Prospective Study

Fluoroscopic Confirmation of Needle Location in Ultrasound-guided Genicular Nerve Radiofrequency Thermocoagulation

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Background: Radiofrequency thermocoagulation of genicular nerves is an effective treatment for chronic pain due to knee osteoarthritis. The procedure can be performed under fluoroscopic or ultrasonographic guidance.

Objectives: The aim of this study was to fluoroscopically check the final location of the needle in ultrasound-guided genicular nerve radiofrequency thermocoagulation and evaluate the treatment's success in patients with knee pain.

Study Design: A 2-center, prospective study.

Setting: A private clinic and a tertiary care health center.

Methods: Thirty-two patients who had unilateral knee pain, and grade 3-4 knee osteoarthritis according to the Kellgren-Lawrence classification were included. Following diagnostic genicular nerve blocks in patients whose knee pain was relieved by ≥ 50%, radiofrequency thermocoagulation was applied to these nerves. The final position of the needle was checked via fluoroscopy in anteroposterior and lateral planes.

Results: The needle was located in the one-third anterior portion of the bone shaft in 69 of 96 patients (71.9%), between one-third and two-thirds in 21 (21.9%), and in the one-third posterior portion in 6 (6.3%). The mean Numeric Rating Scale score for pain was 7.69 ± 0.99 before treatment, 4.03 ± 1.26 at one week, 2.53 ± 1.24 at one month, and 2.19 ± 1.71 at 3 months, indicating a statistically significant decrease ($P < 0.001$).

Limitations: The lack of a study group in which genicular nerve radiofrequency thermocoagulation was performed under fluoroscopy guidance could be cited among the limitations of this clinical study.

Conclusions: The final position of the needle tip in radiofrequency thermocoagulation of genicular nerves can exist at the one-third anterior of the bone shaft, without a need for further advancing the needle to the posterior portion. Although performed more distally compared to fluoroscopy guidance, ultrasound-guided genicular nerve radiofrequency thermocoagulation still provides effective analgesia.

Key words: Genicular nerve, radiofrequency ablation, knee osteoarthritis, interventional ultrasonography, fluoroscopy, pain management

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Osteoarthritis (OA) is the most common musculoskeletal disease in the elderly (1). The incidence of knee OA has been increasing with the aging population and the increasing incidence of obesity (2). Treatment includes pharmacological (oral and topical analgesics), nonpharmacological methods (physical therapy and rehabilitation), nonsurgical interventional procedures (intrarticular steroid injections, hyaluronic acid, and platelet-rich plasma injections), and surgical modalities; however, all these methods may fail in some cases (3). In this context, genicular nerve blocks have been widely used recently in the treatment of chronic knee pain. Moreover, in a double-blind,

randomized-controlled study, Choi et al (3) reported that radiofrequency thermocoagulation (RFT) on genicular nerves was also a useful and effective treatment in this patient population. Subsequent studies confirm that this interventional treatment method is effective in chronic knee pain (4,5).

The knee joint is innervated by the articular branches of the femoral, obturator, saphenous, common peroneal, and tibial nerves (6,7). All these branches around the knee joint are known as genicular nerves (3). Genicular nerve blocks or RFT can be performed via fluoroscopy or ultrasound (ULSD) guidance (8,9). However, considering variations in the course of these nerves, RFT can be troublesome. The procedure can also be painful under fluoroscopic guidance due to the periosteum being touched. Furthermore, ULSD-guided genicular nerve block has been advocated over fluoroscopic guidance because of radiation exposure. In addition, there are some cases described in the literature regarding genicular vascular injury (10). This implies the possibility of the development of certain complications such as pseudoaneurysms, arteriovenous fistulas, hemarthrosis, and osteonecrosis. Therefore, ULSD guidance seems to be more advantageous to prevent vascular injuries in these patients.

There is no consensus in the literature regarding the anatomical course of genicular nerves that innervate the knee joint (11,12). It is also known that the nerves involved in knee innervation differ among individuals (13,14). Although RFT of the genicular nerve is usually performed under fluoroscopy, there are differing opinions about which part of the bone shaft the needle should be positioned on (3,15-17). These disagreements are due to anatomical variations as well as the lack of a clear consensus on which portion of the genicular nerves should be coagulated. Genicular arteries can be visualized sonographically and adjacent genicular nerves can be localized by sensory stimulation (18,19). By this method, RFT is not performed just on the basis of landmarks.

