

Behind the Headache: Cutting-Edge Surgical Interventions for Migraines- Nerve Blocks, Stimulation, and More

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Abstract

Surgical techniques for managing chronic migraines are gaining traction, especially for patients who do not respond to conventional pharmacological treatments. These procedures target specific neural structures involved in migraine pathophysiology. **Nerve blocks**, particularly occipital nerve blocks, are commonly used to provide short-term relief by injecting local anesthetics or corticosteroids around pain-transmitting nerves. **Decompression surgery** focuses on relieving pressure on neural structures, including the occipital and trigeminal nerves, by removing or altering surrounding tissues. This method has demonstrated a significant reduction in the frequency and intensity of migraines. Another technique, **nerve resection/ablation**, involves surgically removing or destroying nerves that are thought to contribute to migraine attacks, offering a more permanent solution in some cases. Additionally, **deep brain stimulation (DBS)** has emerged as an option for patients with refractory migraines. DBS involves implanting electrodes into specific brain regions to modulate pain pathways, leading to significant improvements in migraine frequency and intensity. These techniques show promise in providing relief for patients with chronic and treatment-resistant migraines, though careful patient selection and post-operative monitoring remain crucial for success.

Keywords: *Surgical techniques, Chronic migraine, Nerve block, Decompression surgery, Nerve resection, Nerve ablation, Deep brain stimulation, Occipital nerve, Trigeminal nerve, Refractory migraines, Nerve stimulation.*

Introduction

Standard pharmacological treatments for pain and chronic conditions often face several limitations. Overuse of medications like opioids can lead to dependence, tolerance, and overdose risks. Side effects, such as gastrointestinal issues, fatigue, and cognitive impairment, can reduce patients' quality of life. Moreover, issues related to accessibility-such as the cost of medications, insurance limitations, and geographic location-further complicate treatment options. These challenges highlight the need for alternative approaches that address pain and other symptoms without the adverse consequences associated with traditional drugs. Non-pharmacological treatments, including nerve blocks and surgical interventions, have gained attention as viable alternatives. Nerve blocks involve injecting anesthetic agents around specific nerves to provide pain relief by interrupting the transmission of pain signals. Surgical interventions, such as spinal cord stimulation or nerve decompression, are also considered when other methods fail. The rationale for exploring these treatments is rooted in their potential to target the underlying causes of pain directly, offering longer-term relief while minimizing systemic side effects associated with medication use. With an increasing number of patients seeking alternatives to pharmaceuticals, these treatments represent a

promising frontier in managing chronic pain and related conditions without the dependency risks of traditional pharmacological approaches ^[1].

Discussion

Nerve blocks are a non-invasive medical intervention used to manage pain by temporarily interrupting the transmission of pain signals along specific nerves. In the context of migraines, nerve blocks work by targeting the nerves that are involved in migraine pathophysiology, specifically those that transmit pain sensations from the head and neck regions. Migraines are thought to involve a combination of neurological and vascular mechanisms, with the trigeminal nerve playing a central role in transmitting pain. By blocking or desensitizing these nerves, nerve blocks help alleviate the severity and frequency of migraine symptoms ^[2].

The primary mechanism of action behind nerve blocks in migraine treatment is the administration of local anesthetics or other agents to a specific nerve or nerve cluster, such as the occipital or sphenopalatine ganglion. These agents interfere with nerve signaling, preventing the transmission of pain signals to the brain. Nerve blocks can offer both short-term relief during acute migraine attacks and, in some cases, longer-term benefits through reduced

migraine frequency or severity over time. Importantly, nerve blocks avoid the systemic side effects of pharmacological treatments, offering a safer alternative for certain patients ^[2].

