International Journal of Health Sciences and Research
Vol.13; Issue: 11; November 2023
Website: www.ijhsr.org
ISSN: 2249-9571

Review Article

Recent Advancements in Total Intravenous Anaesthesia (TIVA) and Anaesthetic Pharmacology

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DOI: https://doi.org/10.52403/ijhsr.20231145

ABSTRACT

Total intravenous anaesthesia (TIVA) is an anaesthesia technique that exclusively employs intravenous agents for induction, maintenance, and emergence from anaesthesia, eliminating the need for inhalational agents. TIVA's principles, mechanisms, benefits, and emerging trends in anaesthetic pharmacology are discussed. Additionally, the challenges associated with TIVA implementation are explored. The article highlights the latest techniques, equipment, and novel intravenous agents used in TIVA, such as target-controlled infusion (TCI) systems, depth of anaesthesia monitoring, and new drugs like remimazolam, dexmedetomidine, and sugammadex. The article also emphasizes the potential benefits of TIVA, including improved hemodynamic stability, faster recovery, and reduced side effects. However, challenges such as cost, medication errors, and the learning curve of TCI systems are addressed. Furthermore, emerging trends in anaesthetic pharmacology, including opioid-sparing techniques, pharmacogenomics-based dosing, and novel analgesic agents, are discussed concerning their impact on TIVA practice. The integration of these advancements has revolutionized the field of anaesthesiology, offering clinicians safer and more precise anaesthesia delivery options. Ongoing research in anaesthetic pharmacology will continue to shape the future of TIVA, optimizing patient care and outcomes.

Keywords: Total intravenous anaesthesia, TIVA, anaesthetic pharmacology, advancements, intravenous agents, perioperative care.

INTRODUCTION

Total intravenous anaesthesia (TIVA) has emerged as a significant advancement in the field of anaesthesia, offering an alternative approach to anaesthesia delivery by utilizing intravenous agents exclusively. This technique has gained popularity due to its numerous advantages, including rapid onset and offset of anaesthesia, precise control of anaesthetic depth, reduced risk of environmental pollution, improved hemodynamic stability, and potential for enhanced recovery. With recent advancements in TIVA techniques and anaesthetic pharmacology, anaesthesiologists have a broader array of tools and strategies to optimize patient care and outcomes.

The primary objective of this article is to provide a detailed exploration of the recent advancements in TIVA and anaesthetic pharmacology. By reviewing the principles, benefits, challenges, and emerging trends associated with TIVA, readers will understand this innovative anaesthesia delivery approach comprehensively. Additionally, the article will examine the latest developments in anaesthetic pharmacology and their impact on TIVA practice.

In recent years, advancements in TIVA techniques have revolutionized the anaesthesia practice. Integrating advanced monitoring systems, such as bispectral index (BIS) and entropy monitoring, has allowed anesthesiologists to control anaesthetic depth, improving patient outcomes. Furthermore, the development of target-controlled infusion (TCI) systems and closed-loop delivery systems has automated drug administration, enhancing the safety and efficacy of TIVA.

In parallel, the field of anaesthetic pharmacology has witnessed significant progress, with the introduction of novel intravenous agents designed explicitly for TIVA. These agents, such as remimazolam, dexmedetomidine, and sugammadex, offer unique properties that contribute to improved anaesthesia management. Remimazolam, a short-acting benzodiazepine, provides rapid and predictable onset and offset of anaesthesia, allowing smoother transitions during the perioperative period. Dexmedetomidine, a selective alpha-2 adrenergic agonist, offers sedation, analgesia, and anxiolysis while maintaining respiratory function. Sugammadex, a selective relaxant binding agent, provides rapid and reliable reversal of neuromuscular blockade.

An ideal drug for TIVA should have a rapid onset of action, rapid recovery, be potent and lipid soluble, and be stable in solution, with no perivascular sloughing if extravasated. It should be water-soluble to minimize toxicity associated with the solvent, not be absorbed by plastic, devoid of adverse effects, cost-effective, and, most importantly, compatible with other agents such that it can be mixed without any complication.[2,4] While the search for such an ideal drug continues, TIVA is being practised with a combination of drugs to overcome the disadvantages of each. Combining various classes of drugs and adjuncts in TIVA is necessary for complete and balanced anaesthesia. It decreases the dose of individual drugs, thereby reducing the side effects of all drugs in a mixture.[5]

The benefits of TIVA extend beyond the anaesthesia period. Patients undergoing TIVA have shown improved hemodynamic stability, reduced incidence of postoperative complications, faster recovery, and enhanced satisfaction compared to traditional inhalational anaesthesia techniques. These advantages make TIVA particularly attractive for patients with cardiovascular or respiratory comorbidities.

