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ALTERNATIVE TREATMENTS FOR PAIN MEDICINE (M JONES, SECTION EDITOR)

# Management of Refractory Pain After Total Joint Replacement

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## Abstract

**Purpose of Review** Chronic pain after total joint replacement (TJA), specifically total knee replacement (TKA), is becoming more of a burden on patients, physicians, and the healthcare system as the number of joint replacements performed increases year after year. The management of this type of pain is critical, and therefore, understanding the various modalities physicians can use to help patients with refractory pain after TJA is essential.

**Recent Findings** The modalities by which chronic pain can be successfully managed include genicular nerve radioablation therapy (GN-RFA), neuromuscular electrical stimulation (NMES), transcutaneous electrical nerve stimulation (TENS), and peripheral subcutaneous field stimulation (PSFS). Meta-analyses and case reports have demonstrated the effectiveness of these treatment options in improving pain and functional outcomes in patients with chronic pain after TKA.

**Summary** The purpose of this paper is to review and synthesize the current literature investigating the different ways that refractory pain is managed after TJA, with the goal being to provide treatment recommendations for providers treating these patients.

**Keywords** Refractory pain · Chronic pain · Total joint arthroplasty · Knee osteoarthritis · Postoperative analgesia · Genicular nerve radiofrequency ablation

## Introduction

Osteoarthritis (OA) is the most common cause of hip and knee pain in the USA, affecting about 10% of men and 13% of women over the age of 60 [1]. The gold standard treatment option for those suffering from end-stage OA is total joint arthroplasty (TJA), specifically total knee arthroplasty (TKA) and total hip arthroplasty (THA). The surgery is performed by a board-certified orthopedic surgeon who specializes in hip and knee replacements with the primary goal of the procedure being to restore functional status and alleviate pain. Studies have shown that more than 80% of patients are satisfied with their new joint, leaving about 20% dissatisfied [2]. Much of the dissatisfaction is secondary to pain as 10–34% of patients report moderate-to-severe postoperative pain after TKA [3]. Although most patients receive adequate acute postoperative pain control, the refractory pain exhibited by this small cohort must be addressed in order to increase patient satisfaction and improve functional outcomes.

Models are predicting that by 2030, the number of THAs performed will grow by 171%, surpassing 600,000 cases, and the number of TKAs will grow 189%, surpassing 1 million cases [4]. Projections also demonstrate that the total annual case numbers of THAs and TKAs will increase by 280 and 400% in the next 20 years, respectively [5]. This logarithmic increase in caseload will only lead to an increase in the population of patients who continue to have pain after total joint arthroplasty. This will be problematic because not only will this potentially contribute to the ongoing opioid crisis in America, but it also raises the question whether total joint replacement is the final answer for pain control due to end-stage OA. For those patients who suffer from chronic pain after TKA or THA, it becomes necessary to incorporate modalities of refractory pain control.

Although it is the orthopedic surgeon who is performing the surgery, the care of a patient with refractory postoperative pain requires the aid of specialized pain anesthesiologists.

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There are many techniques by which refractory pain can be treated; however, outcomes are variable, and there is a lack of evidence-based research in the literature. The management of refractory pain is multifaceted and is being actively researched and developed, so this paper will review the recent literature and highlight the acute and chronic modalities in which postoperative pain is managed.

## Chronic Joint Pain

According to the International Association for the Study of Pain, pain is "an aversive sensory and emotional experience typically caused by, or resembling that caused by, actual or potential tissue injury" [6]. Pain is subjective and is shaped by biological, psychological, and social factors, which makes the interpretation of pain difficult to objectify and standardize. However, efforts have been made to do so with the advent of validated subjective scales such as the visual analog scale (VAS). Per the VAS tool, the patient will pick their pain level on a 10-cm line that represents a continuum between "no pain" and "worst pain" based on facial expression associations [7]. VAS can also help to quantify chronic pain and has been subsequently used in many studies in order to help determine the efficacy of different treatment modalities.

Chronic pain is defined as persistent pain for over 3 months [8]. This type of pain affects over 100 million American adults and accounts for more than $600 billion healthcare dollars annually, which is more than double that of that of heart disease, cancer, and diabetes [9, 10]. Chronic pain has the potential to affect every aspect of a person's life and has been reported to have an association with disorders of mental health [10]. Studies have shown depression to be present in up to 54% of people with chronic pain, and in turn, depression is linked with pain complaints and physical impairment [10, 11]. This physical and emotional pain can directly inhibit a patient's postoperative course and rehabilitation process, which will lead to increased immobility and therefore increased morbidity, hence the extreme importance of adequate pain control.

