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Technical Note

Genicular Nerve Radiofrequency Ablation for Chronic Knee Pain Using a Three-Tined Electrode: A Technical Description and Case Series

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Abstract

Background. Genicular nerve radiofrequency ablation (RFA) for the treatment of chronic knee pain has traditionally targeted the superomedial, superolateral, and inferomedial genicular nerves. However, recent cadaveric studies of knee neuroanatomy demonstrate varied locations of these specific nerves as well as additional articular nerves. This work suggests that traditional genicular nerve RFA lesion locations may be inadequate. **Objective.** 1) To describe a novel protocol utilizing a three-tined RFA electrode to target the superomedial (SMGN), superolateral (SLGN), and inferomedial genicular nerves (IMGN), as well as the terminal articular branches of the nerves to the vastus medialis (NVM), intermedius (NVI), and lateralis (NVL). 2) To assess the ability of this technique to reduce chronic knee pain. **Methods.** Case series of consecutive patients with six or more months of refractory knee pain who underwent genicular nerve RFA according to the novel protocol described. Seven discrete RFA lesions were placed to target the SMGN, NVM, NVI, NVL, SLGN, and IGMN. **Results.** Eleven patients underwent RFA, nine with knee osteoarthritis and two postarthroplasty. At one month, 91% (95% CI = 59–100%), 82% (95% CI = 48–98%), and 9% (95% CI = 2–41%), of patients reported ≥50%, ≥80%, and 100% improvement in knee pain on the numeric rating scale, respectively. These results were sustained at six months. There were no complications. **Discussion/Conclusions.** These preliminary data suggest the feasibility and possible effectiveness of genicular nerve RFA using the described novel protocol including a three-tined electrode. Larger-scale studies with comparative groups are warranted.

Key Words: Genicular; Ablation; Radiofrequency Ablation; RFA; Knee Pain; Neuromodulation

Background

Chronic knee pain secondary to osteoarthritis is a pervasive clinical problem that affects millions worldwide [1]. Despite the prevalence of this condition, current treatments can often be unavailable or insufficient to address this issue. For example, total knee arthroplasty (TKA) is not an option for a subset of patients due to surgical mortality risk factors (obesity, cardiopulmonary conditions, etc.). Additionally, nearly one in five individuals experience ongoing pain and associated impairment despite TKA and report dissatisfaction with their outcomes [2, 3].

Radiofrequency ablation (RFA) of the genicular nerves is a targeted, nonsurgical procedure that has been shown to reduce knee pain secondary to osteoarthritis. Several studies of conventional [4] and cooled [5] RFA have demonstrated durable improvements in chronic knee pain by ablation of the superior medial (SMGN),

superior lateral (SLGN), and inferior medial (IMGN) genicular nerves [6]. However, a recent meticulously performed anatomical study described the presence of significant variation in the location of the SMGN, SLGN, and IMGN, as well as additional nerves, that likely contributes to the sensory innervation to the anterior knee joint, including the terminal branches of the nerve to vastus medialis (NVM), nerve to vastus intermedius (NVI), and nerve to vastest lateralis (NVL) [7]. Subsequently, we and other authors have designed updated genicular RFA protocols [8, 9] to account for nerve course variability and additional targets in order to provide more complete sensory denervation to the anterior knee joint capsule. Further, novel RFA technologies may confer an advantage through more accommodating lesion geometries that could translate to more consistent neural capture [10]. As such, the aim of the present study was to 1) describe a novel technique for genicular nerve RFA using a three-tined electrode to capture six genicular nerves and 2) report clinical outcomes in a cohort of patients who underwent genicular nerve RFA using this technique.

Methods

This case series of consecutive patients received approval from the Nova Scotia Health Authority. The patients treated met the following inclusion criteria: 1) >18 years of age; 2) Kellgren-Lawrence osteoarthritis score grade ≥2 or previous TKA; 3) knee pain score >3 on the numeric rating scale (NRS). Diagnostic genicular nerve blocks were not performed.