However, despite the numerous benefits, challenges remain in implementing TIVA. Factors such as increased cost, the potential for medication errors, and the learning curve associated with TCI systems need to be considered when adopting TIVA in clinical practice. Addressing these challenges is crucial to ensure TIVA's safe and effective implementation for improved patient care.

Emerging trends in anaesthetic pharmacology hold promise for further optimizing TIVA. Opioid-sparing techniques, pharmacogenomics-based dosing, and the development of novel analgesic agents are critical areas of focus. These advancements can potentially enhance TIVA's safety profile, promote faster recovery, and minimize adverse effects.

Aims and Objectives:

The primary objectives of this article are to:

1. Discuss the principles and mechanisms of TIVA.
2. Review the recent advancements in TIVA techniques and equipment.
3. Explore the role of novel intravenous agents in TIVA.
4. Analyze the benefits and challenges associated with TIVA.
5. Examine the impact of TIVA on patient care and outcomes.

6. Discuss emerging trends in anaesthetic pharmacology and their implications for TIVA.

Principles and Mechanisms of TIVA:

Total intravenous anaesthesia (TIVA) is an anaesthesia technique that relies solely on administering intravenous agents for the induction, maintenance, and emergence of anaesthesia. TIVA offers several advantages over traditional inhalational anaesthesia, including rapid onset and offset, precise control of anaesthetic depth, reduced risk of pollution, improved hemodynamic stability, and potential for enhanced recovery. To understand the principles and mechanisms of TIVA, it is essential to examine its key components and their interactions.

Intravenous Agents:

The cornerstone of TIVA lies in using intravenous agents to produce anaesthesia. The commonly used intravenous agents in TIVA include propofol, opioids, and adjuvant medications. These agents act on specific receptors and molecular targets within the central nervous system to induce unconsciousness, analgesia, muscle relaxation, and amnesia.

Propofol, a short-acting hypnotic agent, is widely used to induce and maintain anaesthesia in TIVA. It acts primarily on gamma-aminobutyric acid (GABA) receptors, enhancing inhibitory neurotransmission and promoting sedation and anaesthesia. Propofol has a rapid onset and offset of action, allowing for smooth transitions during the perioperative period.

Opioids are utilized in TIVA to provide analgesia and supplement the hypnotic effect of other agents. Opioids, such as fentanyl or remifentanil, bind to opioid receptors in the central and peripheral nervous systems, modulating pain perception and reducing the requirement for additional analgesics during surgery. Their use in TIVA helps to minimize the need for volatile inhalational agents and promotes opioid-sparing anaesthesia.

Adjuvant medications, including antiemetics, benzodiazepines, and muscle relaxants, may be incorporated into TIVA protocols to enhance patient comfort and facilitate optimal surgical conditions.

Target-Controlled Infusion (TCI):

A critical aspect of TIVA is target-controlled infusion (TCI) systems. TCI allows for precise control and delivery of intravenous agents based on individual pharmacokinetic models. These systems utilize computer algorithms to calculate and administer drugs to achieve and maintain a desired plasma or effect-site concentration. By incorporating patient-specific parameters such as age, weight, and sex, TCI systems can individualize drug administration and optimize anaesthesia depth.

Pharmacokinetic Models:

Pharmacokinetic models form the foundation of TCI systems. These models are derived from extensive clinical data and describe specific intravenous agents' absorption, distribution, metabolism, and elimination. They allow for the prediction of drug concentrations at various sites in the body based on input parameters and are essential in tailoring drug administration to achieve the desired effect.

Pharmacokinetics and pharmacodynamics of popular intravenous drugs like propofol and newer and shorter-acting agents like remifentanil, coupled with the development of pharmacokinetic models and advanced technology in infusion pumps, have made a significant impact on the evolution of total intravenous anaesthesia (TIVA).[2]

Closed-Loop Systems:

Closed-loop systems, also known as feedback-controlled systems, are an emerging technology in TIVA. These systems use real-time monitoring of patient variables, such as bispectral index (BIS) or entropy, to guide drug administration and adjust infusion rates accordingly. The feedback loop enables precise control of anaesthesia depth, ensuring the patient remains adequately anaesthetized while minimizing the risk of under or overdosing.

