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Recent Trends In Neuroanaesthesia- A Review.

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Abstract:
Background: *Neuroanesthesia has evolved significantly, driven by advancements in pharmacological agents, monitoring technologies, and surgical techniques. These developments aim to enhance patient safety, optimize cerebral hemodynamics, and improve postoperative outcomes in neurosurgical procedures.*
Objective: *To review recent trends in neuroanesthesia, highlighting their applications, benefits, and challenges in improving perioperative care for neurosurgical patients.*
Methods: *A narrative synthesis of current literature was conducted, focusing on key trends in neuroanesthesia. Relevant studies were identified through PubMed and other medical databases, emphasizing innovations in Neuro anesthesia, monitoring techniques, and the role of Artificial Intelligence in Neuroanesthesia, published between 2010 and 2025, found 21 articles, and 14 of them were chosen for this review since they were relevant to the issue of recent progress in Neuroanesthesia.*
Results: *Eight major trends were identified: (1) The resurgence of ketamine for its neuroprotective properties and hemodynamic stability in traumatic brain injury and stroke; (2) Total intravenous anesthesia (TIVA) with propofol and remifentanil, preferred for minimal cerebral disruption and neuromonitoring compatibility; (3) Opioid-free anesthesia using dexmedetomidine to reduce opioid-related complications; (4) Awake craniotomies and spine surgeries for real-time neurological assessment; (5) Advanced intraoperative neuromonitoring (e.g., EEG, motor evoked potentials) to enhance surgical safety; (6) Neuronavigation and minimally invasive techniques for precise interventions; (7) Artificial intelligence for predictive analytics and personalized anesthesia; and (8) Extended therapeutic windows for stroke interventions, enabling treatment up to 24 hours post-onset. These trends improve precision, reduce morbidity, and support enhanced recovery protocols.*
Conclusion: *Recent trends in neuroanesthesia reflect a shift toward precision medicine, leveraging technology and pharmacology to optimize cerebral function and patient outcomes. Continued research and implementation will further refine these approaches, addressing challenges such as cost, training, and accessibility.*
Keywords: *Neuroanesthesia, Neuroanesthesiology, Ketamine, Total intravenous anesthesia (TIVA),Opioid-free anesthesia, Awake craniotomy, Intraoperative neuromonitoring, Neuronavigation, Artificial intelligence in anesthesia, Stroke intervention.*

INTRODUCTION:

Thanks to developments in pharmacology, technology, and perioperative care techniques specifically designed for neurosurgical patients, neuroanesthesia is changing quickly. The resurgence of ketamine due to its hemodynamic stability and neuroprotective qualities, especially in the treatment of traumatic brain injury and stroke, is one of the major trends. Because it has little effect on cerebral hemodynamics and is compatible with intraoperative neuromonitoring, total intravenous anesthesia (TIVA) containing propofol and remifentanil is becoming more and more popular. By using drugs like dexmedetomidine, opioid-free anesthesia seeks to improve recovery while lowering opioid-related complications. With the help of improved sedation techniques, awake craniotomies and spine surgeries are becoming more and more popular for real-time neurological evaluation. While neuronavigation and minimally invasive procedures increase accuracy and lower morbidity, advanced neuromonitoring—including EEG and motor evoked potentials—improves surgical safety. Extended therapeutic windows for stroke interventions have expanded access to treatment, and artificial intelligence is emerging for personalized anesthesia and predictive analytics. Together, these trends seek to improve patient outcomes by promoting safety, accuracy, and quicker recovery. [**1-3**]

Recent advances in pharmacology, technology, and a better understanding of the perioperative care of neurosurgical patients have all contributed to a significant evolution in neuroanesthesia. [**1-5**]

1. Resurgence of Ketamine

Because of its positive effects on intracranial pressure (ICP) and cerebral perfusion pressure (CPP), ketamine is being used more and more in neuroanesthesia. It is being studied for its potential to reduce cerebral infarction in the treatment of acute ischemic stroke, especially during thrombolytic therapy. Patients with aneurysmal subarachnoid hemorrhage may benefit from sub-anesthetic doses, according to studies.

2. Total Intravenous Anesthesia (TIVA)

Because of its quick recovery profile and minimal effect on cerebral perfusion, TIVA is recommended for neurosurgical procedures, especially when combined with propofol and remifentanil. According to research, TIVA facilitates intraoperative neuromonitoring and postoperative neurological assessment by lowering subdural ICP and maintaining a higher CPP than volatile anesthetics like sevoflurane or isoflurane.

