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Peripheral Nerve Stimulation of the Saphenous Nerve at the Adductor Canal for Chronic Post-Surgical Knee Pain Following Total Knee Arthroplasty

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Background: Total knee arthroplasty (TKA) is effective for osteoarthritis (OA), yet many patients develop chronic post-operative pain. Peripheral nerve stimulation (PNS) has emerged as a minimally invasive alternative for refractory pain.

Case Report: A 79-year-old man with right total knee arthroplasty (TKA) presented with right knee pain unresponsive to genicular nerve radiofrequency ablation. The pain, rated 8/10, was localized to the superomedial knee and worsened with ambulation. Before knee replacement, his pain was confined to the intra-articular space. A peripheral nerve stimulation (PNS) trial targeting the saphenous nerve at the adductor canal was performed under ultrasound guidance. The patient reported 100% pain relief at 1-month follow-up. A Permanent Nalu implant was subsequently placed and that 100% pain relief continued for more than 2 months.

Conclusions: This case demonstrates the use of ultrasound-guided peripheral nerve stimulation targeting the saphenous nerve for chronic postsurgical knee pain following total knee arthroplasty. The intervention provided complete pain relief, underscoring peripheral nerve stimulation as a promising, minimally invasive option for chronic postoperative pain unresponsive to conventional treatments.

Key words: Peripheral nerve stimulation; saphenous nerve; total knee arthroplasty; chronic postsurgical pain; ultrasound-guided intervention

BACKGROUND

Total knee arthroplasty (TKA) is a common procedure used to relieve chronic knee pain secondary to moderate to severe osteoarthritis (OA). The number of annual TKA procedures among Medicare patients increased by 162%, from 93,230 to 243,802, between 1991 and 2010 (1). About 1 in 4 US adults, or 58.5 million people, have diagnosed arthritis, with OA being the most common form (2). The annual number of TKA procedures will likely continue to increase because of the increasing prevalence of OA associated with advanced age and obesity. TKA for the treatment of OA is often pursued after failure of multiple conservative interventions, including physical therapy, nonsteroidal anti-inflammatory drugs, and steroid injections. Although TKA generally reduces knee pain, a considerable number of patients experience chronic postoperative pain. In a systematic review of several prospective studies of patients undergoing TKA, 10% to 34% reported unfavorable pain outcomes between 3 months and 5 years after surgery

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(3,4). One high-quality study found that 20% of patients had unfavorable pain outcomes at 6 months, with recent cohort studies reporting similar rates of chronic pain in 16% to 33% of patients (5-7). The etiology of chronic pain after TKA is multifactorial. In a systematic review and meta-analysis of 32 studies involving more than 30,000 patients at least 3 months after TKA, significant predictors of persistent pain included preoperative pain score, catastrophizing, depression/anxiety, and pain at other sites (8). No universal treatment for chronic knee pain after TKA currently exists. Available options include surgical revision, injections, physical therapy, and pharmacotherapy, while persistent pain can result in substantial disability, increased health care utilization, and societal burden.

Peripheral nerve stimulation (PNS) is a pain management technique that uses electrical current to target specific nerves. PNS involves implanting an electrode near the targeted nerve, which can be stimulated to alleviate pain. Recent reports have described PNS for several pain conditions, including craniofacial, supraorbital, and ilioinguinal neuralgia, as well as chronic pelvic pain, upper and lower extremity pain, back pain (9). Despite the limited literature on neuromodulation for peripheral joint pain and chronic postsurgical pain, several studies suggest that PNS may provide additional therapeutic benefit for patients with chronic or postoperative knee pain (9-11). The literature on perioperative use of PNS in patients undergoing TKA is even more limited.

The authors present a case of a successful PNS trial of the right saphenous nerve at the adductor canal in a patient with chronic right postsurgical knee pain refractory to multiple interventions, including TKA, genicular nerve block (GNB), and genicular nerve radiofrequency ablation (GRFA).