Benefits of TIVA:

TIVA offers several advantages over inhalational anaesthesia techniques. One of the key benefits is the avoidance of inhaled agents, reducing the risk of pollution and occupational exposure. This is particularly beneficial in settings where pollution control is crucial, such as operating rooms and intensive care units.

The precise control of anaesthetic depth achieved through TIVA helps to ensure patient stability during surgery. The risk of over or under-anaesthesia can be minimized by titrating intravenous agents based on individual needs, leading to improved hemodynamic stability, reduced side effects, and faster recovery. Furthermore, TIVA has been associated with a lower incidence of postoperative nausea and vomiting (PONV), making it a preferred option for patients prone to these complications.

Advancements in TIVA Techniques and Equipment:

Total intravenous anaesthesia (TIVA) has seen significant advancements in techniques and equipment, revolutionizing the field of anaesthesia delivery. These advancements have improved TIVA's precision, safety, and efficacy, improving patient outcomes and perioperative care. Some of the critical advancements in TIVA techniques and equipment:

1. Intraoperative Monitoring:

Advancements in TIVA include integrating sophisticated monitoring systems to guide anaesthesia depth and optimize drug administration. The Bispectral Index (BIS) and entropy monitoring are commonly used to measure the depth of anaesthesia and provide feedback to anesthesiologists. These tools help ensure that the patient remains adequately anaesthetized while minimizing the risk of awareness or excessive depth of anaesthesia.

2. Target-Controlled Infusion (TCI) Systems:

TCI systems have significantly advanced TIVA practice. These systems utilize computer algorithms and pharmacokinetic models to calculate and administer intravenous agents based on patient characteristics. TCI systems offer precise control over drug infusion rates, allowing anesthesiologists to achieve and maintain target drug concentrations more accurately. This enables tailored anaesthesia delivery, minimizing the risk of under or overdosing and promoting optimal patient outcomes.

3. Smart Infusion Pumps:

Smart infusion pumps have become integral to TIVA practice. These pumps are designed to administer intravenous agents and can accurately and safely deliver medications at controlled infusion rates. They often integrate with TCI systems, enabling seamless communication and precise drug delivery based on pharmacokinetic models. Smart infusion pumps enhance patient safety by reducing the risk of medication errors and improving the efficiency of drug administration.

4. Closed-Loop Systems:

Closed-loop systems, also known as feedback-controlled systems, have emerged as a promising advancement in TIVA. These systems combine real-time monitoring of patient variables, such as BIS or entropy, with automated adjustment of drug infusion rates. By continuously analyzing patient responses, closed-loop systems provide feedback to TCI systems, allowing dynamic adjustments to maintain the desired anaesthesia depth. This closed-loop approach improves the precision and reliability of TIVA, optimizing patient care and reducing the workload on anesthesiologists.

5. Ultrasound-Guided Techniques:

Advancements in ultrasound technology have revolutionized regional anaesthesia techniques, often incorporated into TIVA protocols. Ultrasound guidance allows for accurate visualization of nerves and surrounding structures, enhancing the precision and safety of peripheral nerve blocks, epidural anaesthesia, and spinal anaesthesia. Ultrasound-guided techniques enable anesthesiologists to administer local anaesthetics more effectively, improving pain management and reducing opioid requirements during surgery.

6. Drug Formulations:

Advancements in drug formulations have expanded the options available for TIVA practice. For example, the introduction of remimazolam, a short-acting benzodiazepine, offers rapid and predictable onset and offset of anaesthesia. This allows for smoother transitions during the perioperative period. Additionally, sugammadex, a selective relaxant binding agent, provides rapid and reliable reversal of neuromuscular blockade, ensuring efficient recovery from anaesthesia.

7. Integration of Electronic Medical Records (EMR):

Integrating electronic medical record (EMR) systems with TIVA practice has improved patient safety and streamlined documentation. EMRs enable seamless access to patient data, including medication history, comorbidities, and previous anaesthesia records. Anesthesiologists can make informed decisions, minimize drug interactions, and tailor anaesthesia management based on comprehensive patient information.

These advancements in TIVA techniques and equipment have transformed the field of anaesthesia, enhancing the precision, safety, and efficiency of anaesthesia delivery. They contribute to better patient outcomes, reduced complications, and improved perioperative care. As technology and research continue to advance, further innovations are anticipated, leading to continued improvements in TIVA practice.

