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Technical Note

A Novel Technical Protocol for Improved Capture of the Genicular Nerves by Radiofrequency Ablation

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Abstract

Background. Fluoroscopically guided cooled genicular nerve radiofrequency ablation (RFA) is an increasingly performed procedure for chronic, refractory knee pain due to osteoarthritis. Traditionally, partial sensory denervation has been accomplished through ablation of the superomedial, superolateral, and inferomedial genicular nerves. However, recent cadaveric studies have demonstrated additional sensory nerves and significant anatomic variation that impact current protocols. **Objective.** We describe an updated cooled genicular nerve radiofrequency ablation protocol that accounts for varied nerve location of the superomedial, superolateral, and inferomedial genicular nerves, as well as capture of the terminal articular branches of the nerves to the vastus intermedius, vastus lateralis, and vastus medialis. Furthermore, we describe an adjusted technique for inferomedial genicular nerve capture that mitigates the risk of pes anserine tendon injury. **Design.** Technical report and brief literature review. **Methods.** Cadaveric studies relating to the sensory innervation of the anterior knee joint were reviewed, and a more accurate and comprehensive cooled genicular nerve radiofrequency ablation (CRFA) protocol is proposed. **Conclusions.** Based on recent, rigorous anatomic dissections of the knee, the proposed genicular nerve CRFA protocol will provide more complete sensory denervation and potentially improve clinical outcomes. Prospective studies will be needed to confirm the hypothesis that this protocol will result in improved effectiveness and safety of genicular nerve RFA.

Key Words: Knee; Pain; Osteoarthritis; RFA; Anatomy; Conservative

Introduction

Osteoarthritis (OA) is a common cause of knee pain that may impair daily functioning and decrease quality of life. Although treatment of knee OA includes medications, weight loss, physical therapy, and corticosteroid injections, patients may have persistent symptoms and seek total knee arthroplasty (TKA). TKA is generally associated with favorable outcomes; however, not all patients are appropriate surgical candidates due age or medical comorbidities. Further, patients may wish to avoid surgery altogether and seek alternative treatments when conventional conservative management strategies have failed. Radiofrequency ablation (RFA) is a technique used to partially denervate the anterior knee joint capsule, thereby reducing pain associated with knee OA [1–3].

RFA has traditionally targeted the superior lateral genicular nerve (SLGN), superior medial genicular nerve (SMGN), and inferior medial genicular nerve (IMGN) [4]. However, a recent cadaveric study by Tran et al. [5], consistent with prior surgical anatomy literature [6], suggests that there are more articular nerves that contribute to the sensory innervation of the anterior knee joint capsule than the studies on which prior genicular nerve radiofrequency ablation protocols are based [1–3]. In addition to the SLGN, SMGN, and IMGN, they

observed consistent sensory contributions from the terminal articular branches of the nerves to the vastus intermedius (NVI), vastus lateralis (NVL), vastus medialis (NVM), common fibular nerve, and recurrent fibular nerve [5]. The NVL was found to course superficially and laterally between the anteromedial border of the vastus lateralis and the muscle belly of the vastus intermedius, with a mean distance of 0.97 ± 0.27 cm from the periosteum of the femur at the level of the suprapatellar bursa. The NVM had a similar depth of 0.71 ± 0.28 cm from the periosteum of the femur at this same location. The articular branches of the NVI all coursed along the periosteum, flanking the patellar tendon both medially and laterally. Further, Tran et al. [2,4] also described much greater variability in the courses of the SLGN, SMGN, and IMGN than had been previously appreciated. Prior ex vivo study of monopolar cooled RFA (CRFA) has demonstrated a relatively spherical lesion size at approximately 0.5–1.0 cm^3 in volume, which projects approximately 4 mm beyond the active tip [7]. Given these parameters, the sensory afferent targets described by Tran et al. [2] would not be captured using the current RFA protocols in the literature. Specifically, the SLGN, SMGN, NVL, NVI, and NVM are likely missed in a proportion of patients. As such, we present an enhanced protocol for genicular nerve CRFA based on the more recent understanding of neuroanatomy to inform future clinical outcomes studies.