CASE PRESENTATION

A 79-year-old man with a medical history of 2 vertebral fractures, atrial fibrillation, 2 right knee meniscus surgeries, recurrent prostate cancer status post external beam radiation, and right TKA in 2018 for severe OA presented to a pain clinic with chronic postsurgical right knee pain after TKA without associated injury. At the initial visit, the patient had nonradiating pain at the superomedial aspect of the right knee, rated 8/10 on the Numeric Rating Scale, exacerbated by ambulation and improved with icing and elevation. Before knee replacement, the pain was confined to the joint. The patient also reported chronic low back pain without sciatica and balance problems leading to frequent falls. Prior interventions included physical therapy and 2 right genicular nerve blocks at the superior medial and inferior medial branches on different dates, with 50%-70% pain relief sustained for 4 months. He experienced mild pain relief with gabapentin 100 mg 3 times daily.

On physical examination, the patient had tenderness to palpation over the medial joint line of the right knee, with no joint laxity and a negative patellar grind test. The patient initially underwent right GRFA, including the suprapatellar branch, under fluoroscopy. However, he experienced no pain relief from GRFA. The decision was made to pursue a PNS trial of the right saphenous nerve at the adductor canal under ultrasound guidance using the SPRINT® PNS System (SPR Therapeutics, Inc.).

After a sterile field was established, the external landmarks, including the anterior superior iliac spine (ASIS) and the base of the patella (BP), were identified, and thigh length was defined from the ASIS to the BP. The linear 15-MHz transducer probe was initially positioned transversely in the distal third of the thigh, medial to the line connecting the ASIS and BP. Internal landmarks for the saphenous nerve approach included the femoral artery (FA), sartorius muscle, vastus medialis muscle, adductor magnus muscle, and vastoadductor membrane. Optimal visibility was obtained in the proximal segment of the adductor canal, where the saphenous nerve was clearly visible anterolateral to the femoral artery. The anatomic variation in which the nerve lies medial to the femoral artery was not observed. The percutaneous sleeve and stimulating-probe lead introduction system were assembled and inserted from lateral under direct ultrasound visualization, with care taken to maintain the proper insertion depth and avoid the FA. Multiple stimulation parameters were used until nerve target acquisition was confirmed. The lead was guided through the needle, verified with electrical stimulation and ultrasound, and anchored to the skin with surgical glue. The patient tolerated the procedure, and all needles were removed after hemostasis was confirmed. An ultrasound image was saved (Fig. 1).

The patient had 100% pain relief at the 1-month follow-up after the PNS trial. Given the positive trial result, the patient was subsequently scheduled for permanent right saphenous nerve PNS implantation with the Nalu™ Neurostimulation System (Nalu Medical). More than 2 months after permanent implantation, he continued to report 100% pain relief.

DISCUSSION

The effectiveness and safety of PNS have been well established. A systematic review by Helm et al (12) reviewed literature published from 1966 through 2021 and concluded that PNS is effective for treating chronic pain. Several studies have explored PNS for knee pain relief. Lin et al (13) conducted a systematic review of 6 studies, 4 addressing postoperative knee pain and 2 addressing neuropathic pain, with positive outcomes. Ilfeld et al (9) conducted a study of 7 patients after total knee arthroplasty, reporting reduced pain scores and improved Six-Minute Walk Test and Western Ontario and McMaster Universities Osteoarthritis Index scores. Based on our review, however, there is a paucity of studies examining the efficacy of PNS trials and/or implants for chronic postsurgical knee pain after TKA. A case series relevant to our clinical scenario showed that daily peripheral electrical stimulation targeting the saphenous and peroneal nerves resulted in significant pain relief and functional improvement, accompanied by notable reductions in Visual Analog Scale pain scores and improved functional capacity during and after stimulation (10). Our case report appears to be the first to illustrate the efficacy of an ultrasound-guided PNS trial targeting the saphenous nerve for chronic postsurgical knee pain following TKA after ineffective right GRFA.