Generally speaking, postoperative pain results from inflammation secondary to direct tissue trauma and from damage to nerves secondary to stretching, compression, or transection [12]. There are many ways in which this acute postoperative pain control is managed pharmacologically in order to decrease the likelihood of chronic postoperative pain from developing. There is strong evidence behind multimodal pain control; however, due to the subjective nature of pain, there remains a cohort of patients whose pain is not well controlled and needs further intervention. Ideally, this review will be used as a way to guide providers towards specific modalities based on a patient's symptomatology to help treat and hopefully eradicate chronic pain.

## Postoperative Pain Control

The goal of acute postoperative pain control is to provide pain relief, which leads to early ambulation, improved patient satisfaction, and decreased hospital lengths of stay. The problem with acute postoperative pain is that less than half of patients undergoing surgical procedures report adequate postoperative pain relief [13]. In an effort to improve postoperative pain control, multimodal analgesia has been implemented using analgesic medications with varying mechanisms of action. Acute postoperative pain control is paramount in order to help decrease the number of patients who suffer from chronic postoperative pain, hence the importance of pain control in this setting.

Perioperative pain management plays an integral role for chronic pain syndromes, as addressing pain in the early postoperative period can correlate with long-term management of pain. Prior literature has identified that poorly controlled postoperative pain can increase the risk for the development of chronic pain, especially in patients who are not opioid-naïve [14–16].

### Acetaminophen

Acetaminophen is an antipyretic, analgesic agent that can be given orally or intravenously. Oral and intravenous dosing is equivalent; however the onset of action was found to be quicker with intravenous administration [13]. A prospective randomized control study by Politi et al. showed that pain and VAS scores were significantly lower in the first 4-h postoperative period in patients who received intravenous acetaminophen compared to oral acetaminophen [17]. However, multiple studies have shown that there is actually no increase in pain relief or decrease in VAS scores when comparing intravenous to oral administration [17, 18]. As beneficial as acetaminophen is in providing analgesia, it does have side effects such as liver damage and anticoagulation potentiation while using warfarin.

### NSAIDS and COX-2 Inhibitors

Nonsteroidal anti-inflammatory drugs (NSAIDs) work by inhibiting the cyclooxygenase-1 (COX-1) and cyclooxygenase-2 (COX-2) enzymes, which inhibit the production of prostaglandins in peripheral tissues, thus decreasing inflammation and providing analgesia. Newer COX-2 inhibitors selectively target COX-2, reducing the risk of peptic ulcers. Studies have shown that by administering NSAIDs or COX-2 inhibitors, both preoperatively and postoperatively for total joint replacements, there is a reduction in opioid use and therefore less risk of respiratory depression [19, 20]. A respective study by Xiao et al. showed that flurbiprofen axetil, a nonselective COX inhibitor, had improved short-term pain relief and lower morphine consumption rates when compared

to celecoxib use, a selective COX-2 inhibitor [19]. Some complications of NSAID use include decreased platelet aggregation, renal injury, and gastrointestinal mucosal damage. Earlier studies thought that a risk of NSAID use was decreased healing and bony ingrowth; however, evidence suggests that preoperative and postoperative administration of NSAIDs does not significantly affect attachment strength or bony ingrowth [21]. NSAIDs are an effective acute postoperative modality of analgesia.

### Gabapentinoids

Gabapentin inhibits the presynaptic voltage-gated calcium channels and causes depression of the presynaptic excitatory input on dorsal horn neurons. Gabapentinoid use in the acute postoperative period has been shown to lower the morphine equivalent dose consumption and improve pain scores [13, 22]. Clark et al. found that by adding gabapentin to the preoperative regimen, patients had less morphine use and showed increased knee range of motion. Although there is no conclusive dose of gabapentin or pregabalin (Lyrica) to provide adequate pain control, both have been studied and demonstrate effective postoperative analgesia [13]. While gabapentinoids provide pain relief, there are side effects such as sedation, water retention, and renal insufficiency.

### Ketamine

Ketamine is a noncompetitive N-methyl-d-aspartate (NMDA) receptor antagonist. A randomized double-blind study by Remerand et al. showed that ketamine decreased the morphine consumption at 24 h postoperatively [23]. Ketamine has also been shown to decrease the proportion of patients with persistent pain at 180 days postoperatively; however, there is no evidence on the optimal dosage or administration timing for ketamine in the current literature [13, 23]. The side effects of ketamine include increased intracranial pressure, increased salivation, nystagmus, hallucinations, and increased sympathetic activity.