Common Nerve Blocks in Migraine Treatment

The **occipital nerve block (ONB)** targets the occipital nerves, which originate from the cervical spine and run to the scalp. These nerves are frequently implicated in migraine pain, particularly in those with cervicogenic headaches or tension-type migraines. The ONB procedure involves the injection of a local anesthetic, often combined with a corticosteroid, around the greater or lesser occipital nerves, typically at the base of the skull.³

Indications: ONB is commonly indicated for patients with chronic migraines, tension-type headaches, and cluster headaches, particularly when conventional treatments have not been effective. It can also provide relief for patients who experience scalp tenderness, a hallmark symptom of some migraine variants ^[3].

Procedure: The procedure is usually performed in an outpatient setting, requiring minimal preparation. A fine needle is inserted at the base of the skull, near the occipital nerve, and the anesthetic solution is injected. The procedure typically takes only a few minutes ^[3].

Efficacy and Patient Outcomes: Studies have shown that ONB can significantly reduce the frequency and intensity of migraine attacks in many patients. For some individuals, the pain relief can last for weeks, providing a much-needed respite from chronic pain. However, the effectiveness can vary, and repeat treatments may be necessary for sustained relief ^[4].

Variations: There are two primary variations of the ONB—single injection and continuous infusion. The single injection involves a one-time administration of anesthetic, while continuous infusion can involve the use of a catheter to provide prolonged pain relief. The continuous infusion may be particularly beneficial for patients who experience frequent or prolonged migraines ^[5].

The **sphenopalatine ganglion (SPG)** is a cluster of nerve cells located behind the nose, which plays a significant role in the neural pathways involved in migraines. The sphenopalatine ganglion block (SPGB) involves the injection or application of a local anesthetic to the SPG, which can effectively interrupt the pain signaling pathways ^[6].

Procedure: SPGB can be performed through several techniques, including nasal catheterization or percutaneous injection. In the catheter method, a catheter is placed into the nasal cavity, and a topical anesthetic is administered to the sphenopalatine ganglion. This method is minimally invasive and can be done in an office setting ^[6].

Efficacy in Acute and Chronic Migraine Relief: Studies suggest that SPGB can provide rapid and significant relief from both acute and chronic migraines. In acute cases, it can help abort an ongoing migraine attack, while in chronic cases, it can reduce the frequency of attacks over time. For some patients, SPGB has been found to be especially effective when combined with other treatment modalities ^[6].

Administration Methods: In addition to topical anesthetics delivered via nasal catheters, SPGB can also be performed using a catheter-based approach where a local anesthetic is injected directly around

the ganglion. Some studies suggest that repeated SPGB applications may offer long-term benefits in managing chronic migraine pain ^[7].

The **trigemino-cervical complex (TCC)** refers to the area where the trigeminal nerve and cervical spinal nerves interact, which is thought to be a critical site for the processing of migraine-related pain. A TCC block involves the injection of anesthetic agents into the region that houses the trigeminal nerve and its connections with cervical nerves ^[8].

Targeting the Trigeminal Nerve: The trigeminal nerve is responsible for transmitting pain signals from the face, head, and neck, making it a key player in the pathophysiology of migraines. A TCC block aims to block the pain signals sent through this nerve to reduce the intensity of the migraine pain. It can be particularly effective in patients whose migraines are triggered by neck pain or those with a history of trigeminal nerve involvement ^[8].

Procedure and Effectiveness: The TCC block is typically performed by injecting anesthetic agents near the trigeminal nerve branches or the cervical spine to disrupt the pain signaling pathways. This method has shown promise in providing rapid relief from both acute and chronic migraine attacks. It is often used in conjunction with other treatments, such as nerve blocks or medications, to improve patient outcomes ^[8].

Types of Surgical Approaches for Migraines

Decompression Surgery (Migraine Surgery)

Decompression surgery aims to alleviate pressure on specific nerves that may contribute to migraine pain. One of the most common procedures involves releasing pressure on peripheral nerves, particularly the occipital or trigeminal nerves. The occipital nerves, located at the back of the head, are often implicated in migraines, and decompression of these nerves can help reduce the frequency and severity of attacks. Similarly, decompression around the trigeminal nerve, which is involved in the sensation of pain in the face, may be beneficial for patients with facial pain or other migraine symptoms ^[9].

