Technical Note

Pulsed Radiofrequency Rhizotomy of the Genicular Nerves of the Knee Guided by Radioscopy and Ultrasonography: Step-By-Step Technique

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Abstract: Osteoarthritis (OA) of the knee is highly prevalent and causes pain, stiffness, and harms the quality of life of millions of patients. Scientific evidence about radiofrequency ablation or rhizotomy of genicular nerves has been presented with increasing frequency in the literature for the treatment of chronic pain related to knee OA as an alternative to total knee arthroplasty. The main indication for this procedure is symptomatic OA unresponsive to conservative treatment, regardless of the disease evolution, although more common indications are in Kellgren—Lawrence grade III or IV, in post-total knee arthroplasty residual pain without an identified cause, in patients with comorbidities and high surgical risk, and those who do not want to undergo surgery. The aim of this study is to describe the step-by-step rhizotomy technique with pulsed radiofrequency of the 3 genicular nerves, guided by radioscopy and ultrasonography.

Knee osteoarthritis (OA) is highly prevalent, causes pain and stiffness, and harms the quality of life of millions of patients. Total knee arthroplasty (TKA) is one of the treatment options for advanced stages of the disease. Although it shows good results in the short and long term, TKA can evolve with serious complications.[1]

Scientific evidence about radiofrequency (RF) ablation or rhizotomy of genicular nerves has been presented with increasing frequency in the literature for the treatment of chronic pain related to OA of the knee as an alternative to TKA.[2] RF ablation of genicular nerves can be performed by 3 techniques (conventional, cooled, or pulsed), promoting improved function and quality of life, with pain relief lasting between 3 and 6 months and occasionally even longer.[3]

The main indication for this procedure is symptomatic OA unresponsive to conservative treatment, regardless of the disease evolution, although more common indications are in Kellgren—Lawrence grade III or IV, in post-TKA residual pain without an identified cause, in patients with comorbidities and high surgical risk, and those who do not want to undergo surgery.[3] As for contraindications to the procedure, we can highlight pregnancy, chronic pain syndrome, psychiatric disorders, coagulation disorders, patients with a pacemaker or nerve stimulator, and acute or chronic infection.[3] The aim of this study is to describe the step-by-step rhizotomy technique

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with pulsed RF of the 3 genicular nerves, guided by fluoroscopy and ultrasonography (USG).

Technical Note (With Video Illustration)

The patient is placed in the supine position. Superficial sedation is performed so that the patient remains responsive to painful stimuli and can report pain to the sensory stimulation and present muscle contraction if the needle is close to a motor nerve.

Sterile surgical drapes are placed. The image intensifier is positioned aligned with the vertical axis and the limb positioned in slight internal rotation, ensuring an accurate anteroposterior radiographic view.

Echogenic and radiopaque RF cannulas (needles) are used and coupled to a drug injector tube with a 10-mm active tip. An electrosurgical plate is placed on the patient's back.

For rhizotomy of the superolateral genicular nerve, the cannula is placed over the skin in line with the lateral cortex, at the transition from the diaphysis to the metaphysis of the distal femur, under fluoroscopic control. It is then introduced close to the periosteum, in a posterior direction for 2 to 3 cm. An anesthetic button with 0.5 mL of 2% lidocaine with a 13- × 0.45-mm needle can be performed before penetrating the skin with the RF cannula.

The fluoroscopy apparatus is then rotated 90°, perpendicular to the long axis of the limb, and this is positioned so that we have an image in absolute lateral view with overlapping of the femoral condyles. We insert the needle until it reaches the middle-posterior third of the diaphysis.

At this time, we use USG positioning control. We use a linear transducer with Doppler function 7.5 to 10 MHz with the transducer index pointing proximally, on the lateral aspect of the thigh, touching the skin at the point where the needle is positioned. We gently move the transducer until the needle is visualized.

We then rotate the transducer 90° so that the index points up and follows the needle in its anteroposterior path. With the Doppler function, we locate the superolateral genicular artery that indicate the location of the nerve nearby. We advance or back the needle so that the active tip is as close as possible to the most posterior part of the nerve.

Nerve visualization is not always possible and so the fine adjustment of proximity to the nerve is obtained by analyzing the local tissue bioimpedance, which must be between 300 and 600 ohms.

A sensitive stimulus at a frequency of 50 Hz and a voltage of up to 0.5 V is applied, and once it is correctly positioned, the patient will report pain consistent with their complaints. Then, we perform a motor stimulus using the parameters 2 Hz and 2 V, ensuring that the procedure is not reaching any motor branch. Thus, there should be no movement, not even muscle fasciculation.