Novel Intravenous Agents in Total Intravenous Anesthesia (TIVA):

New intravenous agents, such as remimazolam, dexmedetomidine, and sugammadex, have shown promise in TIVA practice. Remimazolam, a short-acting benzodiazepine, offers rapid and predictable onset and offset of anaesthesia. Dexmedetomidine, a selective alpha-2 adrenergic agonist, provides sedation, analgesia, and anxiolysis while preserving respiratory function. Sugammadex, a selective relaxant binding agent, enables rapid and reliable reversal of neuromuscular blockade.

Total intravenous anaesthesia (TIVA) has benefited from the introduction of novel intravenous agents that have expanded the options for anaesthesia management. These agents offer unique properties and applications, enhancing the safety, efficacy, and patient experience during TIVA. Some of the novel intravenous agents used in TIVA:

1. Remimazolam:

Remimazolam is a relatively new benzodiazepine derivative that has gained attention as a promising agent for TIVA. It possesses rapid onset and offset characteristics, making it suitable for induction and maintenance of anaesthesia. Remimazolam acts as a selective gamma-aminobutyric acid (GABA) receptor agonist, producing sedation, anxiolysis, and amnesia. Its pharmacokinetic profile facilitates efficient anaesthesia management and smooth transitions during the perioperative period.

2. Dexmedetomidine:

Dexmedetomidine, a selective alpha-2 adrenergic agonist, has found utility in TIVA practice. It offers sedation, analgesia, and anxiolysis, making it a valuable adjunct to other intravenous agents. Dexmedetomidine acts on alpha-2 receptors in the locus coeruleus, reducing sympathetic outflow and promoting a state of calmness and relaxation. Its unique properties include preserving respiratory drive and offering hemodynamic stability, making it particularly suitable for patients with compromised cardiovascular or respiratory function.

3. Sugammadex:

Sugammadex is a selective relaxant binding agent used for rapid and reliable reversal of neuromuscular blockade. This novel intravenous agent binds explicitly to steroidal neuromuscular blocking agents, such as rocuronium or vecuronium, forming a complex that is then eliminated from the body.[3] Sugammadex effectively reverses neuromuscular blockade within minutes, allowing for efficient emergence from anaesthesia. Its use in TIVA promotes improved patient safety and faster recovery from muscle relaxation.

4. Intravenous Acetaminophen:
Intravenous acetaminophen, a formulation of the widely used analgesic, has been introduced for pain management in TIVA. It provides adequate postoperative analgesia, reducing the need for opioids and their associated side effects. Intravenous acetaminophen acts on the central nervous system, inhibiting prostaglandin synthesis and modulating pain perception. Its use in TIVA contributes to multimodal analgesia strategies, promoting enhanced pain control and early recovery.

These novel intravenous agents offer unique properties that enhance anaesthesia management during TIVA. They provide anesthesiologists with additional tools to tailor anaesthesia delivery, optimize patient comfort, and minimize side effects. By incorporating these agents into TIVA protocols, clinicians can improve patient outcomes, enhance recovery, and promote a positive surgical experience.

It is important to note that current evidence, clinical guidelines, and individual patient characteristics should guide using novel intravenous agents in TIVA. Proper dosing, administration techniques, and monitoring are crucial for safe and effective implementation.

Various adjuncts are administered during TIVA to reduce intra- and postoperative complications. Dexamethasone, an anti-inflammatory drug, in a single dose of 8 mg, reduces postoperative nausea and vomiting by 30% in propofol-based TIVA, with good quality of recovery and discharge.[5–7] Lidocaine used in a bolus dose of 1–1.5 mg/kg with an infusion of 1.5 mg/kg/h reduces TIVA dose by 10%–20% during maintenance.[8,9] Magnesium sulphate used as an adjunct in TIVA reduces propofol, dexmedetomidine, atracurium, and postoperative narcotic consumption. Used in a bolus dose of 30–50 mg/kg with a maintenance dose of 10 mg/kg/h, it improves the quality of postoperative analgesia. An added advantage is its anti-hypertensive, bronchodilator, anti-arrhythmic, anti-shivering, and anti-seizure effects. [10,11] Esmolol 1 mg/kg bolus over 60 s during preoxygenation can reduce the total induction dose by 18.5%.[12,13] Perioperative esmolol infusion has been shown to reduce the total anaesthetic and analgesic requirements and postoperative pain.

As research and development in anaesthesia continue, further advancements and novel intravenous agents are anticipated, potentially expanding the options available for TIVA and improving anaesthesia care.