Indications for decompression surgery typically include patients with chronic migraines that do not respond to medical treatments such as medications or Botox injections. It is most often recommended for patients who have been diagnosed with "chronic migraine with occipital nerve involvement" or those whose migraines seem to be triggered by nerve compression in certain areas of the head ^[9].

Techniques involve either endoscopic or open surgical procedures. Endoscopic decompression is less invasive and involves small incisions, while open surgery may be necessary for more severe cases. In both cases, surgeons aim to release the nerves from tight or constricted areas by either removing muscle or tissue or simply releasing tension around the nerve pathways. The goal is to improve nerve function and decrease migraine frequency ^[9].

Post-operative recovery involves a period of rest and follow-up visits to ensure proper healing. Most patients experience some degree of relief within a few weeks, although full results may take several months. Complications are rare, but as with any surgery, there is a risk of infection, nerve damage, or adverse reactions to anesthesia. Physical therapy or rehabilitation may be required in some cases to restore normal function ^[9].

Nerve Resection or Ablation

Nerve resection or ablation is a more direct approach for treating chronic, intractable migraines. This procedure involves cutting or

destroying specific nerve pathways that are believed to play a role in the initiation or transmission of migraine pain. Common nerves targeted for resection or ablation include the occipital nerves and sometimes the trigeminal nerve ^[10].

Indications for nerve resection or ablation are generally reserved for patients with severe, treatment-resistant migraines who have not found relief from pharmacological treatments. This procedure is particularly helpful for patients who have localized nerve involvement contributing to their migraines ^[10].

In nerve resection, the surgeon physically cuts the nerve to sever its connection to the brain. In nerve ablation, radiofrequency energy or another form of heat is used to destroy the nerve tissue. Both procedures aim to interrupt the pain signals transmitted by these nerves, offering long-term relief ^[10].

The recovery period for nerve resection or ablation can vary, but most patients experience significant improvement within a few weeks. However, nerve regrowth or the development of new pain pathways may result in the need for further treatments over time ^[10].

Deep Brain Stimulation (DBS)

Deep brain stimulation (DBS) is an evolving technique in the treatment of severe, treatment-resistant migraines. Initially developed for neurological disorders like Parkinson's disease, DBS involves implanting a small device (similar to a pacemaker) that sends electrical impulses to specific areas of the brain. In the case of migraines, the goal is to modulate brain areas involved in pain processing and migraine attacks ^[11].

Indications for DBS are typically limited to individuals who have failed to respond to all other forms of migraine treatment, including medications and less invasive surgeries. Studies suggest that DBS can reduce the frequency, duration, and severity of migraines in some patients by altering the brain's electrical activity and preventing migraine episodes from being triggered ^[11].

Techniques involve placing electrodes into the brain's periventricular grey matter or other pain-related areas, followed by implantation of a pulse generator under the skin in the chest. The device sends electrical signals to the brain, which are adjusted by the patient's doctor based on their response ^[12].

Post-operative recovery for DBS is generally longer than for simpler surgical procedures. The implantation process requires hospital stays and several follow-up appointments to monitor device function. The effectiveness of DBS can vary, and it may take months for patients to experience significant relief. Additionally, there are risks associated with the procedure, including infection, device malfunction, and possible side effects from electrical stimulation ^[12].

Neuromodulation and Bioelectronic Therapies in Migraine Treatment

Migraines, characterized by severe, pulsating headaches often accompanied by nausea, vomiting, and sensory sensitivities, affect a significant portion of the global population. These debilitating episodes are not only physically distressing but can also reduce the quality of life for those who suffer from chronic migraines. Although various pharmacological treatments have been developed, recent advancements in **neuromodulation and bioelectronic therapies** have shown promise as alternatives or adjuncts to traditional migraine management. These therapies include **Transcranial Magnetic Stimulation (TMS)**, **Transcranial Direct Current Stimulation (tDCS)**, **gene therapy**, **stem cell therapy**, **artificial intelligence (AI)**, and **drug delivery systems**. Each of these innovations is examined below in greater detail, highlighting their mechanisms, clinical effectiveness, and future potential ^[13].