In our study, we aimed to fluoroscopically check the final needle location to determine whether sonographic guidance in genicular nerve ablation is compatible with the C-arm-guided technique. Thus, by using ULSD guidance for RFT, we aimed to test the validity and necessity of the conventional fluoroscopic method. We also aimed to determine whether these imaging techniques and possible differences in final needle locations affect treatment success.

Methods

Study Design and Population

This multicenter, prospective study was conducted at the Department of Pain Management outpatient clinics of 2 hospitals, from June 2021 through April 2023. The institutional ethics committee approved the study protocol (No: 21.11.01). All patients were informed about the nature of the study and written informed consent was obtained. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The data of consecutive patients referred to our center's pain management outpatient clinics were reviewed. Patients who had unilateral knee pain with grade 3-4 knee osteoarthritis, according to Kellgren-Lawrence classification and older than 50-years-old were included in the study. All patients had knee pain for at least 3 months and were refractory to conservative treatment (nonsteroidal anti-inflammatory drugs, physical therapy). RFT was scheduled for patients whose knee pain was decreased by ≥ 50% according to the Numeric Rating Scale (NRS-11) following a diagnostic block. Finally, RFT was performed on a total of 32 patients and 96 genicular nerves.

Exclusion criteria were as follows: having an intraarticular steroid injection within the past 3 months, having a history of acute/subacute trauma, having a considerable amount of intraarticular effusion, and having previous knee surgery. Those with inflammatory rheumatic disease, uncontrolled diabetes mellitus and polyneuropathy, severe cardiac failure, pregnancy, known allergy to local anesthetics, and those receiving anticoagulant treatment were also excluded from the study.

Treatment Protocol

The superomedial genicular nerve (SMGN), inferomedial genicular nerve (IMGN), and superolateral genicular nerve (SLGN) were identified under ULSD guidance. Each nerve was blocked using one mL of 2% lidocaine. In patients whose knee pain was decreased by ≥ 50% according to their NRS-11 score, RFT was performed (20).

The patient was placed supine on the table. The skin was cleaned with polyvinylpyrrolidone-iodine and covered with a sterile drape. Using an ultrasound probe at 12 MHz (SonoSite M-Turbo®, SonoSite Inc.), the SMGN, IMGN, and SLGN were examined, respectively. The SMGN was located beneath the adductor magnus tendon and adjacent to the superomedial artery (Fig. 1a), the IMGN was located beneath the medial