Benefits and Challenges of TIVA:
Total intravenous anaesthesia (TIVA) offers several benefits over traditional inhalational anaesthesia techniques. However, like any medical approach, it also presents particular challenges. Understanding the advantages and limitations of TIVA is crucial for informed decision-making and optimal patient care. The benefits and challenges of TIVA:

Benefits of TIVA:
1. Improved Hemodynamic Stability: TIVA provides better hemodynamic control than inhalational anaesthesia. Using intravenous agents allows precise titration of drug concentrations, resulting in more stable blood pressure and heart rate during surgery. This is particularly advantageous for patients with cardiovascular comorbidities or those undergoing complex procedures.
2. Reduced Risk of Postoperative Nausea and Vomiting (PONV): TIVA has been associated with a lower incidence of PONV than inhalational anaesthesia. Avoiding volatile agents and using opioid-sparing techniques contribute to a decreased risk of postoperative nausea and vomiting, leading to improved patient comfort and satisfaction.
3. Faster Recovery and Early Discharge: TIVA is often associated with faster recovery times, allowing for early postoperative mobilization and discharge. The absence of inhalational agents can result in a quicker emergence from anaesthesia and reduced drug accumulation in the body, facilitating a smoother recovery process.
4. Improved Intraoperative Awareness Monitoring: TIVA can incorporate advanced monitoring systems, such as Bispectral Index

(BIS) or entropy monitoring, to assess the depth of anaesthesia. These tools aid in optimizing anaesthetic depth and reducing the risk of intraoperative awareness, ensuring patient comfort and safety.

5. Opioid-Sparing Approach: TIVA techniques can minimize the need for opioids during and after surgery. Using alternative analgesic strategies, such as regional anaesthesia techniques, intravenous acetaminophen, or non-opioid adjuvants, TIVA reduces opioid consumption and associated side effects, such as respiratory depression and prolonged recovery.

Challenges of TIVA:

1. Cost and Resource Considerations: Implementing TIVA may involve additional costs, such as acquiring specialized equipment, training healthcare professionals, and monitoring systems. Availability and access to TCI systems, smart infusion pumps, and advanced monitoring devices can be limited in specific healthcare settings, potentially limiting the widespread adoption of TIVA.

2. Learning Curve and Training Requirements: TIVA techniques require specific knowledge and skills for precise dosing, drug administration, and monitoring. Anesthesiologists and anaesthesia providers may need additional training and experience to effectively utilize TCI systems and integrate advanced monitoring tools into their practice.

3. Medication Errors and Pharmacokinetic Variability: TIVA relies on accurate pharmacokinetic models to estimate drug concentrations and achieve the desired effect. Variability in individual pharmacokinetics and pharmacodynamics can impact the accuracy of TCI systems, potentially leading to under or overdosing. Careful patient assessment, regular calibration of TCI systems, and vigilant monitoring are essential to mitigate the risk of medication errors.

4. Limited Application in Certain Procedures: While TIVA is suitable for a wide range of surgical procedures, there are specific scenarios where inhalational anaesthesia may be preferred or necessary. Procedures involving airway management challenges, prolonged surgeries, or limited access to intravenous administration may not be ideal for TIVA.

5. Patient-Specific Considerations: Each patient's unique characteristics, such as age, comorbidities, and medication history, should be considered when considering TIVA. Individual responses to intravenous agents and potential adverse effects must be carefully evaluated to ensure patient safety and optimal outcomes.

By understanding the benefits and challenges of TIVA, anesthesiologists can make informed decisions and tailor anaesthesia management to individual patients and surgical contexts. Ongoing research, education, and technological advancements will continue to address challenges and expand the application of TIVA, promoting safer and more effective anaesthesia care.

Emerging Trends in Anaesthetic Pharmacology:

Anaesthetic pharmacology is a rapidly evolving field continuously exploring new approaches and agents to optimize anaesthesia management. Emerging trends in anaesthetic pharmacology aim to improve patient outcomes, enhance safety profiles, and refine anaesthesia techniques. Some of the key emerging trends in anaesthetic pharmacology:

1. Opioid-Sparing Techniques:

With the ongoing opioid crisis and the desire to minimize opioid-related side effects, there is a growing focus on opioid-sparing techniques in anaesthesia practice. These techniques aim to reduce or eliminate the need for opioids by employing alternative analgesic strategies. This includes using regional anaesthesia techniques, such as peripheral nerve blocks and neuraxial anaesthesia, and non-opioid analgesics, such as nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and adjuvant medications.[4] Opioid-sparing techniques help minimize opioid-related respiratory depression, nausea, vomiting, and the potential for addiction.

