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REVIEW

Pain Control Paradigms: A Comparative Review of Anesthesia Techniques in Trigeminal Neuralgia Therapy

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ABSTRACT

This review summarizes the intraoperative anesthesia protocols for radiofrequency thermal coagulation in the treatment of trigeminal neuralgia, focusing on the advantages and disadvantages of two primary anesthesia approaches. The first approach involves the injection of local anesthetics, such as lidocaine, at the radiofrequency target, which can alleviate pain during the procedure but carries potential risks. The second approach discusses the efficacy of intravenous administration of propofol for pain control, highlighting the necessity for vigilant monitoring of vital signs during the procedure. This article aims to provide the latest evidence-based guidance for anesthesia protocol selection in clinical practice.

Keywords: Radiofrequency thermal coagulation; Trigeminal neuralgia; Anesthesia protocol; Local anesthetics; Propofol

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Key Summary Points

Local anesthetic injection at the radiofrequency target site provides immediate pain relief with fewer systemic effects, while propofol offers rapid sedation and elevated pain thresholds, albeit requiring vigilant monitoring for respiratory and hemodynamic risks.

Local anesthetics risk masking incomplete nerve damage or neurotoxicity, whereas propofol carries risks of respiratory depression. Patient-specific factors (e.g., comorbidities, anxiety) dictate protocol selection to optimize safety and efficacy.

Emerging approaches, such as pulsed radiofrequency ablation and multimodal protocols combining local anesthetics, NSAIDs, and gabapentinoids, enhance pain control while reducing opioid reliance, aligning with personalized medicine trends.

Comprehensive preoperative assessment and advanced intraoperative monitoring (e.g., neuromonitoring, cerebral oxygenation tracking) are critical for tailoring anesthesia strategies, minimizing complications, and improving surgical outcomes in trigeminal neuralgia therapy.

INTRODUCTION

Trigeminal neuralgia is characterized by sudden, severe facial pain that can significantly impact a patient's quality of life. This condition is often refractory to conservative treatments, leading to the consideration of various interventional strategies. Among these, radiofrequency thermocoagulation (RFT) has emerged as a widely utilized technique, offering a minimally invasive option with a favorable safety profile. The effectiveness of RFT, however, is heavily influenced by the choice of anesthesia during the procedure. The selection of an appropriate anesthetic protocol is crucial for optimal pain management and procedural success. Current research has focused on comparing different anesthetic approaches to identify the most effective strategies for managing intraoperative pain and ensuring patient comfort [1].

One of the primary anesthetic techniques employed during RFT for trigeminal neuralgia is general anesthesia. This method provides complete unconsciousness and muscle relaxation, which can be beneficial in minimizing movement during the procedure. However, general anesthesia is associated with certain risks, such as respiratory complications and prolonged recovery time. In contrast, local anesthesia combined with sedation has gained popularity due to its ability to maintain patient consciousness while effectively managing pain. This approach allows for a quicker recovery and reduces the risks associated with general anesthesia.

The choice between general anesthesia and local anesthesia with sedation also has implications for the overall surgical experience. For instance, local anesthesia allows for real-time feedback from the patient, which can be advantageous in assessing the effectiveness of the procedure and making necessary adjustments. Furthermore, using local anesthesia can facilitate a more rapid discharge process, enabling patients to return home sooner after the procedure. Nevertheless, the success of local anesthesia depends on the proper administration and the patient's anxiety levels, which may affect their comfort during the intervention. As such, anesthetic choice should be tailored to the individual patient's needs, considering their medical history, anxiety levels, and the specific requirements of the RFT technique being employed [2].

In conclusion, the choice of anesthetic technique during radiofrequency thermocoagulation for trigeminal neuralgia is a critical factor that influences both patient comfort and procedural outcomes. Ongoing research is essential to further elucidate the advantages and disadvantages of various anesthetic approaches, ultimately guiding clinicians in making informed decisions that enhance patient safety and satisfaction. As the landscape of pain management continues to evolve, the integration of newer anesthetic techniques and monitoring technologies may further improve the efficacy and safety of RFT procedures for trigeminal neuralgia [3].