### Opioids and Patient-Controlled Analgesia

Opioids work by binding to opioid receptors that act on mu, kappa, and lambda receptors in the central nervous system and gastrointestinal tract. Many studies have shown that oral opioid administration should be preferred over intravenous administration as oral opioids provide similar pain control with lower morphine equivalent doses [13, 24]. Intravenous patient-controlled analgesia allows patients to control dose frequency and avoid pain medication administration delays. The reason that intravenous patient-controlled analgesia (PCA) is inferior to oral opioid administration is because oftentimes the PCA can provide inadequate analgesia and can cause excessive nausea [25]. Some other side effects of opioids include respiratory depression, potential for addiction and abuse, sedation, nausea, vomiting, and constipation. The risk for addiction and long-term opioid use increased 125% between patients with at least 1 day of opioid use and patients with more than 8 days of opioid use [12].

### Multimodal Pain Control

Multimodal pain control has gained popularity in recent years due to its ability to provide improved pain control while decreasing the rate of opioid consumption. Randomized trials have shown that there is superior pain relief when simultaneously administering analgesia that act through different receptors [13, 26, 27]. While NSAIDs and acetaminophen independently provide pain relief, Thybo et al. showed that the combination of paracetamol and ibuprofen reduced morphine consumption in the first 24 h compared to paracetamol alone [24]. Multimodal analgesia approaches have allowed surgeons to manage pain control preoperatively, intraoperatively, and postoperatively. Parvataneni et al. were able to demonstrate decreased pain scores after THA and TKA by administering preoperative celecoxib and oxycodone; intraoperative injections of bupivacaine, morphine sulfate, and methylprednisolone; and postoperative ketorolac, celecoxib, oxycodone, and acetaminophen [28]. By providing multimodal analgesia throughout the perioperative period, patients were able to have markedly improved functional outcomes and decreased pain scores.

## Refractory Postoperative Pain Control

### Genicular Nerve Radiofrequency Ablation

Genicular nerve radiofrequency ablation (GN-RFA) has been used to treat a variety of conditions such as cancers and cardiac arrhythmias, but in the last 10 years, it has been gaining popularity as a modality in treating chronic knee pain [29]. GN-RFA is a minimally invasive technique that involves a heated probe that targets specific nerves that innervate specific tissues. The knee is innervated by a complex group of nerves known as the genicular nerves, which are articular branches of several major lower extremity nerves including the femoral, tibial, common peroneal, saphenous, and obturator nerves. GN-RFA requires the identification of anatomical landmarks around the knee in order to appropriately target the specific nerves and is usually administered in the superomedial, superolateral, and inferomedial aspects of the knee joint [29, 30]. In addition to conventional GN-RFA, studies have also evaluated the use of pulsed and cooled RFA, which administer the ablation by slightly different methods operating under the same principles.

Since it was first introduced by Choi et al. for the treatment of chronic knee pain in 2010, GN-RFA has been extensively studied; however, much of the literature has described GN-RFA in the treatment of refractory pain secondary to OA and not after TKA [29, 31–33]. That being said, more recent studies have been shifting the focus to GN-RFA in treating refractory pain after TKA. Erdem and Sir studied ultrasound-guided pulsed GN-RFA in 23 patients, 17 with end-stage OA and 6 with a history of TKA, demonstrating improved VAS scores and Western Ontario and McMaster Universities Osteoarthritis (WOMAC) scores in both cohorts. In those with chronic pain after TKA, 67% showed a ≥ 50% improvement in pretreatment VAS scores at 3 and 12 weeks after GN-RFA, demonstrating the positive effect of this treatment modality [32]. Although the power of their study was limited due to their small sample size, their results have been replicated in similar studies and case reports [34, 35].

Sylevester et al. described a case of a 68-year-old female with refractory pain 6 months after a TKA, which presented as referred posterior thigh and posterior knee pain. At that time she described 10/10 pain. After ruling out other etiologies of this persistent pain like lumbar radiculopathy, gluteal muscle injury, sacroiliac joint dysfunction, piriformis syndrome, and posterior femoral cutaneous nerve entrapment, the decision was made to attempt GN-RFA. At her 12-week follow-up, her pain was described as 0/10, with the occasional 2/10 pain at night after daily activities, which is a significant improvement from 10/10. Although this is a nontraditional presentation of chronic pain, this case report highlights the efficacy of GN-RFA as a modality for the treatment of refractory referred pain after TKA [34].