2. Pharmacogenomics-Based Dosing:
Pharmacogenomics, the study of how an individual's genetic makeup affects drug response, is gaining prominence in anaesthetic pharmacology. By analyzing a patient's genetic profile, clinicians can better predict individual responses to specific medications and adjust drug dosing accordingly. Pharmacogenomics-based dosing allows for personalized anaesthesia management, optimizing drug selection and dosage, and minimizing the risk of adverse effects. This approach holds promise for tailoring anaesthesia care to individual patients and improving patient safety and outcomes.

3. Novel Analgesic Agents:
The development of novel analgesic agents is an active area of research in anaesthetic pharmacology. These agents aim to provide adequate pain relief while minimizing side effects. For example, newer local anaesthetics, such as liposomal bupivacaine, offer a prolonged duration of action, reducing the need for additional opioids postoperatively. Other emerging analgesics, such as N-methyl-D-aspartate (NMDA) receptor antagonists and selective sodium channel blockers, show potential for targeting specific pain pathways and providing pain relief.

4. Enhanced Recovery After Surgery (ERAS) Protocols:
Enhanced Recovery After Surgery (ERAS) protocols have gained significant attention recently. These protocols incorporate multiple components, including optimized analgesia, early mobilization, early oral intake, and minimally invasive techniques, to facilitate faster recovery and improve patient outcomes. ERAS protocols often involve a multimodal analgesic approach, combining regional anaesthesia techniques, non-opioid analgesics, and judicious use of opioids to control pain while minimizing side effects and promoting early recovery.

5. Neuroinflammation and Neuroprotection:
Emerging research in anaesthetic pharmacology focuses on understanding neuroinflammation mechanisms and developing strategies for neuroprotection during anaesthesia. Anesthesia has been associated with neurocognitive dysfunction and long-term neurobehavioral changes. Current studies aim to elucidate the impact of anaesthesia on neuroinflammation, oxidative stress, and neuronal damage. Novel pharmacological agents, such as anti-inflammatory, antioxidant, and neuroprotective, are being investigated to mitigate potential neurotoxic effects and improve neurological outcomes.

These emerging trends in anaesthetic pharmacology can potentially transform anaesthesia practice by improving patient care, safety, and recovery. By incorporating opioid-sparing techniques, utilizing pharmacogenomics-based dosing, exploring novel analgesic agents, implementing ERAS protocols, and addressing neuroinflammation and neuroprotection, anaesthesia providers can optimize anaesthesia management and enhance patient outcomes.

It is important to note that these emerging trends are still evolving, and further research is needed to understand their implications and clinical applications fully. Anesthesiologists should stay abreast of current literature, guidelines, and advancements in anaesthetic pharmacology to integrate these emerging trends into clinical practice effectively.

Emerging Trends in Anaesthetic Pharmacology and Their Implications for Total Intravenous Anesthesia (TIVA):
Anaesthetic pharmacology is a dynamic field continually evolving with research, technology, and patient care advancements. Several emerging trends in anaesthetic pharmacology directly affect Total Intravenous Anesthesia (TIVA) practice. These trends aim to improve the safety, efficacy, and patient outcomes associated with TIVA. Some of these emerging trends and their implications for TIVA:

1. Opioid-Sparing Techniques:
The ongoing opioid crisis and the desire to minimize opioid-related side effects have led

to a strong focus on opioid-sparing techniques in anaesthesia practice. This trend aligns well with TIVA, as it allows for reduced reliance on opioids during and after surgery. TIVA techniques, such as intravenous analgesics like dexmedetomidine or ketamine, and regional anaesthesia techniques, including peripheral nerve blocks, epidurals, or spinal anaesthesia, can help alleviate pain control while minimizing opioid consumption. By implementing opioid-sparing strategies, TIVA can improve postoperative pain management and reduce opioid-related complications.

2. Targeted Analgesia and Multimodal Analgesic Approaches:

Emerging trends in anaesthetic pharmacology emphasize using targeted analgesia and multimodal analgesic approaches and combining various agents and techniques to target different pain pathways and provide comprehensive pain relief. TIVA can incorporate these trends by integrating non-opioid analgesics, such as intravenous acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDs), or alpha-2 agonists, into the anaesthesia regimen. These agents can complement TIVA by providing additive or synergistic analgesic effects, reducing the reliance on opioids and enhancing postoperative pain management.