LITERATURE SEARCH STRATEGY

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors. A comprehensive search was conducted in PubMed, Embase, and Web of Science (2010–2025) using the following keywords: "trigeminal neuralgia," "radiofrequency thermocoagulation," "anesthesia protocols," "local anesthetics," and "propofol." Studies were included if they (1) focused on anesthesia techniques for radiofrequency procedures in trigeminal neuralgia, (2) compared local anesthetics with propofol-based protocols, or (3) provided evidence on efficacy/safety outcomes. Case reports, non-English articles, animal studies, articles lacking detailed anesthesia protocol descriptions, and those deemed unsuitable based on methodological quality assessment were excluded. A flowchart summarizing the study selection process is provided in Fig. 1.

Ethical Approval

This article is based on previously conducted studies and does not contain any new studies

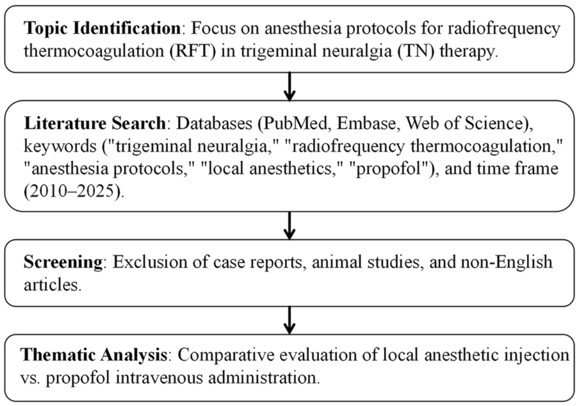

Fig. 1 Flowchart of literature selection and analysis

with human participants or animals performed by any of the authors.

RADIOFREQUENCY TARGET INJECTION OF LOCAL ANESTHETIC DRUGS

Overview of the Procedure

During the anesthetic process, a small amount of local anesthetic, such as lidocaine, is injected at the radiofrequency target site to mitigate pain. This technique is particularly relevant in procedures involving radiofrequency ablation, where the application of high temperatures can cause significant discomfort. The injection of local anesthetic serves to numb the targeted area, thereby reducing the pain experienced by the patient during the procedure. This method is essential for enhancing patient comfort and can lead to a more tolerable experience during what can be an otherwise painful intervention. The use of local anesthetics in this context is supported by clinical evidence, which suggests that their application can effectively decrease the perception of pain associated with thermal injury from radiofrequency energy [4, 5].

Advantages Analysis

The primary advantage of injecting local anesthetics at the radiofrequency target site is the significant alleviation of pain caused by the high temperatures used in the procedure. This pain relief is crucial for improving patient comfort and compliance, as many patients may otherwise experience anxiety or distress due to the anticipated pain of the procedure. Studies have shown that patients receiving local anesthetic injections report lower pain scores during and after radiofrequency ablation compared to those who do not receive such interventions [6, 7]. Moreover, the use of local anesthetics can potentially reduce the need for systemic analgesics, which may carry their own side effects and risks. By providing targeted pain relief, local anesthetics can enhance the overall efficacy of the radiofrequency procedure, leading to better outcomes and higher patient satisfaction [8, 9].

Potential Risks

Despite the benefits, there are potential risks associated with using local anesthetics during radiofrequency procedures. One significant concern is that the anesthetic effect may mask incomplete nerve damage caused by the radiofrequency application. This masking can lead to inaccurate assessments of pain during the procedure, as patients may not be able to accurately report their pain levels if they are under the influence of local anesthetics [10]. Additionally, there is a risk of adverse effects related to the local anesthetic itself, including neurotoxicity and allergic reactions, which can complicate the clinical picture [11]. Furthermore, the technique requires careful administration to avoid complications such as hematoma or inadvertent injection into adjacent structures, which could lead to further pain or complications [12]. Therefore, while the injection of local anesthetics can enhance patient comfort, it is essential for clinicians to weigh these benefits against the potential risks and to monitor patients closely during and after the procedure.