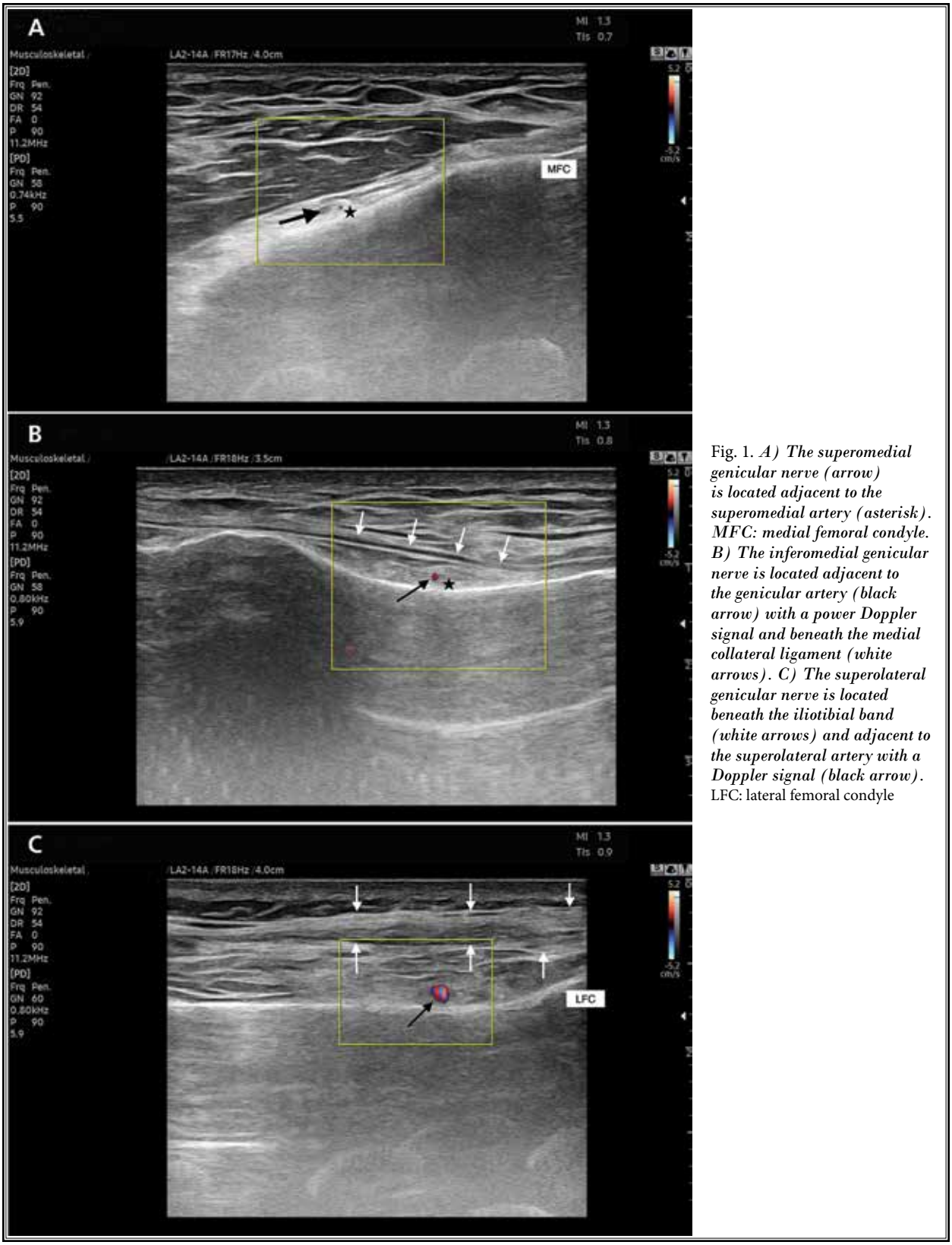

Fig. 1. *A) The superomedial genicular nerve (arrow) is located adjacent to the superomedial artery (asterisk). MFC: medial femoral condyle. B) The inferomedial genicular nerve is located adjacent to the genicular artery (black arrow) with a power Doppler signal and beneath the medial collateral ligament (white arrows). C) The superolateral genicular nerve is located beneath the iliotibial band (white arrows) and adjacent to the superolateral artery with a Doppler signal (black arrow).* LFC: lateral femoral condyle

collateral ligament and adjacent to the inferomedial artery (Fig. 1b), and the SLGN was located beneath the iliotibial band and adjacent to the superolateral artery (Fig. 1c).

The skin and subcutaneous tissue were then anesthetized with 2 mL of 2% lidocaine. A 21G, 10 cm radiofrequency needle with a 10 mm active tip was inserted into the SMGN, IMGN, and SLGN using in-plane or out-of-plane approaches. Paresthesia/dysesthesia was attempted with 50 Hz sensory stimulation at ≤ 0.5 V; if it was felt by the patient, then confirmed the needle's position. The lack of motor contraction at 2 V was also observed. Afterward, under fluoroscopic guidance, images were obtained in the anteroposterior and lateral planes. Following local anesthetic infiltration (one mL of 2% lidocaine to each nerve), conventional RFT (80°C, 90 seconds) was performed.

The final position of the needle in the lateral plane was evaluated by dividing the femoral and tibial shaft into 3 categories: one-third anterior, one-third posterior, and the mid portion of the bone shaft (Fig. 2). The NRS-11 was used to measure the pain at preprocedure, one week, one month, and 3 months. Patient satisfaction was evaluated using a 4-point scale at one and 3 months posttreatment (0 = very dissatisfied; 1 = dissatisfied; 2 = satisfied; 3 = very satisfied).

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics 24.0 software (IBM Corporation). Continuous data were expressed in mean ± SD, while categorical data were expressed in number and frequency. The Kolmogorov-Smirnov goodness-of-fit test was used to check the normality of the continuous variables. The repeated measures analysis of variance (ANOVA) was performed to examine the NRS-11 changes over time, if normal distribution assumption was met. A P value of < 0.05 was considered statistically significant.