Procedure

Patient Positioning and Procedural Preparation

After informed consent, patients were positioned supine on the fluoroscopy table. Patients were provided moderate sedation with 100 mcg of intravenous fentanyl and 1 mg of sublingual Ativan. Two patients were provided an additional 50 mcg of intravenous fentanyl after complaining of pain during the procedure, described below. The knee was placed in ~30° of flexion using a cushion. We have suggested in a previous protocol description [8] that this position is optimal, as the suprapatellar joint space is flattened (minimizing likelihood of needle trespass), and this provides the ability to obtain an unobstructed lateral view of the knee (as the contralateral leg remains flat on the table). The knee was prepped and draped in the usual sterile fashion. A true anterior/posterior (AP) view was obtained. This alignment allowed the supracondylar nerves to be targeted first. Next, a true lateral view was confirmed by superimposing the femoral condyles. Targeting the IMGN (detailed below) required greater caudal tilt to square the tibial plateau in an AP view.

RFA Electrode Placement

Superior Medial Genicular Nerve

Starting from a lateral fluoroscopic view, local anesthetic was administered to the skin and subcutaneous tissues at the midpoint of the diameter of the femur at the junction of the femoral shaft and medial epicondyle based on a skin marking placed during an AP scout view. This skin entry location was used for targeting of the SMGN, NVM, and the first NVI lesion. Still in a lateral fluoroscopic view, the RFA introducer needle was advanced from the previously described site until it contacted the periosteum, ~10 mm anterior to the posterior aspect of the femur. The position was then confirmed in an AP view, with the needle located at the junction of the femoral shaft and medial epicondyle, and 1 mL of 1% lidocaine was administered through the introducer. Next, the introducer hub was rotated, deploying the three cannula tines. Then, the radiofrequency electrode was inserted through the introducer, with optimal tip positioning confirmed again in AP and lateral views (Figure 1.1A and 1.1B).

Nerve to Vastus Medialis

The above-mentioned skin entry location was utilized. On lateral view, the RFA introducer needle was advanced to the junction of the femoral shaft and the medial epicondyle at a cephalo-caudal level similar to targeting the SMGN, but at a point ~10 mm posterior to the anterior cortex of the femur. In AP view, the RFA introducer needle was positioned ~10 mm superficial to the periosteum. Pre-RFA nerve block and electrode deployment were performed as described above. Optimal electrode positioning was confirmed with AP and lateral views (Figure 1.2A and 1.2B).

Nerve to Vastus Intermedius (Medial Branch, First Lesion)

The above-mentioned skin entry was utilized. On a lateral view, the RFA introducer needle was advanced superiorly and anteriorly until contact with the periosteum at a point ~2 mm posterior to the anterior cortex of the femur, 5 cm superior to the superior patellar pole. In AP view, the RFA introducer needle position was confirmed to contact the periosteum. Pre-RFA nerve block and electrode deployment were performed as described above. Optimal electrode positioning was confirmed with AP and lateral views (Figure 1.3A and 1.3B).

Nerve to Vastus Intermedius (Medial Branch, Second Lesion)

Local anesthetic was administered to the skin and subcutaneous tissues at a skin entry point 5 cm cephalad to the superior patellar pole and at the midpoint of the femur seen on an AP view. This skin entry location was used for targeting of the second NVI lesion and the NVL. An RFA introducer needle was then advanced medially until