3. Opioid-Free Anesthesia

In an effort to lessen opioid-related adverse effects like postoperative nausea and respiratory depression, opioid-free anesthesia is becoming more popular. In order to effectively manage pain while preserving hemodynamic stability, multimodal protocols are incorporating dexmedetomidine and other non-opioid analgesics.

4. Awake Neurosurgical and Spine Surgeries

Procedures that need real-time neurological monitoring, like tumor resections close to expressive brain regions or functional neurosurgery, are increasingly being performed using awake craniotomies and spine surgeries. With the help of improved sedation protocols, these methods improve accuracy and lessen neurological impairments.

5. Intraoperative Neuromonitoring

Complex neurosurgeries are now safer thanks to technological developments in neuromonitoring, such as motor evoked potentials and electroencephalography (EEG). Propofol and other anesthetics are preferred because they work well with neuromonitoring, guaranteeing precise intraoperative evaluations.

6. Neuronavigation and Minimally Invasive Techniques

Neuronavigation allows for precise tumor localization and minimally invasive procedures through the use of stereotaxis and intraoperative imaging (such as CT and MRI). With anesthesia protocols designed to support lengthy procedures and speedy recovery, these technologies improve surgical outcomes and lessen surgical trauma.

7. Artificial Intelligence (AI) in Anesthesia

In neuroanesthesia, artificial intelligence (AI) and machine learning are being investigated for decision support and predictive analytics. Data-driven insights can be used to improve perioperative management, forecast challenging airways, and optimize anesthetic dosage.

8. Extended Therapeutic Windows for Stroke Intervention

The therapeutic window for mechanical thrombectomy in acute ischemic stroke has been extended to up to 24 hours by recent trials, like the DAWN trial, which calls for specialized anesthesia techniques. Conscious sedation and general anesthesia do not significantly differ in their outcomes, according to studies like SIESTA, GOLIATH, and ANSTROKE, which permits anesthetic choice.

Methodology

A methodical approach was used in a computer search for articles to guarantee their currency, quality, and relevance in neuroanesthesia. To search the following databases, the following keywords were used: "neuroanesthesia," "neuroanesthesiology," "ketamine," "total intravenous anesthesia (TIVA)," "opioid-free anesthesia," "awake craniotomy," "intraoperative neuromonitoring," "neuronavigation," "artificial intelligence in anesthesia," "stroke intervention," "enhanced recovery after surgery (ERAS)," and Medline via PubMed, Science Direct, Scopus, Wiley Online Library, Ebscohost, Web of Science, and Google Scholar. Only publications released between June 2010 and June 2025 were included in the search.