In other patients, GN-RFA has been shown to be as effective in pain reduction as corticosteroid injections. Qudsi-Sinclar et al. conducted a double-blind, randomized clinical study comparing radiofrequency ablation to local anesthetic and corticosteroid block of the superolateral, superomedial, and inferomedial genicular nerves in patients suffering from chronic pain after TKA [36]. Results demonstrated a significant decrease in pain and improvement in function in the first 3–6 months after treatment without a significant difference between the groups, redemonstrating the effectiveness of GN-RFA [36]. However, the similarity in effectiveness between GN-RFA and corticosteroid injections questions the need for GN-RFA as a treatment modality. That being said, the subjective nature of pain, and therefore the subjective nature of the resolution of pain, leads each patient to have an individualized response to the different treatments. The important conclusion is that GN-RFA is effective in managing chronic pain.

Interestingly, a recent study by Walgea et al. demonstrated no effect on postoperative pain control when GN-RFA was administered 2–6 weeks preoperatively. The authors performed a randomized sham-controlled prospective clinical trial, following patients up to 6 months postoperatively. Their results showed no difference in pain or functional measures at any point during the study [37]. Although this study demonstrates GN-RFA to have minimal to no effect on acute postoperative pain control, other studies have demonstrated its effectiveness in chronic pain control, highlighting the difference in etiology between acute and chronic pain. Perhaps it is the mechanism by which chronic pain is experienced and the different neural pathways involved that allows it to be successfully managed with GN-RFA, compared to that of acute pain (Table 1).

## Neuromuscular Electrical Stimulation

Neuromuscular electrical stimulation (NMES) has been trialed as a non-pharmacologic modality of refractory pain control with promising results [35]. NMES works by stimulating the proximal quadriceps muscles as well as the distal aspect of the vastus medialis obliquus (VMO), the quadriceps muscle most intimately associated with the total knee arthroplasty operation. During a TKA, the most common way the joint is exposed is through a medial parapatellar arthrotomy, with the most proximal aspect of the arthrotomy being at the lateral edge of the distal VMO. Although the arthrotomy is repaired at the end of the procedure, this direct tissue trauma plays a role in the high rates of postoperative quadriceps weakness. Full strength of the quadriceps muscle is known to be critical in pain reduction, which is why NMES has been studied [38, 39].

NMES stimulates muscle fibers to increase the recruitment of type II muscle fibers, acting as a neuromodulatory technique that strengthens the quadriceps. In a recent randomized control trial, Avramidis et al. demonstrated that the use of NMES led to significant increases in Oxford knee scores, American Knee Society function scores, and SF-36 physical component summary scores at 6, 12, and 52 weeks [40]. Increases in these scores are directly related to decreases in postoperative pain, demonstrating a role for NMES in refractory pain control. Another study showed significant improvement in resting and worst reported pain scores in the NMES group compared to control, demonstrating better scores for quadriceps lag, timed up and go, time to ascend and descend one flight of stairs, and single-leg-stance time [38]. It is important to realize that Delanois et al. studied NMES in the more acute postoperative period; however, it is reasonable to think that refractory pain secondary to a weak quadriceps muscle can also be alleviated with NMES.

## Transcutaneous Electrical Nerve Stimulation

The accepted mechanism of transcutaneous electrical nerve stimulation (TENS) is via pulsing electrical currents across the intact surface of the skin, activating the endogenous

**Table 1** Modalities of chronic pain management after total joint arthroplasty

| Modality | Author | Year | *N* | Type of Study | Outcomes |
|---|---|---|---|---|---|
| Genicular nerve radiofrequency ablation (GN-RFA) | Erdem and Sir | 2019 | 23 | Retrospective review | 67% with ≥ 50% reduction in VAS and WOMAC scores |
| | Walega et al. | 2019 | 70 | Sham-controlled prospective randomized clinical trial | No effect on pain or functional measures |
| | Sylvester et al. | 2017 | 1 | Case report | 6 months after TKA: 10/10 pain<br>12-week follow-up: 0/10 pain |
| | Qudsi-Sinclair et al. | 2016 | 28 | Double-blind randomized clinical study (GN-RFA vs. corticosteroids) | Decrease in pain and improvement in function in the first 3–6 months after treatment without a significant difference between the groups |
| Neuromuscular electrical stimulation (NMES) | Delanois et al. | 2019 | 26 | Prospective matched cohort study | Decrease in resting and worse pain, decrease in timed up and go, decrease in quad lag, increase in single-leg-stance time |
| | Avramidis et al. | 2011 | 70 | Randomized clinical trial | Significant increases in Oxford knee scores, American Knee Society function scores, and SF-36 physical component summary scores |
| Transcutaneous electrical nerve stimulation (TENS) | Zhu et al. | 2017 | 529 | Meta-analysis | Significant VAS reduction in 24 h |
| | Li and Song | 2017 | 472 | Meta-analysis | Significant VAS reduction in 48 h |
| | Zheng et al. | 2012 | 104 | Randomized clinical trial | KOOS scores significantly improved after 9 months |
| Peripheral subcutaneous field stimulation (PSFS) | McRoberts and Roche | 2010 | 2 | Case series (TKA) | Significant reduction in VAS |
| | Yakovlev et al. | 2010 | 12 | Case series (THA) | 50% reduction in VAS scores, with sustained pain relief at 1-year follow-up |