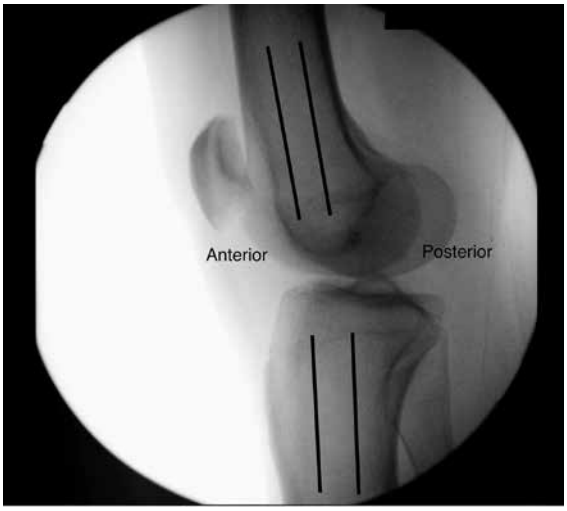

Fig. 2. *Division of femoral and tibial shafts into 3 categories in the longitudinal plane.*

Results

A total of 32 patients with Grade 3-4 knee osteoarthritis according to the Kellgren-Lawrence classification were included in the study. Of the patients, 10 were men and 22 were women, with a mean age of 69.03 ± 8.43 (range, 54 to 85) years (Table 1). The mean body mass index was 29.98 ± 3.21 (range, 24.8 to 34.2) kg/m^2.

Pain was localized in the left knee in 53.1% and in the right knee in 46.9%. At the end of the ULSD-guided procedures, anteroposterior and lateral fluoroscopic views were taken. On the anteroposterior view, the needle tips were at the junction of the femoral shaft and epicondyles and at the junction of the tibial shaft and medial condyle, compatible with the generally accepted landmarks (Fig. 3). On lateral imaging, the needle was mostly located in the one-third anterior of the bone shaft under ULSD-guided RFT (Fig. 4). The needle was located in the one-third anterior portion of the bone shaft in 69 of 96 patients (71.9%), between one-third and two-thirds in 21 (21.9%), and in the one-third posterior portion in 6 (6.3%) (Table 1). No procedure-related complications were observed.

All patients were discharged on the same day of the procedure and scheduled for follow-up in the outpatient setting at one week, one month, and 3 months. The mean NRS-11 was 7.69 ± 0.99 pretreatment, and 4.03 ± 1.26 at one week, 2.53 ± 1.24 at one month, and 2.19 ± 1.71 at 3 months posttreatment, indicating a statistically significant decrease ($P < 0.001$). The mean pain reduction according to the NRS-11 compared to the baseline was 47.6%, 67.1%, and 71.5% at the end of one week, one month, and 3 months, respectively. The percentage of patients who achieved at least 50% relief in knee pain compared to baseline was 40.6% (n = 13) at one week, 87.5% (n = 28) at one month, and 84.4% (n = 27) at 3 months, posttreatment.

Regarding posttreatment patient satisfaction, at one month 17 patients (53.1%) were very satisfied, 9 patients (28.1%) were satisfied, and 6 patients (18.8%) were dissatisfied with the treatment. At 3 months

follow-up, 14 patients (43.8%) were very satisfied, 11 patients (34.4%) were satisfied, and seven patients (21.8%) were dissatisfied with the treatment.

Discussion

In daily practice, RFT on genicular nerves can be applied under fluoroscopy or ULSD guidance. However, there is no consensus on a precise and single definition of the target point in fluoroscopy-guided RFT. In their study, Choi et al (3) used fluoroscopy-guided RFT on genicular nerves. They used the SMGN, IMGN, and SLGN targets that are supposed to pass periosteal areas connecting the femoral shaft to bilateral epicondyles and the tibial shaft to the medial epicondyle; however, it remains unclear how far the needle should be advanced posteriorly. In addition, Reddy et al (17) and Davis et

Table 1. *Demographic characteristics, treatment outcomes, and follow-up data of patients.*