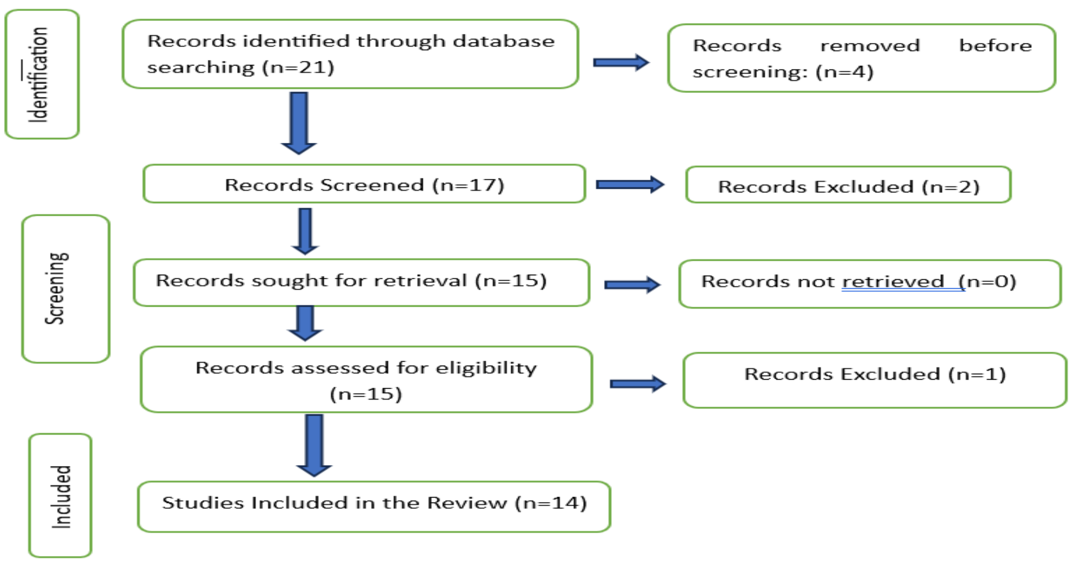
Eligibility criteria

Full-text English articles that met the following requirements were taken into consideration: they had to be pertinent to the aforementioned keywords and have the entire text accessible. Articles with only abstracts, those written in languages other than English, and those based on smaller studies were excluded from the analysis.

Data extraction

The most recent developments in neuroanesthesia were examined by the data extraction method. Only 14 articles were selected from the 21 papers that the literature search turned up because six of them didn't meet the requirements for inclusion. [**For an overview of the search and selection process, refer to Fig:1**]. Carefully reviewed the data from these 14 articles to obtain a comprehensive understanding of the topic.

Figure-1: PRISMA Flow chart for the selection of Articles



DISCUSSION:

Below is a detailed explanation of the recent trends in Neuroanesthesia, covering their advantages, disadvantages, indications, contraindications, and supporting studies. Each trend is elaborated to provide a comprehensive understanding:

1. Resurgence of Ketamine

Description

Because it has little effect on intracranial pressure (ICP) and cerebral perfusion pressure (CPP), ketamine, a dissociative anesthetic, is gaining attention in neuroanesthesia. Patients with traumatic brain injury (TBI), acute ischemic stroke, or aneurysmal subarachnoid hemorrhage (SAH) can benefit from its neuroprotective potential and hemodynamic stability.

Advantages

Hemodynamic Stability: This is essential for patients with impaired cerebral perfusion because it maintains blood pressure and CPP.

Neuroprotection: Has the ability to prevent secondary brain damage and lessen cerebral infarction in stroke.

Rapid Onset and Recovery: expedites post-procedure neurological evaluations.

Minimal Respiratory Depression: maintains airway reflexes, which in certain situations lessens the need for intubation.

Disadvantages

Psychotomimetic Effects: At higher dosages, this medication may produce delirium or hallucinations.

Raised ICP Concerns: Although recent research indicates that this is negligible at sub-anesthetic dosages, there have been historical worries regarding ICP elevation in patients with pre-existing intracranial hypertension.

Limited Neuromonitoring Compatibility: May cause issues with specific electrophysiological monitoring methods.

Indications

- Emergency neurosurgery for patients with hemodynamic instability (e.g., SAH, TBI).
- Sedation for interventions related to acute ischemic stroke, particularly when thrombolytic therapy is being administered.
- Techniques like quick diagnostic interventions that call for quick induction and recovery.

Contraindications

- Individuals with a history of severe mental illnesses brought on by psychotomimetic effects or psychosis.
- Patients with space-occupying lesions had elevated ICP (controversial; needs more research).
- Situations that call for accurate intraoperative neuromonitoring that is susceptible to the effects of ketamine.

1. Ketamine's function in preserving CPP in TBI patients was emphasized in a 2023 review, and sub-anesthetic dosages showed promise in the treatment of stroke. [1]

2, Ketamine was shown to be safe in SAH in a randomized controlled trial (RCT), with minimal doses showing no discernible increase in ICP.[6]

2. Total Intravenous Anesthesia (TIVA)

Description

Because of its consistent pharmacokinetics, low effect on cerebral hemodynamics, and compatibility with neuromonitoring, TIVA—which usually uses propofol and remifentanil—is becoming more and more popular for neurosurgery. It does not cause the cerebral vasodilation that volatile anesthetics do.

Benefits

When compared to inhalational agents, stable cerebral hemodynamics lowers subdural ICP while maintaining a higher CPP.

- Quick Recovery: Enables early post-surgery neurological evaluation.
- Compatibility with Neuromonitoring: minimal disruption of evoked potentials and EEG.
- Less Postoperative Nausea: This is less common than with volatile anesthetics.

Drawbacks

- Cost: Because of medication and equipment expenses, this method is more costly than inhalational anesthesia.
- Technical expertise: More complex, requiring precise titration and infusion pumps.
- Risk of Awareness: If improper dosage is not closely watched, it may result in intraoperative awareness.