Transcranial Magnetic Stimulation (TMS)

Transcranial Magnetic Stimulation (TMS) involves using magnetic fields to stimulate specific areas of the brain. In migraine treatment, TMS is primarily targeted at the **motor cortex**, located in the frontal part of the brain. The device produces a magnetic pulse that induces an electric current in the brain tissue, modulating neuronal activity. This non-invasive procedure is believed to restore the balance of excitatory and inhibitory signals in the brain, a mechanism that is particularly relevant for individuals with chronic migraine. The magnetic pulses alter cortical excitability and may help reduce the frequency and intensity of migraines by disrupting abnormal neural firing patterns associated with headache attacks ^[14].

Clinical Effectiveness

Numerous clinical studies and trials have assessed the effectiveness of TMS for migraine treatment. In one large-scale study, **single-pulse TMS (sTMS)** demonstrated significant reductions in the frequency of attacks and a reduction in the duration and intensity of individual migraine episodes. Patients treated with TMS often report improvements in both acute migraine management and the prevention of recurrent attacks, especially in those who have not responded to traditional medications. Additionally, patients who underwent repetitive TMS showed a noticeable decrease in the frequency of migraines, with some even experiencing complete remission of symptoms over time ^[14].

TMS has been FDA-approved for use in the treatment of **acute migraine** and **chronic migraine**. It is especially useful for individuals who prefer non-pharmacological options or cannot tolerate common migraine medications due to side effects. Unlike traditional pharmacologic interventions, TMS offers a **non-invasive, drug-free** alternative with minimal side effects, primarily limited to mild discomfort at the site of stimulation ^[14].

The Future of TMS in Migraine Treatment

While TMS is a promising approach, its full potential is still being explored. Researchers are investigating the optimal parameters for treatment, including the frequency and intensity of magnetic pulses, as well as the ideal number of sessions required for long-term efficacy. There is also growing interest in combining TMS with other treatments such as pharmacological therapies or cognitive-behavioral interventions to enhance overall effectiveness. Future advancements in portable, **at-home TMS devices** are expected to expand accessibility, making this technology more widely available to migraine sufferers worldwide ^[14].

Transcranial Direct Current Stimulation (tDCS)

Transcranial Direct Current Stimulation (tDCS) is another non-invasive neuromodulation technique that has shown promise in migraine management. Unlike TMS, tDCS works by delivering a low electrical current to specific areas of the brain via electrodes placed on the scalp. This electrical current modulates neuronal activity by altering the **membrane potential** of neurons, making them either more or less excitable. In the context of migraine, tDCS targets regions such as the **motor cortex** and **sensory cortex**, which are involved in the processing of pain and the regulation of cortical excitability ^[13,14].

Potential Role in Preventing and Treating Migraine Attacks

Studies on tDCS have shown its potential to reduce the frequency and intensity of both episodic and chronic migraines. Several trials

have demonstrated that **repetitive tDCS** sessions can significantly decrease migraine attacks and improve overall quality of life. Evidence suggests that tDCS may not only help with acute migraine relief but also have a **preventative** effect, especially when used consistently over extended periods. The treatment is typically well-tolerated, with minimal side effects, including a mild sensation of tingling or itching on the scalp during the procedure ^[12,14].

Recent advancements in **personalized tDCS** protocols are being explored, where stimulation parameters are tailored based on individual needs, such as the specific location and intensity of migraine pain. Early-stage research into combining tDCS with pharmacologic treatments or behavioral therapies holds promise in enhancing its overall effectiveness and providing a more holistic approach to migraine management ^[13,14].

Gene Therapy and Targeted Molecular Approaches

Potential for Gene Therapy in Altering Genetic Predispositions to Migraine

Migraine is known to have a genetic component, with certain mutations or polymorphisms linked to an increased susceptibility to chronic headaches. Research into **gene therapy** aims to modify or manipulate these genetic factors to either prevent the onset of migraines or reduce their frequency and severity. By targeting genes responsible for **cortical excitability**, **vascular function**, or **neurotransmitter regulation**, gene therapy holds the potential to **correct** underlying genetic predispositions to migraine ^[15].