PROPOFOL INTRAVENOUS BOLUS ADMINISTRATION PROTOCOL

Protocol Overview

The intravenous bolus administration of propofol prior to radiofrequency procedures serves a critical role in managing patient comfort and pain during surgery. This protocol involves the administration of propofol to induce a brief loss of consciousness, allowing for a more controlled surgical environment. The primary objective is to alleviate intraoperative pain and anxiety, which can significantly enhance the overall surgical experience for patients undergoing procedures such as radiofrequency ablation for trigeminal neuralgia. By inducing a state of sedation, propofol helps to minimize the psychological and physiological stress responses that can occur during invasive procedures. The rapid onset of action of propofol, typically within seconds, makes it particularly suitable for this purpose, as it allows for immediate sedation and is easily titratable to achieve the desired level of consciousness and analgesia [4].

Advantages Analysis

Using propofol in intravenous bolus administration offers several advantages that contribute to improved surgical outcomes. One of the most significant benefits is its rapid onset of action, which allows for quick sedation and pain relief, thereby facilitating smoother transitions into surgical procedures [6]. Propofol has been shown to effectively elevate pain thresholds, which is particularly beneficial in procedures that may otherwise provoke significant discomfort, such as radiofrequency ablation. This elevation in pain threshold not only aids in the immediate management of surgical pain but also helps in reducing the overall requirement for additional analgesics during and after the procedure [5]. Furthermore, propofol's favorable pharmacokinetic profile, including its rapid clearance from the body, allows for quicker recovery times post-surgery, enabling patients to regain consciousness and cognitive function more swiftly than with other sedative agents [8]. Overall, the use of propofol enhances patient comfort, minimizes intraoperative complications, and promotes a more efficient surgical workflow.

Monitoring Requirements

Continuous monitoring of vital signs is essential during the administration of propofol to ensure patient safety and the effectiveness of sedation. During the procedure, healthcare providers must closely observe parameters such as heart rate, blood pressure, oxygen saturation, and respiratory rate to detect any adverse reactions or complications that may arise from propofol use [7]. Given that propofol can induce respiratory depression and hypotension, vigilant monitoring is crucial to promptly address any significant changes in a patient's physiological status [10]. Additionally, intraoperative neuromonitoring techniques may be used to assess the patient's neurological status and ensure that sedation levels are appropriate for the procedure being performed. This comprehensive monitoring approach not only safeguards the patient's well-being but also contributes to the overall success of the surgical intervention by allowing for timely interventions if complications arise [9]. In summary, effective monitoring is a critical component of the propofol intravenous bolus administration protocol, ensuring both safety and optimal outcomes during surgical procedures.

COMPARISON OF TWO ANESTHESIA PROTOCOLS

The rationale for focusing on local anesthetic injection and propofol intravenous administration as the primary protocols in this review is threefold. First, these approaches represent the most clinically dominant strategies in TN-RFT therapy, supported by extensive evidence from randomized controlled trials and systematic reviews. Their widespread adoption stems from their efficacy in balancing pain control and procedural safety. Second, their distinct mechanisms of action—targeted nerve blockade versus systemic sedation—create a natural framework for comparative analysis, enabling clinicians to weigh risk-benefit profiles tailored to individual patient needs. Finally, while emerging techniques such as pulsed radiofrequency ablation and multimodal protocols show promise, they remain investigational or lack sufficient large-scale validation. To avoid superficial coverage, this review prioritizes depth over breadth, reserving discussion of novel methods for future updates as clinical evidence matures.

Pain Control Effectiveness

When evaluating the effectiveness of two anesthesia protocols in pain management, it is crucial to consider both the immediate and long-term outcomes for patients. Studies have shown that regional anesthesia, particularly when combined with general anesthesia, can provide significant pain relief postoperatively. For instance, a meta-analysis indicated that patients receiving a combination of general and regional anesthesia experienced lower pain scores compared to those receiving general anesthesia alone [13]. This suggests that regional anesthesia can enhance analgesic efficacy, especially in surgeries with expected high pain levels. Furthermore, the choice of anesthesia should also be tailored to specific patient populations. For example, patients with a history of chronic pain may benefit more from regional techniques, which can provide targeted pain relief and reduce reliance on systemic opioids [14]. Conversely, general anesthesia may be preferable for patients undergoing longer or more invasive procedures where rapid induction and control of the airway are paramount. Ultimately, the effectiveness of pain control is not solely dependent on the anesthesia type but also on the individual patient's needs, the surgical procedure, and the associated risks.