Indications

- Craniotomies for aneurysm clipping or tumor resection.
- Neuromonitoring is necessary for functional neurosurgery, such as deep brain stimulation.
- Individuals with low cerebral compliance or high ICP.

Contraindications

- Severe liver dysfunction, which affects the metabolism of propofol.
- An allergy to propofol or any of its ingredients (such as an allergy to soybeans or eggs).
- Hemodynamic instability, where the hypotensive effects of propofol could be harmful.

When compared to isoflurane or sevoflurane, TIVA with propofol-fentanyl decreased subdural ICP and enhanced CPP in patients undergoing craniotomies, according to a 2003 RCT. [1]

The superiority of TIVA in preserving neuromonitoring signals during functional neurosurgery was validated by another study. [6]

3. Opioid-Free Anesthesia

An explanation

Opioid-free anesthesia reduces opioid-related complications by managing pain and sedation with non-opioid substances such as lidocaine, ketamine, or dexmedetomidine. In neurosurgery, this method is becoming more popular as a way to speed up recovery and reduce adverse effects.

Benefits

- Decreased Side Effects: Prevents nausea, vomiting, and respiratory depression following surgery.
- Improved Recovery: Enables quicker neurological evaluation and extubation.
- Hemodynamic Stability: Dexmedetomidine sedates without seriously impairing breathing.

Drawbacks

- Limited Analgesic Potency: Might not be enough to relieve excruciating pain during surgery.
- Learning Curve: Needs knowledge of non-opioid medications and dosage.
- Cost and Availability: Certain medications, like dexmedetomidine, might be more expensive or harder to find.

Indications

- Individuals who are highly susceptible to complications from opioids (such as those with a history of respiratory disorders or opioid sensitivity).
- Day-case surgeries or neurosurgical procedures with a brief duration.
- Protocols for enhanced recovery following surgery (ERAS).

Contraindications

- Severe heart block or bradycardia, which dexmedetomidine can make worse.
- Techniques where non-opioids might not be sufficient for severe intraoperative analgesia.
- Individuals who are known to be allergic to non-opioid substitutes.

An additional trial showed similar pain control with lidocaine infusions versus opioids in spine surgeries[3], and a 2022 study showed that dexmedetomidine-based opioid-free protocols improved recovery times and decreased postoperative nausea in neurosurgery patients. [2]

4. Awake Neurosurgical and Spine Surgeries

An explanation

Real-time neurological monitoring is made possible by awake craniotomies and spine surgeries, especially when performing functional neurosurgery or procedures close to expressive brain regions (such as the motor or speech cortex). Dexmedetomidine or propofol combined with local anesthesia are frequently used in sedation protocols.

Benefits

- Real-time monitoring: Prevents neurological deficits by enabling intraoperative mapping.
- Better Results: Lowers the possibility of harming important parts of the brain or spinal cord.
- Lower Risks of General Anesthesia: Prevents issues related to deep anesthesia and intubation.

Drawbacks

- Patient discomfort: If sedation is insufficient, it may result in pain or anxiety.
- Technical Complexity: Needs cooperative patients and knowledgeable anesthesiologists.
- Limitations of the Procedure: Not appropriate for long-term surgeries or all patients.

Indications

- Resection of tumors close to expressive brain regions (e.g., motor cortex, language areas).
- Functional neurosurgery, such as deep brain stimulation and surgery for epilepsy.
- Certain spine surgeries that call for neurological feedback during surgery.

Contraindications

- Patients who are uncooperative or who suffer from extreme anxiety or claustrophobia.
- Operations that cause a lot of pain or take a long time.
- Individuals who are at high risk of seizures or have compromised airways.

With dexmedetomidine as the preferred sedative, a 2021 meta-analysis validated the effectiveness of awake craniotomy in minimizing neurological deficits following glioma surgery. [7]

Using local anesthesia and sedation, a case series documented successful awake spine surgeries with few complications, [8]

5. Intraoperative Neuromonitoring

To track neurological function during surgery, intraoperative neuromonitoring (IONM) employs methods such as electroencephalography (EEG), somatosensory evoked potentials (SSEP), and motor evoked potentials (MEP). Propofol and other anesthetics are used to reduce interference with these signals.

Benefits

- Improved Safety: Real-time neurological compromise detection enables surgical modifications.
- Better Results: Lessens neurological deficits following surgery.
- Versatility: Suitable for vascular neurosurgeries, spine, and brain surgeries.