Methods: Genicular Nerve Radiofrequency Ablation Protocol

Patient Positioning and Preparation

After informed consent and a procedure timeout, the patient is positioned in a supine position and the affected knee is placed at 30° of flexion using a pillow or bolster. This angle is optimal for two reasons: 1) the suprapatellar joint space is flattened, which minimizes the chance of needle trespass, and 2) this angle allows for an unobstructed lateral view of the knee, whereas the contralateral knee is maintained flat on the table with no flexion. Next, the knee is prepped and draped. Fluoroscopic scout images are obtained to align the femur in an anterior-posterior (AP) view in order to target the genicular nerves at locations above the femoral condyles. When targeting the inferior medial genicular nerve, an AP view requires greater caudal tilt of the fluoroscope in order to square off the tibial plateau to obtain an appropriate AP view. Two to 3 mL of 1% lidocaine is used to anesthetize the skin and subcutaneous tissues before cannula insertion at each target site.

RFA Electrode Placements

Superior Lateral Genicular Nerve

The introducer needle is advanced through the skin wheal placed 1–2 cm lateral to the femur, at the junction of the lateral femoral shaft and the lateral epicondyle in an AP fluoroscopic view. The needle is advanced until it contacts the bone. A lateral fluoroscopic view is then obtained (in which the femoral condyles are superimposed), and the needle is repositioned until the stylet tip is positioned at three-fourths the diameter of the femoral shaft and adjacent to the periosteum. The stylet is then removed from the introducer, and 1–2 mL of local anesthetic is administered. The radiofrequency ablation (RFA) electrode is inserted such that the distal active tip is located at a point two-thirds across the diameter of the femoral shaft and approximately 4 mm superficial to periosteum. Appropriate AP and lateral positioning are again confirmed, and lesioning is performed (Figure 1a and b); the lesion method is described below. After the first RFA lesion, the cannula and electrode are withdrawn en bloc until the distal end of the active tip is located at a point one-third across the diameter of the femoral shaft. Confirmatory fluoroscopy is performed, 1–2 mL of local anesthetic is administered, and a lesion is made here (Figure 1c).

Superior Medial Genicular Nerve and the Nerve to the Vastus Medialis

The introducer cannula is advanced through the skin wheal placed 1–2 cm medial to the femur at the junction of the medial femoral shaft and the medial epicondyle in an AP fluoroscopic view and advanced until it contacts the bone. A lateral fluoroscopic view is then obtained (in which the femoral condyles are superimposed), and the cannula stylet tip is positioned three-fourths the distance across the femoral shaft. The stylet is then removed, and 1–2 mL of local anesthetic is administered. The electrode is inserted and adjusted such that the distal end of the active tip is located at a point two-thirds the diameter of the femoral shaft and 4 mm superficial to periosteum, and final positioning is confirmed before lesioning (Figure 1a and b) to target the SMGN. After this lesion, the cannula/electrode is withdrawn en bloc until the distal end of the active tip is located at a point one-third the diameter of the femoral shaft and approximately 1 cm superficial to the periosteum. Then 1–2 mL of local anesthetic is administered, and lesioning is done here (Figure 1c) to primarily target the NVM.

Nerves to the Vastus Intermedius

The cannula is advanced through the skin wheal placed approximately 5 cm superior to the upper patellar pole and 5 mm toward the midline from the medial border of the femoral shaft in an AP fluoroscopic view in order to avoid trespass of the quadriceps tendon. The needle is advanced until it contacts the bone. A lateral fluoroscopic view is then obtained (in which the femoral condyles are superimposed), and the cannula is repositioned until the tip is positioned adjacent to periosteum. The stylet is then removed, and 1–2 mL of local anesthetic is