The innervation of the knee joint is complex, with 10 potential nerves innervating the anterior knee and 2-3 nerves innervating the posterior region via the popliteal plexus (14). Among these, the saphenous nerve contributes to knee innervation. The saphenous nerve is a purely sensory nerve that arises from the L3-L4 nerve roots as a terminal branch of the femoral nerve, travels along the proximal third of the thigh, descends lateral to the femoral sheath in the adductor canal, and crosses anteromedial to the femoral artery before emerging from the canal (15). After leaving the adductor canal, the saphenous nerve pierces the fascia lata between the tendons of the gracilis and sartorius muscles to become subcutaneous, dividing into the infrapatellar and sartorial branches before descending along the medial aspect of the lower leg (15). The infrapatellar branch of the saphenous nerve provides sensory innervation to the anteromedial and inferomedial regions of the knee joint without posterior innervation (14,16). Accordingly, we targeted the right saphenous nerve with PNS to address the patient's chronic postsurgical pain in the medial right knee, consistent with the physical examination findings.

The most commonly proposed mechanism of action for PNS relates to gate control theory, which suggests that nonnociceptive input closes gates to nociceptive

Fig. 1. Visualization of the percutaneous lead guided through the needle and delivered to a location in proximity to the nerve.

input in the spinal cord dorsal horn, thereby affecting pain perception (17). Additional proposed mechanisms of PNS analgesia include excitation failure in C-fiber nociceptors leading to suppression of dorsal horn activity, stimulation-induced blockade of cell membrane depolarization that prevents axonal conduction, decreased hyperexcitability and long-term potentiation of dorsal horn neurons, and regulation of neurotransmitter release (17). However, pain perception is complex and involves multiple components and interactions, with the brain ultimately determining which stimuli are perceived as painful. For PNS used to treat chronic postsurgical knee pain after TKA, the precise mechanism of pain relief remains uncertain. In the case series by McRoberts et al (10), the authors hypothesized that pain relief from PNS for chronic postsurgical knee pain after TKA may involve direct stimulation of sensory nerves in the knee as well as distal A-beta fibers in the dermis surrounding the knee.

Limitations

Although our case report provides evidence supporting ultrasound-guided PNS for refractory chronic postsurgical knee pain following TKA and unsuccessful GRFA, several limitations should be considered. First, as a single case report, the results may not be generalizable to a larger population. Future research should focus on larger randomized controlled trials with appropriate control groups to establish the efficacy and safety of PNS for chronic postsurgical knee pain following TKA. The patient had 100% pain relief at the 1-month follow-up after the PNS trial. Given the positive trial result, the patient was subsequently scheduled for permanent right saphenous nerve PNS implantation with the Nalu™ Neurostimulation System (Nalu Medical). More than 2 months after permanent implantation, he continued to report 100% pain relief. Investigation of potential mechanisms of PNS in patients with chronic postsurgical knee pain following TKA could provide insight into the underlying pathophysiology and inform development of future PNS-based treatment approaches.

CONCLUSION

In conclusion, this successful trial demonstrates the potential benefit of PNS for prolonged and sustained pain relief in chronic postsurgical knee pain following TKA after unsuccessful conventional treatments, including GRFA.

Author Contributions

Yacine Issioui, MD: First and corresponding author. Led the conception, organization, and preparation of the manuscript. Structured the case report according to journal guidelines, refined the content for submission, and coordinated all author contributions and final revisions for publication.

Loc Lam, DO: Manuscript drafting, case narrative development, and literature review. Assisted in data organization and early version preparation of the report.

Emanuel Narcis Husu, MD: Senior author and supervising attending. Performed the procedure, provided clinical and technical oversight, contributed to case interpretation, and critically reviewed and approved the final manuscript for accuracy and intellectual content.

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