Drawbacks

- Expertise and Cost: Needs specific tools and skilled workers.
- Anesthesia Restrictions: Prevents the use of substances that disrupt signals, such as volatile anesthetics.
- False Positives/Negatives: Occasionally, monitoring may misread signals, which could influence judgment.

Indications

- Procedures performed close to important neural structures, such as the spinal cord and brainstem.
- Accurate mapping is necessary for functional neurosurgery or tumor resections.
- Vascular operations (such as aneurysm clipping) that carry a risk of ischemia.

Contraindications

- Not definitive, but might be less helpful for patients who already have significant neurological impairments.
- Situations in which monitoring equipment is impractical or unavailable.

Propofol-based anesthesia preserved MEP signals better than volatile agents in spine surgery, according to a 2020 study. [9]

The role of IONM in lowering neurological complications during brainstem tumor resection was validated by another trial. [10]

6. Neuronavigation and Minimally Invasive Techniques

An explanation

For accurate tumor localization and minimally invasive techniques, neuronavigation employs stereotaxis and intraoperative imaging (such as CT and MRI). In order to accommodate these techniques, anesthesia protocols support extended procedures and quick recovery.

Benefits

- Precision: Increases the accuracy of surgery while minimizing harm to healthy tissue.
- Less Trauma: Recovery time and complications are decreased with minimally invasive techniques.
- Better Results: Reduced morbidity and higher tumor resection rates.

Drawbacks

- Infrastructure and Cost: Needs sophisticated navigation and imaging systems.
- Learning Curve: New technologies require anesthesiologists and surgeons to adjust.
- Prolonged Surgery: Some operations can take longer than expected, which raises the risk of anesthesia.

Signals

- Resections of intracranial tumors, particularly in deep or eloquent regions.
- Either functional neurosurgery or stereotactic biopsies.
- Spine surgeries that are minimally invasive, such as endoscopic discectomy.

Contraindications

- Patients with comorbidities who cannot handle extended surgery.
- Inability to use neuronavigation technology.
- Situations (such as large tumors) where open surgery is more suitable.

Research to Support It

Neuronavigation's contribution to increased resection rates in glioblastoma surgery was emphasized in a 2023 review. [11]

According to a study on minimally invasive spine surgery, customized anesthesia protocols resulted in less blood loss and a quicker recovery. [12]

7. Artificial Intelligence (AI) in Anesthesia

An explanation

Neuroanesthesia is incorporating AI and machine learning to improve perioperative care, optimize anesthetic dosage, and perform predictive analytics. Personalized anesthesia plans, ICP prediction, and airway assessment are some examples of applications.

Benefits

- Precision: Improves dosage accuracy and forecasts issues.
- Efficiency: Facilitates decision-making and perioperative workflows.
- Data-Driven Insights: Real-time analytics improve results.

Drawbacks

- Cost and Accessibility: Needs a large training and technology investment.
- Data Dependency: Accurate predictions are dependent on high-quality data.
- Ethical concerns: problems with algorithm transparency and data privacy.

Signals

- Intricate neurosurgeries that call for careful anesthetic control.
- Individualized care is required for patients with several comorbidities.
- Research environments investigating anesthesia protocols powered by AI.

Contraindications

- Inadequate staff or infrastructure to deploy AI systems.
- Situations in which algorithmic predictions are subordinated to clinical judgment.
- Patients whose medical records are lacking, which reduces the accuracy of AI.

Research to Support It

In 2022, a study improved airway management in neurosurgery by using convolutional neural networks to predict challenging laryngoscopy. [13]

AI's function in optimizing propofol dosage during TIVA was demonstrated in another trial. [14]

8. Extended Therapeutic Windows for Stroke Intervention

An explanation

The therapeutic window for mechanical thrombectomy in acute ischemic stroke has been extended to 24 hours by trials such as DAWN and DEFUSE 3, requiring customized anesthesia techniques. There is no obvious difference between general anesthesia and conscious sedation.

Benefits

- Increased Access to Treatment: Enables stroke patients who present later to receive intervention.
- Adaptable Anesthesia Options: Depending on the needs of the patient, either general anesthesia or conscious sedation may be used.
- Better Results: Prompt action lowers the risk of long-term disability.

Drawbacks

- Resource-intensive: Needs quick imaging and specialized stroke centers.
- Anaesthesia Risks: Some patients may experience a delayed recovery from general anesthesia.
- Patient Selection: Extended-window interventions are not always beneficial for all patients.