Age	Gender	BMI (kg/m^2)	Side	NRS-11 (Pre-treatment)	NRS-11 (Week 1)	NRS-11 (Month 1)	NRS-11 (Month 3)	SMGN	IMGN	SLGN
54	W	33.7	left	7	3	1	0	1/3 ant	1/3 ant	1/3 ant
64	W	31.6	left	8	5	3	2	1/3 ant	middle	1/3 ant
85	W	26.4	left	8	5	3	3	middle	1/3 ant	middle
57	W	34.2	left	8	3	2	0	1/3 ant	1/3 ant	1/3 ant
64	W	33.5	left	9	5	4	3	1/3 ant	1/3 ant	1/3 ant
74	M	31.6	left	8	4	1	1	1/3 ant	1/3 ant	1/3 ant
63	W	32.9	left	7	3	2	0	1/3 ant	1/3 ant	1/3 ant
71	M	28.3	left	8	6	3	3	middle	1/3 ant	1/3 ant
67	W	30.1	left	7	4	1	4	1/3post	1/3 ant	1/3 ant
66	W	28.9	left	9	5	4	3	middle	middle	1/3 ant
76	M	26.5	left	8	5	4	3	1/3 ant	1/3 ant	1/3 ant
71	W	26.1	left	9	5	2	1	1/3 ant	1/3 ant	middle
63	W	25.8	left	8	5	4	4	1/3 ant	middle	1/3 ant
59	W	25.7	left	6	4	2	3	1/3post	1/3 ant	1/3post
74	M	27.1	left	7	3	3	3	1/3 ant	1/3 ant	1/3 ant
68	W	31.1	left	9	5	4	5	1/3 ant	middle	1/3 ant
77	W	32.3	left	6	3	3	3	1/3post	middle	middle
72	W	30.9	right	8	2	1	1	1/3 ant	1/3 ant	1/3 ant
71	M	30.5	right	6	4	4	6	1/3 ant	1/3 ant	1/3post
79	M	28.9	right	7	2	2	1	middle	middle	middle
65	W	32.6	right	8	1	1	1	1/3 ant	1/3 ant	1/3 ant
76	M	25.1	right	7	4	4	5	1/3 ant	middle	middle
54	W	33.7	right	7	5	4	4	1/3 ant	middle	1/3post
84	M	24.8	right	9	5	2	1	1/3 ant	1/3 ant	1/3 ant
67	W	32.7	right	8	6	4	3	1/3 ant	1/3 ant	middle
81	M	32.8	right	8	3	1	0	1/3 ant	1/3 ant	middle
73	W	31.6	right	7	4	2	0	1/3 ant	1/3 ant	1/3 ant
69	W	25.8	right	10	5	2	0	1/3 ant	1/3 ant	1/3 ant
58	W	33.8	right	8	5	3	3	middle	1/3 ant	1/3 ant
64	W	32.2	right	6	2	0	0	1/3 ant	1/3 ant	1/3 ant
82	M	24.9	right	8	3	1	1	1/3 ant	1/3 ant	1/3 ant
61	W	33.4	right	7	5	4	3	middle	1/3 ant	1/3 ant

*BMI: body mass index; NRS-11: Numeric Rating Scale; SMGN: superomedial genicular nerve; IMGN: inferomedial genicular nerve; SLGN: superolateral genicular nerve; W: woman; M: man; ant: anterior; post: posterior.

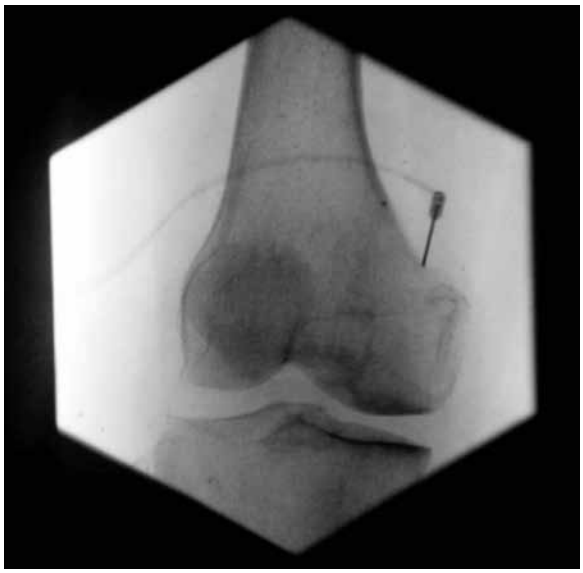

Fig. 3. *Final position of the radiofrequency electrode under anteroposterior fluoroscopic guidance.*