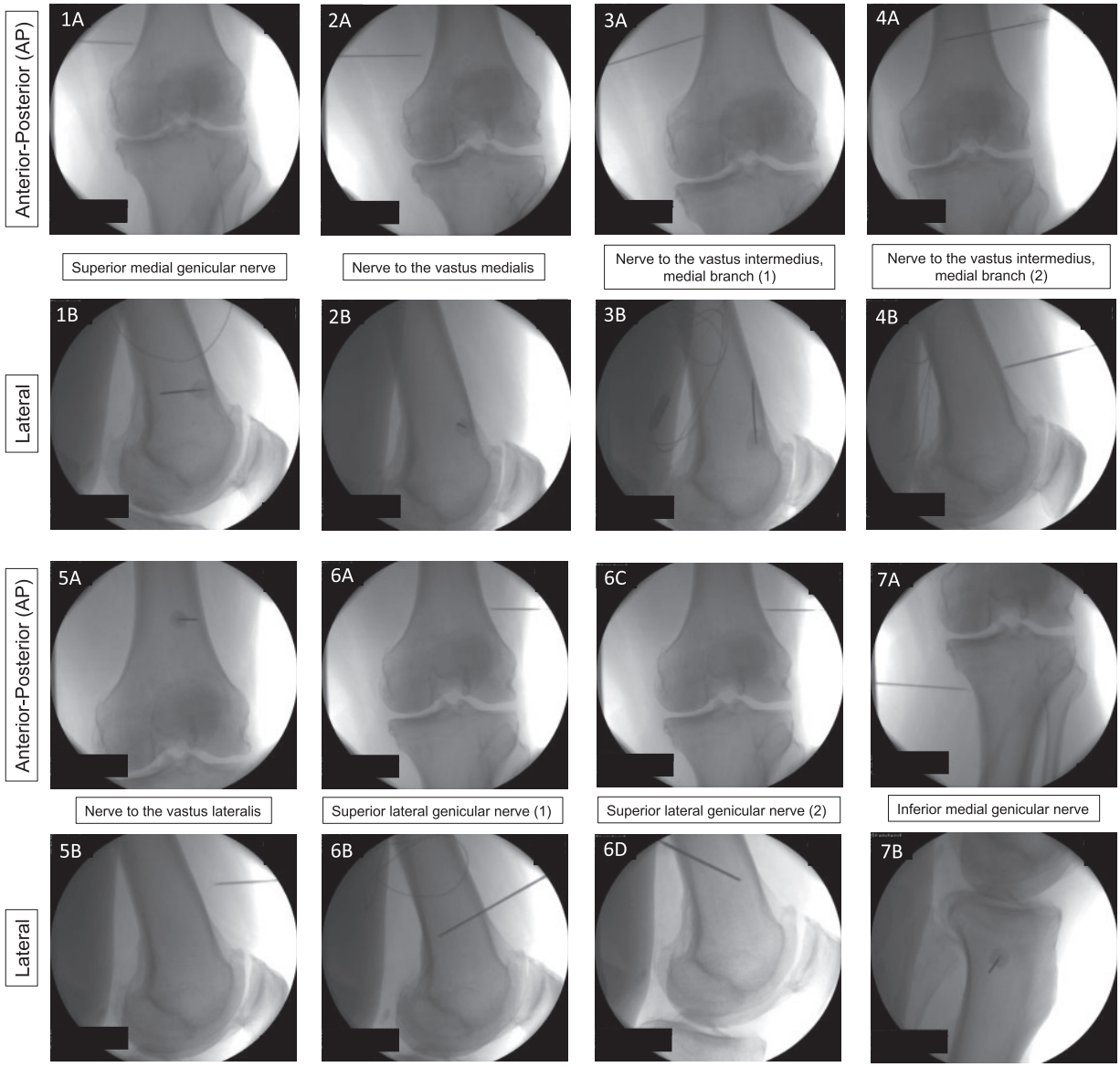

Figure 1. Anterior–posterior and lateral views, genicular radiofrequency ablation.

contacting the periosteum at a point ~10 mm toward the midline from the medial cortex of the femur. The RFA introducer needle was confirmed to touch the periosteum in the lateral view. Pre-RFA nerve block and electrode deployment were performed as described above. Optimal electrode positioning was confirmed with AP and lateral views (Figure 1.4A and 1.4B).

Nerve to Vastus Lateralis

The above-mentioned skin entry location was utilized. In an AP view, the RFA introducer needle was advanced laterally until ~5 mm toward midline from the lateral cortex of the femur, ~5 cm cephalad to the superior pole of the patella. In a lateral view, the RFA introducer needle was positioned at a depth of ~10 mm superficial to the anterior cortex of the femur. Pre-RFA nerve block and electrode deployment were performed as described above. Optimal electrode positioning was confirmed with AP and lateral views (Figure 1.5A and 1.5B).

Superior Lateral Genicular Nerve (Lesion 1)

Starting from a lateral fluoroscopic view, local anesthetic was administered to the skin and subcutaneous tissues at the midpoint of the diameter of femur at the junction of the femoral shaft and medial epicondyle based on a skin marking placed during an AP scout view. Still in a lateral fluoroscopic view, the RFA introducer needle was advanced from the previously described site until it contacted the periosteum, ~10 mm anterior to the posterior aspect of the femur. The position was then confirmed in an AP view, with the needle located at the junction of the femoral shaft and lateral epicondyle. Pre-RFA nerve block and electrode deployment were performed as

Table 1. Demographics

Demographics	
No.	11
Median patient age (IQR), y	55 (6)
Male, No.	10
Female, No.	1
Previous TKA	2
Duration of pain, median (IQR), y	18 (10)

IQR = interquartile range; TKA = total knee arthroplasty.

described above. Optimal electrode positioning was confirmed with AP and lateral views (Figure 1.6A and 1.6B).