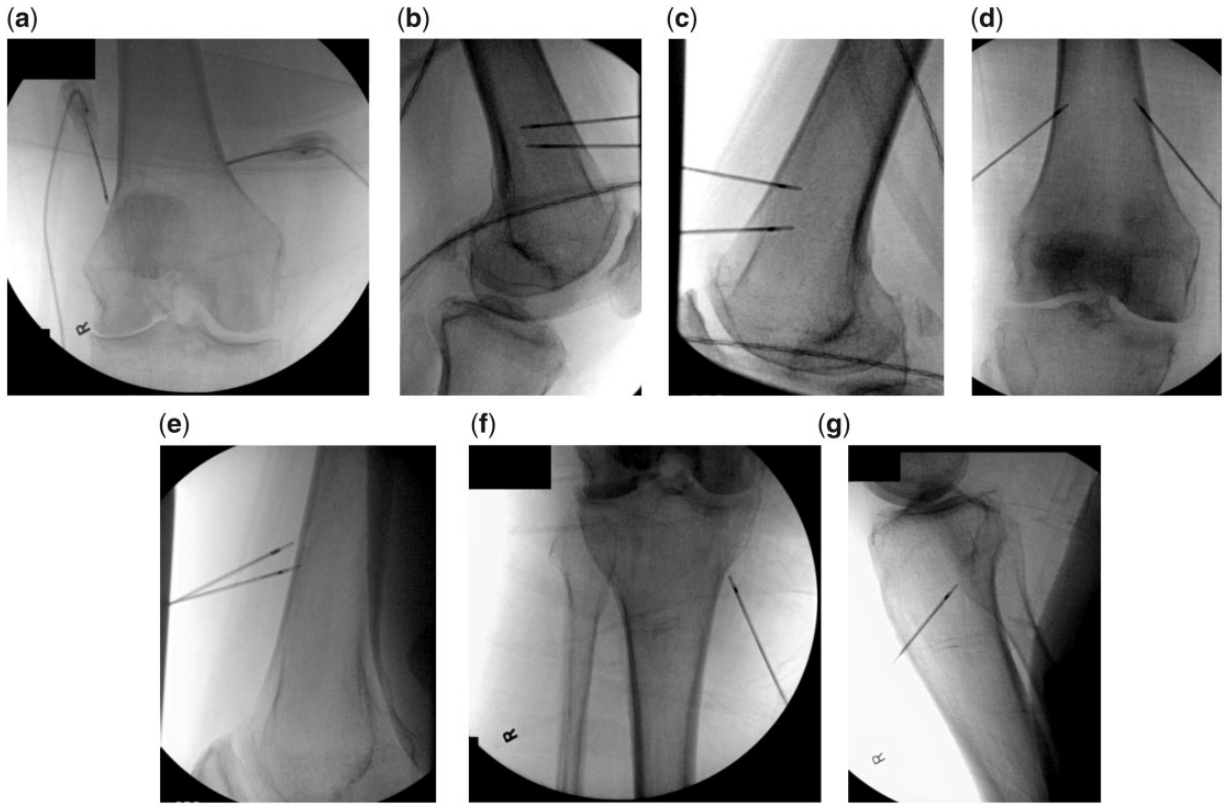

Figure 1. a) Anterior-posterior view of the electrode placements for the superior lateral genicular nerve (left), superior medial genicular nerve (right), and the nerve to the vastus medialis (right). b) Lateral view of the posterior electrode placements for the superior lateral genicular nerve, the superior medial genicular nerve, and the nerve to the vastus medialis. c) Lateral view of the anterior electrode placements for the superior lateral genicular nerve, the superior medial genicular nerve, and the nerve to the vastus medialis. d) Anterior-posterior view of the electrode placements for the nerve to the vastus lateralis (left) and the nerve to the vastus intermedius (right). e) Lateral view of the electrode placements for the nerve to the vastus lateralis (upper) and the nerve to the vastus intermedius (lower). f) Anterior-posterior view of the electrode placement for the inferior medial genicular nerve. g) Lateral view of the electrode placement for the inferior medial genicular nerve.

administered. The electrode is then inserted so the distal end of the active tip is located approximately 4 mm superficial to periosteum. This position targets the medial branches of the NVI. Not seen on the lateral view presented (Figure 2b) is the final electrode position to target the lateral branches of the NVI, like that of the nerve to the vastus lateralis, except that it is advanced to a greater depth (i.e., approximately 4 mm from the femoral periosteum) rather than superficially at the level of the quadriceps tendon. Appropriate AP and lateral positioning are again confirmed, and lesioning is done here (Figure 1d and e).

Nerve to the Vastus Lateralis

The cannula is advanced through the skin wheal placed approximately 5 cm superior to the upper patellar pole and 5 mm toward the midline from the lateral border of the femoral shaft in an AP fluoroscopic view in order to avoid trespass of the quadriceps tendon, and it is advanced until it contacts the bone. A lateral fluoroscopic view is then obtained (in which the femoral condyles are superimposed), and the needle is repositioned until the stylet tip is positioned approximately 1 cm superficial to the periosteum. The stylet is then removed, and 1–2 mL of local anesthetic is administered. The electrode is inserted such that the distal end of the active tip is located approximately 1 cm superficial to the periosteum at the level of the quadriceps tendon, and lesioning performed (Figure 1d and e). The lateral branches of the NVI lie deep to this location along periosteum and can be targeted with minimal repositioning, either before or after lesioning of the NVL.