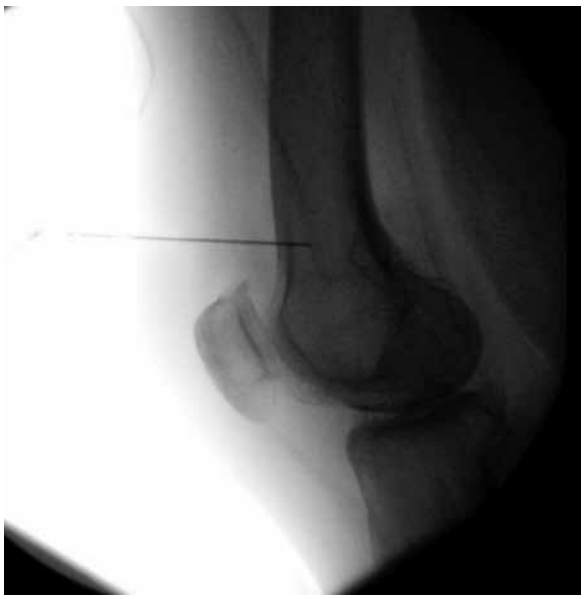

Fig. 4. *Final position of the radiofrequency electrode under lateral fluoroscopic guidance. It is seen that the genicular nerve is coagulated more distally at the anterior portion unlike the usual position.*

al (15) suggested using the mid portion of the femoral and tibial shafts as the targets. In another single-blind, randomized-controlled study, El-Hakeim et al (16) investigated the efficacy of fluoroscopy-guided radiofrequency neurotomy on genicular nerves in patients with chronic knee OA and advanced the cannula to the junction of the two-thirds anterior and one-third posterior of the bone. Similarly, Gönüllü and Tekin (8) evaluated the effects of fluoroscopy-guided conventional RFT on genicular nerves in 28 patients who were dissatisfied with total knee arthroplasty. The insertion sites of the needle were the junctions of bilateral epicondyles of the femoral bone and the femoral shaft, and the junction of the medial condyle of the tibial bone and the tibial shaft. To place the needle posteriorly, they advanced the needle to the mid portion of the bone shaft in the lateral view. Furthermore, Sarı et al (21) compared the efficacy of intraarticular injection and radiofrequency neurotomy on genicular nerves in patients with knee OA but no specific target was defined.

In our present study, we performed RFT on genicular nerves under ULSD guidance. On the fluoroscopic final anteroposterior view, the needle tips were at the junction of the femoral shaft and epicondyles and at the junction of the tibial shaft and medial condyle, compatible with the generally accepted landmarks (Fig. 3). However, our study results show that the needle tip location for coagulating genicular nerves is not compatible with the landmarks defined for lateral imaging by fluoroscopy. In fluoroscopy-guided RFT, the needle is recommended to be inserted into the mid portion of the femoral and tibial shaft or one-third posterior of the bone shaft (8,15-17). However, in our study, it was reasonable to place the needle in the one-third anterior of the bone shaft, without a need for further advancing to the posterior portion. In this context, imaging the genicular arteries next to the nerves and confirming the needle position by acquiring paresthesia with 50 Hz sensory stimulation at ≤ 0.5 V increases the reliability of our study.

In our study, the rate of patients who achieved at least a 50% reduction in knee pain compared to baseline after RFT was 40.6% (13 patients) at one week, 87.5% (28 patients) at one month, and 84.4% (27 patients) at 3 months posttreatment. These rates were also reported by Choi et al's study (3), in which they used fluoroscopic guidance, as 59%, 65%, and 59% at one week, one month, and 3 months posttreatment, respectively (3). In the present study, the average pain relief according to the NRS-11 compared to the baseline was 47.6%, 67.1%, and 71.5% at the end of one week, one month, and three months posttreatment, respectively. Iannacone et al (4), in their article examin-

ing the results of genicular nerve thermocoagulation under the guidance of fluoroscopy, found the mean pain reduction at 3 months postprocedure was 67%, and 64% at the end of 6 months (4). Remarkable pain relief and high patient satisfaction during follow-up indicate treatment success in our present study. As expected, there was a greater level of pain relief at one and 3 months, since RFT-induced acute injury and muscle spasm may increase pain severity in the first postprocedure week.