inhibitory mechanisms of opioid receptors of the underlying nerves [41]. TENS and NMES work similarly; however, NMES works on the muscle affecting the peripheral nervous system, while TENS works directly on the nerves and has been thought to affect both the central and peripheral nervous systems.

Zhu et al. performed a meta-analysis to investigate the effect of TENS and found a significant improvement in VAS scores in the 24-h postoperative period but not at the 2-week period, making it seem as though TENS is ineffective in the non-acute setting [41]. However, their study was limited by using only 6 RCTs, 4 of which with sample sizes under 100. Although Zhu et al. does not discuss refractory pain, one of the studies they reviewed out of China had a 9-month follow-up. Zheng et al. were able to demonstrate that after 9 months, knee injury and osteoarthritis outcome scores (KOOS) were improved in the TENS group relative to the control group, suggesting that TENS has the ability to improve knee function and decrease pain in the refractory pain period as well [42].

A more recent meta-analysis was conducted to evaluate the use of TENS after TKA and found that it significantly decreased VAS scores and overall pain in the acute postoperative period [43]. The reduction of pain in the acute postoperative period with the use of TENS shows promising results, reflecting its ability to do so in the chronic period as well. That being said, most of the current studies and meta-analyses evaluating the use of TENS are focused on the acute period, and more research needs to be conducted to assess its efficacy in the chronic period in order for it to be used as an evidence-based management technique for refractory pain.

## Peripheral Subcutaneous Field Stimulation

Case reports have shown that refractory pain after TKA can be effectively managed with peripheral subcutaneous field stimulation (PSFS) [44]. PSFS is a neuromodulation surgery for refractory pain control in which electrodes are placed subcutaneously in order to stimulate the surrounding nerves [45]. The electrodes were initially designed for spinal cord stimulation; however, in this case, the leads were placed in the periarticular area of the knee using small incisions on the medial and lateral aspect of the knee. McRoberts and Roche studied two patients with chronic pain 1 year after TKA who had failed multiple interventions ranging from NSAIDs, opioids, local anesthetic patches, TENS, and even revision surgery. The authors were able to show that by implanting this permanent neurostimulating implant in the periarticular region of the knee, VAS scores were significantly reduced, and overall functional status was greatly improved [44].

Although chronic pain management after THA has been less studied than that of TKA, PSFS has been shown to be an effective modality in the treatment of chronic pain after

THA [46]. Yakovlev et al. studied 12 patients with continued pain after THA and greater trochanteric bursectomy. They were able to demonstrate over a 50% reduction in VAS scores after treatment with PSFS, with sustained pain relief at 1-year follow-up. The mean pain score reported before implantation was 7.5 and was a mere 2 after treatment, demonstrating a significant reduction in pain [46].

PSFS is a safe and effective treatment option for managing chronic pain after TJA and has many advantages over other therapeutic modalities. The high success rate of the implant is likely secondary to patients being able to test the efficacy of the implant before implantation and to manually program the level of stimulation required to control their pain [46]. This puts patients in the driver's seat of their own pain control, and the ease of reversibility makes PSFS that much more desirable.