Inferior Medial Genicular Nerve

The cannula is advanced through the skin wheal placed 2–3 cm medial and 3–4 cm inferior to the tibial shaft at the junction of the medial tibial shaft and the tibial flare in an AP fluoroscopic view. The needle is advanced until it contacts the bone. A lateral fluoroscopic view is then obtained (in which the femoral condyles are superimposed), and the cannula is repositioned until the stylet tip is positioned at a point approximately three-fourths the diameter of the tibial shaft. The stylet is then removed, and 1–2 mL of local anesthetic is administered. The electrode is then inserted such that the distal active tip is located at a point two-thirds the diameter of the tibial shaft

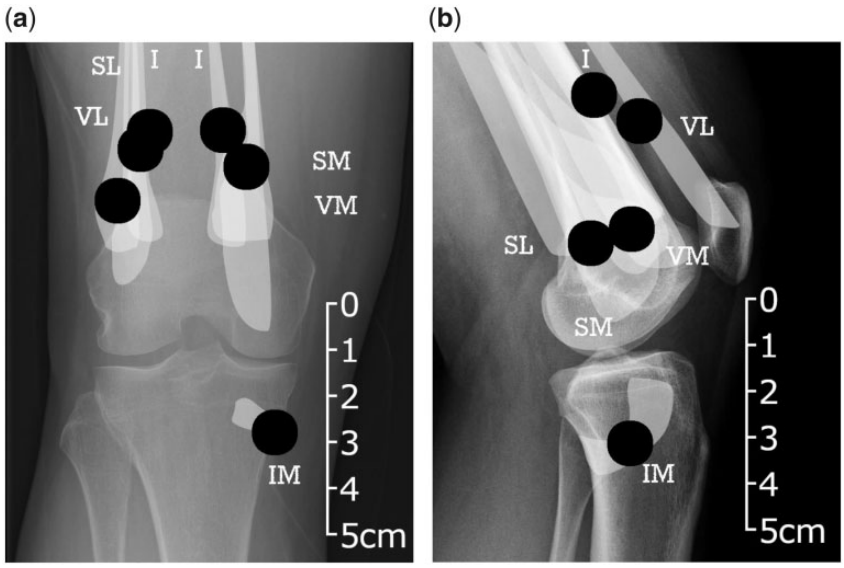

Figure 2. a) Anterior-posterior radiographic image of the knee with representations of the variable courses of the genicular nerves based on dissections by Tran et al. [8] (light gray clouds) for the superior lateral genicular nerve (SL), the superior medial genicular nerve (SM), the nerve to the vastus lateralis (VL), the nerve to the vastus intermedius (I), the nerve to the vastus medialis (VM), and the inferior medial genicular nerve. Radiofrequency lesion placements at the goal locations in order to appropriately target these nerves are also superimposed (black circles). b) Lateral radiographic image of the knee with representations of the variable courses of the genicular nerves based on dissections by Tran et al. [8] (light gray clouds) for the SL, the SM, the VL, the I, the VM, and the inferior medial genicular nerve. Radiofrequency lesion placements at the goal locations in order to appropriately target these nerves are also superimposed (black circles).

and approximately 4 mm superficial to the periosteum. After confirmation, lesioning is done (Figure 1f and g).

Radiofrequency Lesioning

Lesioning of each of the genicular nerves is performed using a CRFA electrode with a 4-mm active tip for 180 seconds each. Before lesioning of the genicular nerves, sensory stimulation at 50 Hz is utilized for supplementary confirmation of nerve location. The RFA generator is set to a temperature of 60°C, which produces an intralesional temperature of 77°C, as per an ex vivo study by Cosman et al. [7]. After RFA lesioning, the needles are withdrawn, and bandages are placed.

