those from Schmoch et al. and Kim et al., imply that inhalational drugs could offer quicker emergence in some procedures and that the anaesthetic approach may not have a substantial impact on long-term survival outcomes. This highlights the necessity of making decisions based on the individual patient rather than using a one-size-fits-all strategy.

There are particular anaesthetic hazards associated with brainstem manipulation and anterior fossa operations, such as haemodynamic fluctuations, air embolism, and PONV. In these situations, TIVA has shown useful in reducing PONV and promoting easier intraoperative care. However, in difficult or extensive operations where customised anaesthetic depth and neuromonitoring compatibility are crucial, balanced Anaesthesia—a prudent mix of both intravenous and inhalational agents—is becoming more and more popular as a practical alternative.

There are still gaps in the literature despite the encouraging data for TIVA, especially with regard to its effect on long-term neurological outcomes and its relative effectiveness in paediatric neurosurgery, emergency situations, and endovascular operations. Furthermore, TIVA's place in future practice may be further strengthened by a wider move towards intravenous procedures brought on by environmental worries about the greenhouse gas emissions from volatile agents.

CONCLUSION

In their day-to-day clinical practice, neuro-anaesthesiologists always struggle with selecting the right anaesthesia technique and anaesthetic medications. Although there is mixed evidence in the literature, intravenous anaesthesia is becoming more and more popular for neurosurgery because of its clinical benefits as well as worries about the

environmental effects of inhaled drugs. TIVA has a number of advantages, such as improved brain relaxation, regulated intracranial pressure, haemodynamic stability, and accelerated recuperation. But completely ignoring the function of inhalational drugs is counterproductive because they are still important in some situations. These include brainstem stimulation treatments, low-resource settings, patients without increased ICP, paediatric neurosurgery, and as part of balanced anaesthesia.

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