Complication Risks

The exploration of complication risks associated with different anesthesia methods is essential for informed clinical decision-making. General anesthesia, while effective for many procedures, carries inherent risks such as respiratory depression, cardiovascular instability, and postoperative nausea and vomiting [15]. In contrast, regional anesthesia is often associated with a lower incidence of these complications. For instance, a study comparing outcomes from regional versus general anesthesia for orthopedic surgeries found that regional techniques resulted in fewer postoperative complications, particularly in terms of respiratory issues [16]. However, regional anesthesia is not without its own risks, including nerve injury and local anesthetic systemic toxicity. Therefore, it is vital for clinicians to weigh these risks against the benefits of each anesthesia type. Moreover, patient factors such as age, comorbidities, and the type of surgical procedure should guide the choice of anesthesia. For example, older patients or those with preexisting respiratory conditions may be better suited for regional anesthesia to minimize the risk of complications associated with general anesthesia [17]. Ultimately, a thorough understanding of the potential complications associated with each anesthesia method is critical for optimizing patient safety and outcomes in surgical settings.

RESEARCH PROGRESS IN IMPROVING ANESTHESIA PROTOCOLS

Application of New Drugs

Recent advancements in the treatment of trigeminal neuralgia (TN) have highlighted the potential application of novel local anesthetics. Traditional treatment options, primarily involving anticonvulsants and invasive procedures, often fall short for patients suffering from refractory TN. New agents, such as pulsed radiofrequency (PRF) ablation, have emerged as promising alternatives to conventional methods. PRF offers a minimally invasive approach that minimizes tissue damage while providing effective pain relief, making it an attractive option for managing TN that does not respond to standard therapies [7]. Furthermore, studies have indicated that using lidocaine, ropivacaine, and bupivacaine may enhance the efficacy of other analgesics, potentially improving patient outcomes [4]. These amide-type local anesthetics have been shown to exert growth-inhibitory effects on certain cancer cells, suggesting that they may also have a role in pain management through mechanisms beyond simple analgesia [18]. The exploration of these new drugs underscores a shift towards more targeted therapies that address both pain relief and the underlying pathophysiology of conditions like TN.

Development of Multimodal Anesthesia Protocols

The development of multimodal anesthesia protocols represents a significant advancement in pain management strategies, particularly for conditions like trigeminal neuralgia. Multimodal approaches combine various analgesic techniques to enhance pain control and minimize opioid use, which is crucial given the ongoing opioid crisis. For instance, integrating regional anesthesia techniques with systemic medications can lead to improved pain outcomes and reduced reliance on opioids [19]. Research has shown that employing a combination of local anesthetics, nonsteroidal anti-inflammatory drugs (NSAIDs), and adjuncts like gabapentinoids can effectively manage acute pain while promoting faster recovery [20]. This approach not only addresses the immediate pain but also targets the inflammatory processes associated with conditions like TN, potentially altering the pain trajectory and improving long-term outcomes [21]. The emphasis on individualized anesthesia plans tailored to the patient's specific needs and pain profiles is a hallmark of modern anesthesia practice, reflecting a broader trend towards personalized medicine in pain management.