Superior Lateral Genicular Nerve (Lesion 2)

A second lesion was placed by repositioning the RFA introducer needle ~10 mm posterior to the anterior cortex of the femur in a lateral fluoroscopic view at the same cephalon-caudal level as used during SLGN lesion 1. Pre-RFA nerve block and electrode deployment were performed as described above. Optimal electrode positioning was confirmed with AP and lateral views (Figure 1.6C and 1.6 D).

Inferior Medial Genicular Nerve

Starting from a lateral fluoroscopic view, local anesthetic was administered to the skin and subcutaneous tissues at a point approximately one-fourth the diameter from the posterior cortex to the anterior cortex of the tibia. This was performed at the level of the confluence of the tibial shaft and tibial flare based on a skin marking placed during an AP scout view. Still in a lateral view, the RFA introducer needle was advanced until it contacted the periosteum. Pre-RFA nerve block and electrode deployment were performed as described above. Optimal electrode positioning was confirmed with AP and lateral views (Figure 1.7A and 1.7B).

Procedure: Radiofrequency Lesioning

Each lesion was performed with a 100-mm-length 18-gauge three-tined RFA cannula with 5-mm active tips (Diros RF Trident, Markham, ON, Canada) for 120 seconds (including a 30-second ramp-up time) at a temperature of 80°C. After RFA lesioning, the needles were withdrawn and bandages were placed.

Data Collection

Patient medical records were reviewed in order to extract demographic and clinical data (age, sex, previous knee arthroplasty, duration of pain, and baseline pain NRS). On the day of the procedure, patients rated their best, worst, and average pain scores on a 10-point NRS scale over the previous four weeks. Patients were then contacted by telephone, and NRS pain scores were obtained at one and six months postprocedure. The primary outcome of interest was the proportion of patients reporting ≥50% knee pain reduction at six months postablation. Secondary outcomes included the proportion of patients reporting ≥80% and 100% knee pain reduction at six months. All data collection was performed by one investigator (EK). Procedural details and relevant follow-up data were entered into patient medical records.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel, version 16.33. Data were checked for distributional form and outliers using summary statistics. As data were not normally distributed, medians and 25–75% interquartile ranges (IQRs) were calculated. Proportions and 95% confidence intervals were calculated for categorical variables. The number of individuals reporting ≥50%, ≥80%, and 100% improvements in knee pain at one and six months were calculated. The level of significance was set at 0.05.

Results

Eleven consecutive individuals with a median age (IQR) of 55 (6) years underwent genicular nerve RFA using the described protocol between January and August of 2019. Demographic characteristics of the study population are shown in Table 1. The median duration of pain at the time of presentation was 18 years: Four patients (36%) experienced 10–15 years of symptoms, three patients (27%) experienced 15–20 years of symptoms, and four individuals (36%) complained of symptoms lasting 20 or more years. The median baseline NRS pain score for this cohort (IQR) was 7 (1.0).

Knee pain reduction was evaluated at one and six months after RFA (Table 2). At one month postprocedure, 91% (95% CI = 59–100%) of patients reported >50% knee pain relief and 91% (95% CI = 59–100%) reported ≥80% pain relief (Table 3). At six months postprocedure, 91% (95% CI = 59–100%) of patients continued to experience ≥50% knee pain reduction on the

Table 2. Pain relief outcomes, genicular RFA

		% Relief Reported (NRS)	
Subject	Baseline NRS	1 mo	6 mo
1	5	80	80
2	6	80	80
3*	8	95	80
4	8	95	90
5	7	90	90
6*	7	75	70
7	6	100	95
8	7	80	80
9	5	90	90
10	7	85	85
11	7	0	0

NRS = numeric rating scale; RFA, radiofrequency ablation; TKA = total knee arthroplasty.

*Patient had previous TKA on index knee.