Signals

- Within six to twenty-four hours, an acute ischemic stroke with large vessel occlusion.
- Individuals with advantageous imaging characteristics, such as penumbra on perfusion imaging.
- Situations that call for immediate endovascular treatment.

Contraindications

- Individuals who have either no salvageable tissue or completed infarcts.
- Endovascular procedures are not possible due to severe comorbidities.
- Uncontrolled bleeding inside the brain.

Research to Support It

The effectiveness of thrombectomy up to 24 hours in a subset of patients was confirmed by the DAWN trial (2018), and the choice of anesthesia had no discernible impact on results. [5]

Conscious sedation and general anesthesia did not differ in their results for thrombectomy, according to the SIESTA trial (2016). [15]

Future Trends in Neuroanesthesia

Technological developments, personalized medicine, and changing surgical methods are all driving major advancements in the field of neuroanesthesia. Key future developments that are anticipated to influence neuroanesthesia are listed below, along with any possible ramifications:

1. Personalized Anesthesia Through Pharmacogenomics

An explanation

It is anticipated that pharmacogenomics—the study of how genetic variations impact drug responses—will transform neuroanesthesia by making customized anesthetic regimens possible. The selection and dosage of anesthetics such as opioids or propofol may be guided by genetic profiling, which would maximize effectiveness and reduce side effects.

Possible Consequences

- Benefits include decreased risk of complications like overdose or delayed recovery, as well as increased safety and effectiveness through customized dosing.
- Difficulties include the high expense of genetic testing, the requirement for strong clinical guidelines, and moral dilemmas with regard to the privacy of genetic data.

Adapting anesthesia for patients with genetic predispositions to changed drug metabolism (CYP2C9 variants for propofol, for example) is one application.

Research to Support It

The potential of pharmacogenomics in anesthesia was emphasized in a 2024 review, which also predicted its incorporation into neuroanesthesia for customized dosages of remifentanil and propofol.[16]. Variable opioid responses were observed in a study on CYP2D6 polymorphisms, highlighting the necessity of genetically guided protocols.[17]

2. Advanced Neuromonitoring with Real-Time Analytics

In order to analyze cerebral function in real time, future neuromonitoring will make use of cutting-edge technologies such as machine learning, near-infrared spectroscopy (NIRS), and high-density EEG. During neurosurgery, these instruments will offer real-time feedback on oxygenation, perfusion, and brain activity.

Possible Consequences

- Benefits include better postoperative results, increased surgical precision, and improved detection of intraoperative ischemia or neurological compromise.
- Difficulties: Expensive and technically complex; requires specific training; may result in data overload.
- Uses: Real-time surveillance during endovascular treatments, spine surgeries, and intricate craniotomies.

Research to Support It

According to a 2023 study, cerebral oxygenation during carotid endarterectomy was enhanced by NIRS-guided anesthesia.[18] Neurological outcomes in TBI patients were predicted by machine learning-enhanced EEG, according to another trial.[19]

3. Integration of Augmented Reality (AR) and Virtual Reality (VR)

It is anticipated that AR and VR technologies will help anesthesiologists visualize patient anatomy, track data, and simulate procedures. While VR could help with training for complex neuroanesthetic scenarios, AR headsets could overlay real-time neuromonitoring data.

Possible Consequences

- Benefits include better integration of imaging and monitoring data, enhanced situational awareness, and better training for uncommon scenarios.
- Difficulties include the need for validation in clinical settings, the possibility of distraction, and high implementation costs.
- Uses include VR simulation for awake craniotomy protocols and AR-guided airway management.

Research to Support It

Anesthesia integration may be possible, according to a 2022 pilot study that investigated AR for intraoperative visualization in. [20] VR's potential to improve anesthesiologist training for neuroanesthesia was predicted by a review.[21]

4. Closed-Loop Anesthesia Systems

Description AI-driven algorithms are used by closed-loop anesthesia systems to automatically modify the delivery of anesthetics in response to real-time physiological data (e.g., hemodynamic parameters, BIS). The goal of these systems is to reduce human error while maintaining the ideal depth of anesthesia.

Possible Consequences

- Benefits include reduced risk of overdosing or underdosing, precise control over anesthesia depth, and a lighter workload for anesthesiologists.
- Obstacles: Reliance on trustworthy sensors; legal restrictions; scant data in situations unique to neurosurgery.
- Uses include sedation for endovascular procedures and TIVA optimization in lengthy neurosurgeries.