The rhizotomy is started fluoroscopy with pulsed RF with the following parameters: wavelength of 5 to 20 m can be used, frequency of 2 Hz, and voltage of 45V, with a maximum temperature of 42°C for 4 minutes. Then, a solution of 1 mL of 0.5% bupivacaine plus 1 mL of dexamethasone is infiltrated (Table 1).

Rhizotomy of the superomedial genicular nerve follows the same parameters as the lateral, except that now the needle enters close to the periosteum of the medial femoral aspect. To locate the inferomedial genicular nerve, we use the fluoroscopy apparatus in the anteroposterior view to penetrate with the needle at the transition from the diaphysis to the metaphysis of the proximal tibia close to the periosteum. In lateral view, we deepen its entry until reaching the middle-posterior third of the tibia. At this moment, we use the USG in the same way as reported about the superior genicular nerves and the control by bioimpedance, sensory and motor stimuli.

Rhizotomy of this nerve also follows the same recommendations as the previous ones. If the surgeon has 3 cannulas, he or she can position each one of them and perform the rhizotomy of the 3 genicular branches simultaneously.

The radioscopy and USG image control of needle placement are presented in Figs 1, 2, 3, and 4, and the complete procedure can be seen in Video 1.

Rehabilitation

The patient can be discharged from the hospital soon after the procedure with a prescription for a simple analgesic in case of pain. Walking is allowed and encouraged, as well as physical therapy to gain mobility and muscle strengthening as usually performed in the rehabilitation of knee OA.

Discussion

Genicular and intra-articular rhizotomy has been increasingly studied as an alternative to knee joint replacement surgery, particularly in high-risk patients due to comorbidities or when patients or attending doctors intend to postpone arthroplasty surgery. However, the correct location of these nerves is not always easy due to the wide anatomical variability of these nerves.[4] Thus we believe that combining the maximum available resources of imaging techniques to find them is of utmost importance, so that the method efficacy and reproducibility might be improved. The advantages, disadvantages, and risks of the genicular and intra-articular rhizotomy are described on Table 2.

Pineda et al.[5] evaluated the RF of genicular nerves in knee OA in a prospective, observational, uncontrolled study in patients with grade 3 or 4 OA and visual analog scale (VAS) > 6 during a 1-year follow-up (FU). They

Table 1. Checklist to Perform Pulsed Radiofrequency Rhizotomy of the Genicular Nerves of the Knee

Knee Rhizotomy Steps	Numerical Parameters	Patient Reaction
Bioimpedance	300 to 600 ohms	
Sensitive stimulus	Frequency 50 Hz voltage to up to 0.5 V	Patient must report pain
Motor stimulus	Frequency 2 Hz and voltage to up to 2 V	Should be no movement of the patient, not even muscle fasciculation
Start pulsed radiofrequency	Wavelength 5 to 20 m Frequency of 2 Hz Voltage of 45 V Maximum temperature 42°C for 4 min	
Final solution to be infiltrated	1 mL of 0.5% bupivacaine plus 1 mL of dexamethasone is infiltrated.	

performed RF of the 3 genicular nerves and reported more than 50% improvement in the level of pain by the VAS: 1st month (22/25, 88%), 6th month (16/25, 64%), and 12th month (8/25, 32%). They also observed an improvement in the Western Ontario and McMasters Universities Osteoarthritis Index (WOMAC) functional score throughout the FU.[5]

Davis et al.[6] evaluated the efficacy and safety of cooled RF compared with the use of joint corticosteroids in chronic knee pain in patients with OA in a prospective, multicenter, randomized study with 151 patients. They reported superior RF results in relation to articular corticoids regarding providing pain reduction greater than 50% (74.1% vs 16.2%), pain reduction by visual analog scale score (4.9 vs. 1.3), functional score by Oxford Score (35.7 vs 22.4), and the patient's perception of global improvement (91.4 vs 23.9). In addition, there were no adverse events in either group.[6]