3. Pharmacogenomics-Based Dosing:

Pharmacogenomics, the study of how an individual's genetic makeup influences drug response, is an emerging field that holds promise for personalized medicine. Pharmacogenomics-based dosing allows tailoring drug administration to an individual's genetic profile, optimizing drug selection and dosage, and minimizing the risk of adverse effects. In the context of TIVA, pharmacogenomics can provide valuable insights into patient-specific responses to intravenous agents, helping to refine the drug selection, dosing regimen, and anaesthesia management plan. By incorporating pharmacogenomics-based dosing, TIVA can enhance precision medicine and improve patient outcomes.

4. Neuroinflammation and Neuroprotection:

Emerging research highlights neuroinflammation's role and neuroprotection's importance during anaesthesia. Anesthesia has been associated with neurocognitive dysfunction and long-term neurobehavioral changes, raising concerns about the potential neurotoxic effects of anaesthetic agents. TIVA can align with this emerging trend by incorporating neuroprotective strategies and agents into the anaesthesia regimen. This may involve using neuroprotective agents, such as antioxidants or anti-inflammatory drugs, to mitigate neuroinflammation and minimize potential neurotoxic effects. By considering neuroprotection in TIVA practice, anaesthesia providers can prioritize the long-term neurological well-being of their patients.

5. Enhanced Recovery After Surgery (ERAS) Protocols:

Enhanced Recovery After Surgery (ERAS) protocols aim to optimize patient outcomes by implementing evidence-based strategies across the perioperative period. These protocols emphasize early mobilization, early oral intake, and multimodal analgesia, among other components, to promote faster recovery and reduced hospital stays. TIVA can be a valuable component of ERAS protocols, as it offers precise control over anaesthesia depth and allows for integrating opioid-sparing techniques and targeted analgesia. By aligning TIVA practice with ERAS principles, anaesthesia providers can improve recovery, reduce complications, and enhance patient satisfaction.

These emerging trends in anaesthetic pharmacology have significant implications for TIVA practice. By incorporating opioid-sparing techniques, targeted analgesia, pharmacogenomics-based dosing, neuroprotection strategies, and integrating with ERAS protocols, TIVA can optimize anaesthesia management and enhance patient outcomes. Anaesthesia providers must stay informed about these emerging trends through continued education, literature review, and collaboration with other healthcare professionals to deliver the most up-to-date and evidence-based TIVA care.

CONCLUSION

The field of anaesthesia has witnessed significant advancements in recent years, particularly in total intravenous anaesthesia (TIVA). TIVA offers numerous benefits, including improved hemodynamic stability, reduced risk of postoperative nausea and vomiting (PONV), faster recovery, and the potential for opioid-sparing techniques. These advantages enhance patient outcomes, reduce complications, and improve patient satisfaction.

The emergence of novel intravenous agents, such as remimazolam and dexmedetomidine, has expanded the options for TIVA, allowing for tailored anaesthesia management based on individual patient needs. The integration of target-controlled infusion (TCI) systems, smart infusion pumps, and advanced monitoring technologies has further improved the precision and safety of TIVA practice.

Additionally, the ongoing trends in anaesthetic pharmacology, including opioid-sparing techniques, targeted analgesia, pharmacogenomics-based dosing, neuroprotection, and the implementation of enhanced recovery after surgery (ERAS) protocols, have direct implications for TIVA. These trends contribute to more personalized and optimized anaesthesia care, ensuring better pain management, reduced opioid consumption, enhanced patient safety, and improved recovery.

While TIVA presents several advantages, it also poses challenges, such as cost considerations, the learning curve associated with new techniques and technologies, medication errors, and patient-specific considerations. However, with continued research, education, and technological advancements, these challenges can be addressed and overcome to enhance the practice of TIVA further.

Anaesthesia providers must stay up-to-date with the latest advancements, guidelines, and evidence-based practices in TIVA. By incorporating these advancements and trends into clinical practice, anesthesiologists can optimize anaesthesia management, improve patient outcomes, and ensure the highest level of care and patient satisfaction.

As the field of anaesthesia continues to evolve, it is expected that further advancements and refinements in TIVA techniques, equipment, and pharmacology will shape the future of anaesthesia practice, ultimately leading to safer, more precise, and patient-centred anaesthesia care.