Since 3 genicular branches were coagulated in each patient, the number of coagulated nerves in those patients who achieved at least 50% reduction in knee pain was 42 at one week, 84 at one month, and 81 at 3 months. In addition, of those nerves, the number coagulated in the one-third anterior of the bone shaft was 32 (82.1%), 63 (75%), and 61 (75.3%), respectively (Table 1). In our study, as assessed by lateral imaging, 69 (71.9%) of the 96 nerves coagulated in total were located in the anterior one-third of the bone shaft. Considering these findings, among the patients with ≥ 50% pain relief, the rate of nerves coagulated in the one-third anterior of the bone shaft was similar to the overall study cohort, or even slightly higher. Taken together, these findings suggest that, despite ablation of the genicular nerve is produced more distally contrary to fluoroscopic guidance, ULSD-guided RFT also provides effective analgesia.

Nonetheless, there are some limitations to our study. Variations in treatment success may have resulted from variations in the genicular nerves. To illustrate, when RFT is applied more distally, the nerve can be already divided into terminal branches, although appropriate responses to the sensory stimulation are achieved (12). This may lead to partial coagulation of the end branches of the genicular nerve, but not complete coagulation of the nerve itself. Since our study is not a cadaveric study, it is unlikely to ensure whether the nerve is terminally branched at the point where it is coagulated distally. It is also unlikely to speculate that it is possible to obtain a higher analgesic effect by performing genicular nerve RFT more proximally. Considering the one- and 3-month follow-up outcomes of our patients, however, this risk did not have much of an effect on outcomes and remained clinically insignificant.

Compared to previous studies using fluoroscopy-guided genicular nerve ablation (3,4), their treatment success is comparable to our study. How the anterior needle placement was as effective as the posterior placement can be explained as follows: the medial compartment and its anterior part are the most affected parts in knee osteoarthritis (22,23). It is reasonable that earlier involvement of this knee portion may be more responsible for the chronicity and persistent pain. Therefore, the fact that the genicular nerve is coagulated more distally (i.e., anteriorly), in knee OA may be sufficient to suppress the nociceptive input to a large extent. Nevertheless, the lack of a study group in which genicular nerve RFT was performed under fluoroscopic guidance could be cited among the limitations of our clinical study.

Ultrasound is a portable and inexpensive tool that is available in almost every center. It provides real-time visualization of the adjacent vascular structures in a noninvasive way without any radiation exposure. Owing to its merits, it has been increasingly used for genicular nerve block worldwide (9,24,25). Genicular nerves are accompanied by genicular arteries. With the help of ULSD guidance, genicular arteries, and genicular nerves, can be visualized and genicular nerve block can be effectively maintained at the junctions of the epiphysis with the femoral and tibial shafts (25-27). It allows positioning the needle precisely above the nerve without touching the periosteum, reduces procedural time, and minimizes postprocedure pain. Because the genicular artery may have variations, the needle position may differ if the needle is inserted under ULSD imaging based on the genicular artery. In this case, the posttreatment results may be different. However, we aimed not only to consider the location of the artery, but also to view the nerve. We confirmed the location by sensory and motor stimuli when the nerve could not be visualized. Nevertheless, since a paresthesia response can be considered partially subjective, it cannot be claimed that this limitation can be completely overcome.

Conclusion

In conclusion, ULSD-guided RFT provides effective analgesia, even if the needle is not advanced to the posterior portions of bone shafts. Nonetheless, although RFT of genicular nerves under ULSD guidance offers a practical and cost-effective treatment modality with a low rate of arterial injuries and no radiation exposure, these procedures are currently mostly performed under fluoroscopic guidance, probably due to practitioner habits. Further large-scale, prospective, randomized clinical studies are warranted to define landmarks and draw a firm conclusion regarding treatment success.

Author Contribution

All authors contributed to the conception and design of this study. Data collection and analysis were performed by Özgür Emre Polat and Serdar Kokar. The first draft of the manuscript was written by Özgür Emre Polat. Review and editing were made by both authors. All authors read and approved the final manuscript.

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