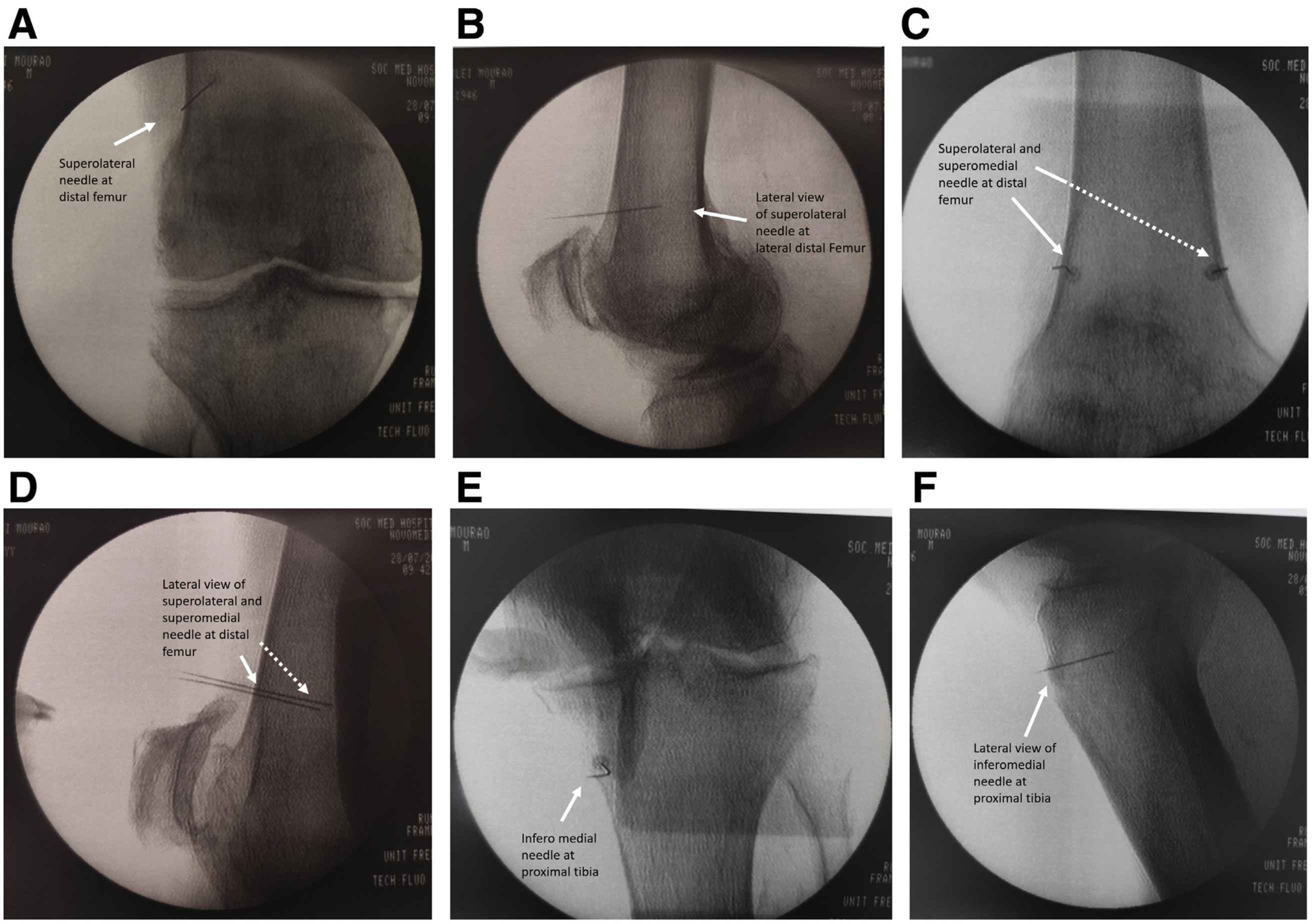

Fig 1. Radioscopy images. (A) anteroposterior (AP) view of superolateral needle placement at distal femur; (B) lateral view of superolateral needle placement at distal femur; (C) AP view of superomedial needle placement at distal femur; (D) lateral view of superomedial needle placement at distal femur; (E) AP view of inferomedial needle placement at proximal tibia; and (F) lateral view of inferomedial needle placement at proximal tibia.