Discussion

Despite promising results, current protocols for CRFA for knee pain do not adequately capture all of the relevant and accessible sensory afferents of the anterior knee joint capsule [5]. By additionally targeting the NVM, NVI, and NVL sensory branches, we propose an enhanced protocol that may improve pain relief and nonresponder rates with CRFA. Furthermore, this protocol accounts for nerve depth, anatomic variability, and CRFA lesion size to accomplish more consistent ablation of all targeted nerves. CRFA has been shown to be effective for managing pain secondary to osteoarthritis; at six months after CRFA, 60% of patients experience >50% pain reduction and avoidance of TKA [1]. In a recent multicenter randomized controlled trial, CRFA was superior to intra-articular steroid injections for the treatment of pain from knee OA. In those who had CRFA, 74% experienced ≥50% reduction in numeric rating scale for pain (NRS) scores, as compared with only 16% of those who underwent intra-articular steroid injections at six months, showing the superiority of CRFA [3]. Our protocol may further improve these responder rates and the magnitude of pain relief in responders. Prospective study will be needed to test this hypothesis.

In addition to targeting the NVL and NVM, this new protocol describes additional CRFA electrode placements needed in order to capture both branches of the NVI. Although the NVI was found to be a solitary sensory branch located near the midfemoral position adjacent to periosteum in one anatomic study [4], a recent and more rigorous dissection demonstrated a lateral branch from the NVI that consistently crossed the femur obliquely before descending into the anterior joint capsule superolaterally. Along the distal femur, the medial and lateral branches of the NVI run opposite each other, flanking the quadriceps tendon at the level of the periosteum [5]. Our protocol targets the lateral branch of the NVI as well as this recently described sensory branch. Based upon frequency maps developed by Tran et al., the IMGN uniformly originated from the tibial nerve, coursing anteriorly and inferior to the medial epicondyle along the periosteum to reach the anterior knee joint. By ablating more posteriorly near the nerve's bifurcation point, this new protocol aims to more consistently and reliably

capture the IMGN. Because of the anatomic variability of the SMGN and SLGN, as noted by Tran et al., these nerves cannot be reliably captured in all patients using a single 4-mm monopolar CRFA lesion, and, as such, we recommend two separate CRFA lesion placements in order to increase the likelihood of complete disruption of each of these sensory nerves.

Although genicular CRFA is generally considered safe, the potential for complications was considered in this new lesioning protocol. The pes anserine tendons/tendon footprint may be at risk of injury when using traditionally described genicular nerve RFA protocols [1–3]. By taking a more inferior and posterior approach, the risk of pes anserine tendon injury is decreased [9]. To reduce the risk of skin burns in those with minimal subcutaneous fat, a 2-mm active tip electrode may be considered, particularly at the site of the inferior medial genicular nerve [10]. As with all procedures, a strict sterile technique should be observed. In addition to precise localization with multiplanar fluoroscopy, vigilance is necessary to prevent superficial electrode migration during ablation, both for reasons of safety and effectiveness.

Prospective study will determine the clinical effectiveness of this proposed protocol; case series will provide indirect outcome comparisons, but ultimately head-to-head trials will be needed to determine if this protocol truly improves upon its predecessor. As only one small sham-controlled trial of genicular nerve CRFA exists [2], investigators may consider the addition of a sham control arm to further establish efficacy. Prior prognostic block protocols targeting SMGN, SLGN, and IGMN have not been predicative of CRFA success [1]. Prior study of prognostic blocks likely demonstrated minimal value because of a mismatch between the territories anesthetized during the block procedure and the tissue eventually ablated. One mL of local anesthetic likely spreads to a much larger volume of tissue than what is captured by a single monopolar CRFA lesion [8]. Because of the variable locations of these nerves, use of a lower volume of injectate may improve their prognostic value. Prior studies of prognostic blocks have not intentionally targeted the NVI, NVL, or NVM; as such, future study will be needed in order to develop a more accurate prognostic block paradigm. This method, as with any new technique, may have unforeseen side effects, though the authors have made every attempt to minimize collateral injuries.

Conclusions

Genicular nerve CRFA is a promising treatment for knee pain from OA. Based on recent, rigorous anatomic dissections of the knee, the proposed genicular nerve CRFA protocol provides more complete denervation of sensory afferents and has the potential to improve clinical outcomes through additional targeting of the NVI, NVL, and NVM and more consistent lesioning of the SMGN, SLGN, and IMGN. Prospective trials are indicated to further establish the clinical efficacy, tolerability, and safety of this new protocol.

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