CLINICAL APPLICATION RECOMMENDATIONS

Preoperative Assessment

A comprehensive preoperative assessment is crucial for developing a personalized anesthesia plan tailored to the specific needs of each patient. Before selecting an anesthesia regimen, it is essential to evaluate the patient's medical history, current health status, and any potential risk factors that could impact the surgical outcome. This assessment should include a thorough review of the patient's cardiovascular, respiratory, and neurological status as well as any comorbidities that may complicate anesthesia management. For instance, older adults or those with chronic health issues may require additional monitoring and modification of standard protocols to mitigate risks associated with surgery and anesthesia [22]. Furthermore, understanding the patient's functional status and any previous reactions to anesthesia can guide the selection of appropriate anesthetic agents and techniques, ultimately enhancing patient safety and comfort during the procedure [23]. The preoperative assessment should also involve interdisciplinary collaboration among anesthesiologists, surgeons, and other healthcare providers to ensure a holistic approach to patient care [24]. By prioritizing a tailored preoperative evaluation, healthcare providers can significantly reduce the likelihood of complications and improve overall surgical outcomes.

Intraoperative Monitoring Techniques

Intraoperative monitoring is vital to ensuring patient safety and optimizing surgical outcomes during anesthesia. Best practices in intraoperative monitoring involve the use of advanced technologies and techniques to continuously assess the patient's physiological parameters, including heart rate, blood pressure, oxygen saturation, and neuromuscular function. Employing intraoperative neuromonitoring techniques, such as electromyography

(EMG) and somatosensory evoked potentials (SSEPs), can provide real-time feedback on the functional status of critical neural structures, thereby reducing the risk of intraoperative neurological injuries [25]. Moreover, the integration of technologies like near-infrared spectroscopy (NIRS) for monitoring cerebral oxygenation has shown promise in enhancing patient safety during neurosurgical procedures [26]. The implementation of goal-directed fluid therapy and individualized ventilation strategies, particularly in high-risk populations such as the obese or older patients, can further mitigate complications associated with anesthesia [27]. Continuous assessment of the depth of anesthesia is also crucial, as it helps prevent awareness during surgery and ensures adequate analgesia, which can lead to improved postoperative recovery [28]. By adhering to these best practices in intraoperative monitoring, healthcare providers can enhance the safety and efficacy of anesthesia, ultimately leading to better patient outcomes.

CONCLUSION

The choice of intraoperative anesthesia for radiofrequency thermocoagulation in the treatment of trigeminal neuralgia is crucial in ensuring effective pain control and enhancing surgical safety. This review has highlighted the comparative advantages and disadvantages of local anesthetic injections versus propofol intravenous administration. From an expert perspective, it is essential to recognize that the optimal anesthesia regimen should not be a one-size-fits-all approach; rather, it must be tailored to the individual characteristics of each patient as well as the specific demands of the surgical procedure.

The development of anesthesia protocols in this context has seen significant advancements, influenced by both clinical practice and emerging research. Analyzing the findings presented in this review showed that the interplay between patient factors—such as age, comorbidities, and pain thresholds—and the technical aspects of the procedure need to be carefully balanced. For instance, while local anesthetics may offer immediate pain relief with a lower systemic impact, propofol intravenous administration may provide greater sedation and ease of surgical manipulation, albeit with potential risks of respiratory depression or hemodynamic instability.

Furthermore, this review emphasizes the importance of a multidisciplinary approach in refining anesthesia strategies. Collaboration among anesthesiologists, neurosurgeons, and pain specialists can lead to more comprehensive assessments that consider both the physiological and psychological aspects of patient care. Future research should focus on larger, multi-center trials to validate these findings and explore additional factors that may influence patient outcomes.

In conclusion, optimizing the anesthesia strategy for radiofrequency thermocoagulation in trigeminal neuralgia will not only enhance pain management but also improve overall surgical safety. By embracing a patient-centered approach and staying attuned to ongoing research developments, clinicians can better navigate the complexities of anesthesia selection, ultimately leading to more favorable outcomes for patients suffering from this debilitating condition. As the field continues to evolve, ongoing dialogue and investigation will be essential in shaping best practices in the anesthesia management of trigeminal neuralgia.

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Author Contribution. Conception/design (Keyue Xie); drafting or revising (Lan Lai and Keyue Xie); final approval (Lan Lai and Keyue Xie). We agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved by all authors.

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Data Availability. Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Declarations

Conflict of interest. Lan Lai and Keyue Xie declare that they have no conflict of interest.

Ethical approval. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

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