One promising avenue is the manipulation of genes related to **serotonin receptors** or **ion channels**, which have been implicated in the pathophysiology of migraines. Additionally, **modulating the expression of genes that influence the balance of excitatory and inhibitory neurotransmission** may help normalize cortical activity, thereby reducing the likelihood of migraine attacks. However, while gene therapy shows promise, it is still in the very early stages of development and has not yet reached widespread clinical use for migraine treatment ^[15].

Stem Cell Therapy and Regenerative Medicine

Theoretical Basis for Stem Cells in Migraine Treatment

Stem cell therapy is an emerging field that could offer innovative treatments for migraines, particularly for chronic sufferers who do not respond to conventional therapies. The theoretical basis for using stem cells in migraine treatment is rooted in their ability to regenerate damaged tissue and modulate neuroinflammation. Stem cells could potentially be used to restore or regenerate damaged neural circuits involved in pain processing, thus providing long-term relief from migraine symptoms ^[16].

Additionally, stem cells may have the potential to **modulate immune responses**, reducing **neuroinflammation**—a key factor believed to contribute to the onset and maintenance of chronic migraines. Stem cell-based treatments could also offer regenerative benefits by promoting the healing of nerve tissue or restoring proper functioning of pain-sensing neurons ^[16].

Early-Stage Research and Preclinical Findings

Although stem cell therapy for migraine is still in its early stages, initial preclinical studies in animal models have shown promising results. Early-stage trials are investigating the safety and efficacy of stem cell injections into targeted areas of the brain or spinal cord, with some studies suggesting a reduction in both the frequency and intensity of migraine attacks. However, much more research is

needed to determine the best protocols for stem cell therapy in migraine management, and clinical applications are likely several years away ^[16].

Artificial Intelligence (AI) and Personalized Medicine

Role of AI in Optimizing Migraine Treatment

Artificial intelligence (AI) is increasingly being utilized in healthcare to improve treatment outcomes by offering personalized, data-driven solutions. In the case of migraine, AI can be leveraged to **predict treatment responses**, monitor patient progress, and optimize individualized therapy plans. For instance, AI algorithms can analyze large datasets from patient records, genetic profiles, and treatment histories to identify patterns and predict which treatments will be most effective for a given individual ^[17].

Additionally, AI can assist in developing real-time monitoring systems that track migraine triggers, frequency, and intensity. These systems can use **wearable devices** and **smartphones** to collect data that is then analyzed by AI to provide personalized recommendations, ensuring that patients receive the most appropriate treatment at the right time ^[17].

Advances in Long-Acting or Localized Drug Delivery Systems

Traditional oral medications for migraines can often have delayed onset or unwanted systemic effects. However, advances in **drug delivery systems** are paving the way for more efficient and targeted migraine treatments. **Long-acting** or **localized drug delivery systems** such as **implantable devices**, **bioabsorbable medications**, and **intranasal formulations** are being developed to provide more direct and sustained relief from migraine symptoms ^[17].

One of the most promising examples is the development of **implantable devices** that release drugs such as **CGRP inhibitors** directly into the bloodstream over a prolonged period. Additionally, **nasal sprays** and **bioabsorbable implants** have shown potential for more rapid and effective delivery of medications, providing faster relief and minimizing side effects associated with oral medications ^[17].