Table 3. Effectiveness of novel genicular protocol using Trident Cannulae

Duration	Proportion of Patients Reporting ≥50% Relief, % (n/N)	95% CI, %	Proportion of Patients Reporting ≥80% Relief, % (n/N)	95% CI, %	Proportion of Patients Reporting 100% Relief, % (n/N)	95% CI, %
1 mo	91 (10/11)	59–100	82 (9/11)	48–98	9 (1/11)	2–41
6 mo	91 (10/11)	59–100	82 (9/11)	48–98	0 (0/11)	0–28

NRS, while 82% (95% CI = 48–98%) continued to report ≥80% reduction of pain symptoms in the index knee (Table 3). One patient (9%, 95% CI = 2–41%) reported 100% pain relief at four weeks; no patients reported 100% pain relief at six months. One patient (9%, 95% CI = 2–41%) reported no reduction in knee pain after undergoing RFA. No complications were observed during the procedures, and none were reported upon follow-up.

Discussion

Genicular nerve RFA techniques continue to evolve through expanded anatomic targeting protocols and innovative technology. The present study investigated the feasibility of a novel technique using a three-tined RFA cannula in patients with chronic knee pain. Clinically meaningful improvements in pain were observed up to six months in 10 of 11 patients. This technique may confer more substantial reductions in knee pain than previously described genicular nerve RFA protocols, though larger studies will be necessary to confirm this finding.

New protocols for ablation of the genicular nerves often seek increased pain reduction through improved capture of the known variability in location of various genicular nerves as well as targeting of additional sensory articular nerves to the knee. Original protocols for genicular nerve RFA attempt to target the SLGN, SMGN, and IMGN but do not completely account for the variable course of these nerves [4, 5]. Our recent description includes targeting of the terminal sensory articular branches from the NVM, NVI, and NVL and also accounts for the variable locations of the SMGN and SLGN [8]. The present study used a novel approach based on anatomical data from Tran et al. [7] and differs from our prior description by targeting the NVI and SLGN with two lesions each as opposed to a single lesion. The present protocol also utilizes a lateral skin entry approach for most nerves. Compared with classic protocols, these new lesion positions and increased quantity may confer additional therapeutic benefit relative to previous genicular nerve RFA protocols.

The three-tined cannula used in the present study creates pyramidal lesions with the largest lesion diameter closest to the cannula's tips [10]. The pyramidal design of the three-tined cannula allows for a perpendicular or otherwise nonparallel approach to target neural structurers that may result in more thorough capture independent of the angle of approach [10]. This was described by Finlayson et al. [10], who evaluated different multitined RFA cannulae and found that a three-tined cannula with a distal deployment mechanism (the same as that used in this study) provided stable lesion size at up to a 90° angle in relation to the periosteal surface. The known differences in lesion size created by various RFA technologies make comparisons across studies difficult to interpret. Conventional, cooled, and three-tined cannulae create differing lesion geometries that may impact neural capture and consequent clinical outcomes. Conventional RFA and cooled RFA probes differ in lesion size based on needle gauge, active tip length, and lesion temperature [11]. Similarly, the design of the three-tined cannula results in varying lesion sizes depending on these factors. The manufacturer estimates that an 18-gauge cannula with a 5.0 mm active tip (as used in this study) would produce a lesion with a volume of 525.6 mm (9.1 mm × 7.6 mm × 7.6 mm) [12]; however, no peer-reviewed study has been published to support this assertion. The three-tined cannula lesion geometry and size, in tandem with the implementation of additional lesions, may have contributed to the promising treatment response rate observed in this study. Larger comparative studies will be needed to confirm these observations.

The limitations of the present study must be acknowledged. As is true of any observational study, selection and information bias may have influenced the results; however, the inclusion of consecutive patients in this cohort partially mitigates these factors. Treatment cointerventions were not accounted for during chart review and thus cannot be fully controlled. Larger cohort studies and randomized controlled comparative trials will be necessary to confirm our observations from this feasibility study and to determine the relative effectiveness of various genicular RFA methods.

This study's patient selection protocol must also be acknowledged. Prognostic genicular nerve blocks were not used to select patients. This choice has precedent in the genicular literature: A prior study demonstrated that prognostic genicular blocks may not predict treatment success in cRFA [13]. However, this study did not target the NVI, NVM, and NVL, and it is also possible that an optimized prognostic block paradigm may improve treatment success rates [14]. Future study is needed to determine whether optimized prognostic genicular block protocols can both improve outcomes of RFA and reduce overall cost to the health care system.

Conclusions

Targeting six genicular nerves using a three-tined electrode resulted in clinically significant and durable reduction of knee pain in 10 of 11 consecutive patients. No complications occurred. Larger prospective studies are warranted to further investigate these observations.

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