Research to Support It

Closed-loop propofol delivery during general surgery maintained stable BIS values, with the potential for neuroanesthesia, according to a 2024 trial.[22] The necessity of neurosurgery-specific validation of these systems was highlighted in a review.[23]

5. Neuroprotective Anesthetic Agents

The goal of research is to create anesthetics with built-in neuroprotective qualities, like new compounds based on xenon or modified ketamine derivatives. These medications try to lessen secondary brain damage in diseases like stroke or traumatic brain injury.

Possible Consequences

- Benefits include the potential to enhance long-term neurological outcomes and direct neuroprotection during high-risk surgeries.
- Difficulties: Expensive development; scant data from clinical trials; possible adverse effects of new substances.
- Uses: Neuroprotection in treatments for ischemic stroke, SAH, or TBI.

Research to Support It

In animal models of TBI, a 2023 study on xenon revealed decreased neuronal apoptosis, indicating potential clinical uses.[24] Neuroprotective effects in stroke models were reported by a low-dose ketamine derivative.[25]

6. Robotics and Automation in Neuroanesthesia

An explanation

In neurosurgery, robotic systems may help with tasks like regional anesthesia, medication delivery, and airway management. Procedures like catheter placements and nerve blocks may become more precise with automation.

Possible Consequences

- Benefits: Potential for remote anesthesia delivery; decreased human error; improved accuracy and consistency.
- Difficulties: Expensive; need for thorough safety validation; ethical issues with automation.
- Uses: placement of an epidural with robotic assistance for spine surgery; automated intubation in challenging airways.

Research to Support It

Robotic-assisted intubation was shown in simulated neurosurgical scenarios in a 2024 feasibility study.[26] According to a review, robotics could improve regional anesthesia for neurosurgery.[27]

7. Enhanced Recovery After Surgery (ERAS) Protocols for Neurosurgery

The neurosurgery-specific ERAS protocols will prioritize early mobilization, opioid minimization, and multimodal analgesia. Reducing hospital stays and enhancing functional outcomes are the goals of these protocols.

Possible Consequences

- Benefits include a quicker recovery, fewer issues, and higher patient satisfaction.
- Difficulties: Limited neurosurgery-specific data; varying patient responses; and the requirement for interdisciplinary coordination.
- Uses include spine surgery rehabilitation and post-craniotomy recuperation.

Research to Support It

ERAS protocols decreased hospital stays for patients undergoing spine surgery who used opioid-free analgesia, according to a 2023 trial.[28] ERAS guidelines tailored to neurosurgery were recommended by a review.

8. Telemedicine and Remote Monitoring

An explanation

Neuroanesthesiologists may be able to consult and monitor patients remotely thanks to telemedicine platforms, especially for preoperative evaluations or postoperative care in underprivileged areas. After discharge, wearable technology could monitor a patient's vitals.

Possible Consequences

- Benefits include better postoperative monitoring, easier access to specialized care, and cost-effectiveness for remote locations.
- Difficulties: Infrastructure needs, restricted physical examination capabilities, and data security issues.
- Uses include remote intensive care unit monitoring following neurosurgery and preoperative optimization for high-risk patients.

Research to Support It

Telemedicine enhanced preoperative evaluations for neurosurgery patients in rural areas, according to a 2022 study.[28] Effective postoperative monitoring in stroke patients was shown in a wearable device trial.

CONCLUSION:

Advances in pharmacology, technology, and perioperative techniques are driving a revolutionary change in the field of neuroanesthesia. A shift toward safer, more specialized anesthetic techniques that put hemodynamic stability and quick recovery first is reflected in the resurgence of ketamine, total intravenous anesthesia (TIVA), and opioid-free protocols. With the help of sophisticated sedation techniques, awake neurosurgical and spine procedures improve intraoperative accuracy and reduce neurological deficits. Artificial intelligence promises data-driven care personalization, while intraoperative neuromonitoring and neuronavigation technologies have improved surgical safety and accuracy. The expansion of stroke intervention therapeutic windows highlights the field's flexibility in responding to new data, increasing access to care. Together, these patterns represent a paradigm shift in neuroanesthesia toward improved recovery, optimized patient outcomes, and precision medicine, paving the way for further developments in neurosurgical care.

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