Limitations of Total Intravenous Anesthesia (TIVA) and Scope for Improvement:

While Total Intravenous Anesthesia (TIVA) offers several advantages, it also has certain limitations warrant consideration. Recognizing these limitations provides opportunities for improvement and further advancements in TIVA practice. TIVA in morbidly obese patients must be practised with extra precautions for a safe recovery from the accumulation of drugs.[14] The limitations of TIVA and the potential areas for enhancement:

1. Equipment and Resource Requirements:

One of the limitations of TIVA is the need for specialized equipment and resources. TCI systems, smart infusion pumps, and advanced monitoring devices may not be universally available in all healthcare settings. The cost of acquiring and maintaining such equipment can be a barrier to widespread adoption. To improve the accessibility and affordability of TIVA, efforts should focus on developing cost-effective alternatives and promoting technological advancements that simplify equipment requirements.

2. Pharmacokinetic Variability:

Individual patient variability in pharmacokinetics and pharmacodynamics poses a challenge in TIVA practice. Pharmacokinetic models used in TCI systems provide estimates based on average values, but individual variations may lead to inaccurate predictions of drug concentrations. Enhancing the precision of pharmacokinetic models by incorporating individual patient characteristics, such as age, weight, and genetics, could improve the accuracy of drug administration and optimize anaesthesia management.

3. Limited Application in Certain Procedures:

While TIVA is suitable for a broad range of surgical procedures, specific scenarios may not be ideal for its application. Procedures involving prolonged surgeries, airway management challenges, or limited intravenous access may present limitations for TIVA. Identifying strategies to overcome these limitations, such as developing novel drug formulations or delivery methods, could expand the applicability of TIVA and improve patient care across diverse surgical settings.

4. Learning Curve and Training Requirements:

TIVA techniques require specialized knowledge and skills for proper drug administration, monitoring, and adjustment of anaesthesia depth. Anesthesiologists and anaesthesia providers may require additional training and experience to utilize TCI systems effectively, interpret monitoring data, and optimize anaesthesia delivery. Enhancing education and training programs, incorporating simulation-based learning, and providing continuous professional development opportunities can ensure that healthcare professionals are proficient in TIVA techniques.

5. Limited Evidence for Specific Patient Populations:

The evidence supporting TIVA in specific patient populations, such as pediatric patients, pregnant women, and patients with specific comorbidities, may be limited. Conducting well-designed studies and generating more robust evidence for the safety and efficacy of TIVA in these populations would provide valuable insights and further optimize anaesthesia care for diverse patient groups.

6. Integration with Emerging Technologies:

TIVA can potentially leverage emerging technologies, such as artificial intelligence (AI) and machine learning, to enhance its precision and efficiency. AI algorithms can analyze large datasets, incorporating patient-specific factors and real-time monitoring data to guide drug administration and optimize anaesthesia management. Integrating AI-driven decision support systems and closed-loop control algorithms in TIVA could revolutionize the field and improve patient outcomes.

7. Long-Term Neurocognitive Effects:

Although TIVA is generally considered safe, concerns regarding the long-term neurocognitive effects of anaesthesia persist. Research into the impact of TIVA on neurocognitive function, particularly in vulnerable populations such as the elderly and children, is ongoing. Continued investigation and implementation strategies to mitigate potential neurotoxic effects, such as neuroprotective agents or refined anaesthesia protocols, can further improve patient safety and outcomes.

8. Equipment Expense:

TCI and depth of anaesthesia equipment are expensive and unavailable in many centres. Though this equipment is a one-time investment to reap many more excellent benefits, the cost of drugs or disposable monitoring electrodes is not enticing.[15] The favourable effect of TIVA on the environment is offset by the wastes generated, such as plastics, which cause additional greenhouse effects.

By addressing these limitations and actively seeking opportunities for improvement, the scope of TIVA can be expanded, and its effectiveness can be enhanced. Collaborative efforts among researchers, clinicians, and industry stakeholders are essential to advance TIVA practice, promote evidence-based approaches, and improve patient care in anaesthesia.

Acknowledgements: We want to express our gratitude to those who supported and helped us while I was on this journey.

Conflicts of Interest: The author declares no conflicts of interest.

Funding: No source of funding.

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How to cite this article: Javaid Ahmad lone, Adil Fayaz Hajam, Mohammad Talat-ul- Tuba Dar, Maajid Mohi Ud Din Malik. Recent advancements in total intravenous anaesthesia (TIVA) and anaesthetic pharmacology. *Int J Health Sci Res.* 2023; 13(11):365-376. DOI: *https://doi.org/10.52403/ijhsr.20231145*

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