### Regional Anesthesia

Regional anesthesia utilizes local anesthetics to directly target sensory pain pathways, helping block the perception of pain. These techniques involve spinal anesthesia, epidural anesthesia, and specific nerve blocks and are all frequently utilized following total knee arthroplasty [47, 48]. A major benefit to regional anesthesia is that it can directly target specific pain pathways, without effecting the entire body as many oral medications, such as opioids, do. Additionally, regional anesthesia has been associated with a decrease in deep vein thrombosis and pulmonary embolism formation, as well as transfusion requirement, pneumonia, and respiratory depression as compared to general anesthesia [49]. Furthermore, a recent large-scale nationwide study also identified general anesthesia to be associated with increased postoperative complications and non-home discharge as compared to spinal anesthesia in patients who underwent total hip and knee arthroplasty [50]. In one meta-analysis, the authors evaluated 45 eligible randomized control trials (2710 TKA patients) and found femoral nerve blocks to provide more effective analgesia than PCA opioid alone [51]. Adductor canal blocks have also shown to be effective in managing pain following total knee arthroplasty and have the advantage of not causing motor signal block to the quadriceps [52, 53].

### Neuromodulatory Techniques

Dorsal column stimulation, or spinal cord stimulation (SCS), has been shown to improve quality of life and reduce pain/paresthesias and analgesic medication consumption. SCS functions by applying electrical impulses through electrodes which are placed at the correlative spinal level associated with the dermatomal distribution of the pain generating site. By stimulating specific sensory nerve fibers, SCS can then block pain signals. However, the effect of SCS is primarily on the dorsal column, which is not necessarily the only route for pain signal transmission. The dorsal route ganglion (DRG), however, is a pathway for all peripheral sensory signals into the spinal cord. Additionally, the physiologic makeup and location of the DRG can allow for more uniform and targeted electrical stimulation [54]. In a sub-analysis of a large randomized clinical trial, Deer et al. compared 75 subjects (41 DRG and 34 SCS) and found more patients who underwent DRG stimulation had ≥ 50% reduction in pain at 3 months without experiencing any paresthesia as compared to SCS subjects (13/41 [32%] vs. 3/34 [9%]; $p < 0.05$). The group also found that DRG can be effective in providing pain relief, by producing paresthesia that are less frequent and intense as well as more targeted than SCS. Additionally, Antony et al. performed a meta-analysis with a particular subset analysis in hip and knee arthroplasty patients and described advantages of utilizing DRG stimulation despite joint pain traditionally being understood as nociceptive [55].

## Conclusion

Chronic pain is a well-documented sequela of total joint replacement. Most patients receive adequate postoperative analgesia and report good outcomes after total knee replacement; however, the focus must be shifted to the 10–34% of patients who report chronic pain and how that pain can be effectively managed [56]. With the impending surge in the number of TJAs each year, the number of patients who will suffer from refractory pain will increase, again highlighting the importance of managing such pain. The obvious goal of postoperative analgesia is to adequately treat acute pain in order to prevent chronic pain from ever occurring; however, this is not always possible, hence the importance of being able to identify those who are at risk for developing chronic pain.

The use of multimodal analgesia and combinations of acetaminophen, NSAIDs, opioids, ketamine, and gabapentinoids has been extensively studied in the literature and has proven to be effective at managing acute postoperative pain. That being said, there is much more sparse literature regarding the management of chronic pain after TJA. Four major modalities have been shown to have promising results, including genicular nerve radiofrequency ablation, neuromuscular electrical stimulation, transcutaneous electrical nerve stimulation, and peripheral subcutaneous field stimulation. Most of existing literature has shown a significant improvement in pain scores based on either the visual analog scale, Oxford knee scores, American Knee Society function scores, SF-36 physical component summary scores, Western Ontario and McMaster Universities Osteoarthritis, or the knee injury and osteoarthritis outcome scores. A limitation with analyzing this data is the lack of a standardized way to quantify pain, as seen by the various pain scales used between each study. Also,

most of the literature does not analyze these treatment modalities in the 3–6-month postoperative period which is the official definition of chronic pain; however, the long-term follow-up can be analogized to the chronic period. Another major limitation with the current data is the lack of power secondary to small sample sizes, which can be attributed to the difficulty with identifying those suffering from chronic pain. Future studies need to incorporate randomized control trials with larger sample sizes in order to demonstrate the best ways to manage chronic pain.

This review demonstrates the lack of evidence in regard to the management of chronic pain after total joint replacement. Because of the complexity of chronic pain, there are many different modalities that are being tested as adequate treatment options. These patients need to be properly identified so that studies can be conducted, assessing the efficacy of GN-RFA, NMES, TENS, PSFS, and more. As the number of people affected by chronic pain after total joint replacement continues to increase, the development of an evidence base in regard to the care for these patients should be a research priority for the benefit of the patient, the provider, and the healthcare system.

## Declarations

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

**Conflict of Interest** The authors declare that they have no conflicts of interest.

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