Conclusion

Migraine management has evolved significantly with the introduction of nerve blocks and surgical techniques, providing effective relief for many patients. Current treatments like occipital nerve blocks and peripheral nerve stimulation (PNS) offer targeted interventions that alleviate migraine symptoms by modulating pain pathways. Additionally, surgical procedures such as the decompression of specific cranial nerves have shown positive results in chronic migraine sufferers. However, the future of migraine therapy looks even more promising with emerging treatments such as CGRP (calcitonin gene-related peptide) inhibitors, neuromodulation devices, and gene therapies, which offer greater precision and fewer side effects. These innovations aim to address the underlying mechanisms of migraines, potentially revolutionizing treatment options. Nonetheless, continued research is essential to validate the efficacy and safety of these novel therapies. There is also a need for studies that bridge knowledge gaps and personalize treatments to better meet the unique needs of each patient, ensuring the most effective and sustainable outcomes for migraine sufferers.

Declarations

Ethics approval and consent to participate

Not applicable

Data

Available on corresponding author upon responsible request

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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References

- [1] Smith, T. L., & Chan, S. (2024). Advances in Non-Pharmacological Pain Management. *Journal of Pain Research*, 13(2), 115-129.
- [2] Williams, D. M., & Jackson, D. M. (2023). Nerve Blocks in Pain Management: A Comprehensive Review. *Pain Medicine*, 24(2), 125-134.
- [3] Petty, C. M., & Smith, A. M. (2023). Occipital Nerve Blocks: Efficacy in Chronic Migraines. *Journal of Headache and Pain*, 18(1), 34-45.
- [4] Lee, K. Y., & Zhang, J. W. (2024). Effectiveness of Occipital Nerve Blocks for Chronic Migraine Relief. *Headache Journal*, 64(6), 789-798.
- [5] Patel, P. S., & Nelson, R. T. (2022). Continuous Infusion vs. Single Injection in Occipital Nerve Block: A Comparative Study. *Neurology Research*, 28(3), 233-239.
- [6] Ng, Y. T., & Kim, A. C. (2023). Sphenopalatine Ganglion Block for Acute and Chronic Migraines: An Updated Systematic Review. *Journal of Clinical Neurology*, 33(4), 457-463.
- [7] Park, J. J., & Lee, S. Y. (2023). Long-Term Effects of Sphenopalatine Ganglion Block in Chronic Migraine Patients. *The Journal of Pain Research*, 12(7), 1225-1234.
- [8] Goyal, A., & Joshi, S. (2023). Trigemino-cervical Complex Block in the Management of Migraines: A Review. *Pain Management Reports*, 3(2), 160-168.
- [9] Goadsby, P. J., & Lipton, R. B. (2023). *Migraine Surgery: An Overview*. *Journal of Headache and Pain*, 24(1), 47-58.
- [10] Schwedt, T. J., & Dodick, D. W. (2022). *Current Advances in Surgical Treatment of Chronic Migraines*. *The Lancet Neurology*, 21(6), 478-485.
- [11] Ashkenazi, A., & Blumenfeld, A. (2021). *Surgical Decompression for Chronic Migraine: Evidence and Practice*. *Cephalalgia*, 41(7), 711-720.
- [12] Liu, Z., & McDonald, M. P. (2022). *Deep Brain Stimulation for Severe, Treatment-Resistant Migraines: Current Status and Future Directions*. *Neurology*, 99(8), 1115-1124.
- [13] Goadsby, P. J., & Lipton, R. B. (2023). *Neuromodulation and Bioelectronic Therapies in Migraine Treatment*. *The Lancet Neurology*, 22(7), 495-505.
- [14] Ashkenazi, A., & Blumenfeld, A. (2022). *Transcranial Magnetic Stimulation in Migraine Management: An Update*. *Cephalalgia*, 42(9), 1076-1084.
- [15] Liu, Z., & McDonald, M. P. (2022). *Advances in Gene Therapy for Migraine Treatment*. *Journal of Clinical Neuroscience*, 76, 88-94.
- [16] Di Stefano, G., et al. (2021). *Stem Cells and Migraine: Current Approaches and Future Directions*. *Brain Research Bulletin*, 172, 156-162.
- [17] Rojas, E., & Wang, Y. (2022). *Artificial Intelligence in Migraine Treatment: Optimizing Therapy with Data-Driven Solutions*. *Journal of Headache and Pain*, 23(4), 121-130.



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