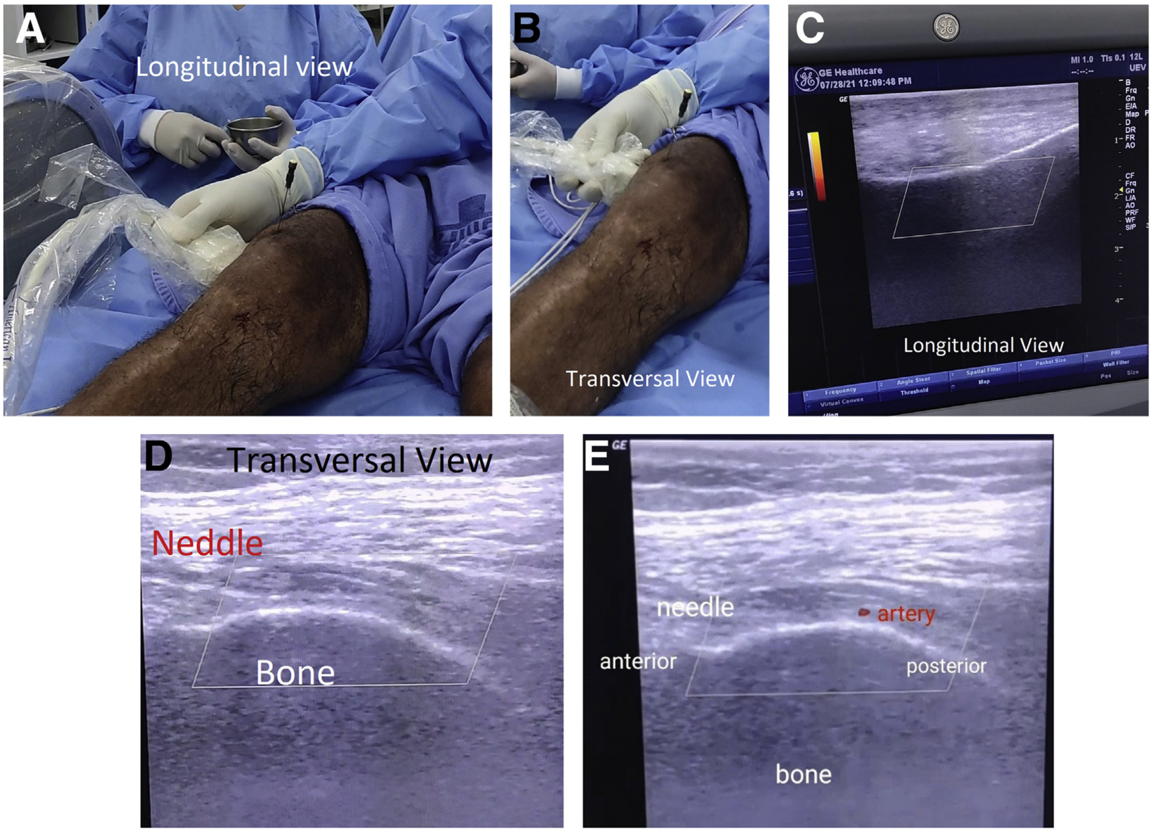

Fig 2. Ultrasonographic images of needle placement, of superolateral genicular nerve: ultrasonographic image control. (A) Ultrasound transducer aligned parallel to the femoral long axis; (B) ultrasound transducer aligned perpendicular to the femoral long axis; (C) ultrasound image corresponding to (A); (D) ultrasound image corresponding to (B); and (E) Doppler view of the genicular artery near the needle tip.

Leoni et al.[7] evaluated the extra-articular pulsed RF of the genicular nerves plus intra-articular (RFP EA + IA) in relation to the isolated extra-articular RF (RFP EAI), retrospectively, in 78 patients with moderate-to-severe OA. They reported pain reduction in both groups and longer pain relief in RFP EA+ IA.[7]

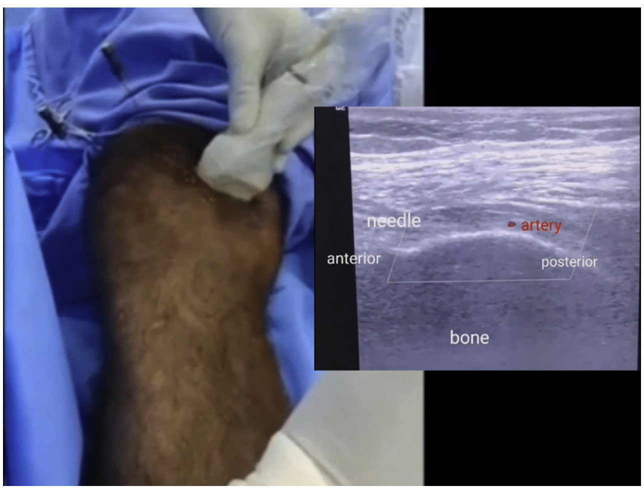

Fig 3. Ultrasonographic images of needle placement. Superomedial genicular nerve: transversal ultrasonographic visualization of the needle. Cannula close to the periosteum with the tip near the artery.

Fig 4. transversal ultrasonographic visualization of the needle. Cannula close to the periosteum with the tip near o the artery.

Table 2. Advantages, Disadvantages, and Risks Related to the Percutaneous Pulsed Genicular Rhizotomy

Advantages	Disadvantages	Risks
Pain control by minimally invasive technique	Needs hospital admission to use the radioscopic apparatus	Skin thermal injury in skinny individuals (be careful to keep the active tip away from the skin)
Correct location by combining radioscopy, USG and motor-sensitive control.	Requires an USG device with Doppler function	Iatrogenic motor nerve injury (practically nonexistent with the 3 checks: radioscopy, USG, and sensory-motor)
Cost-effective technique in compared with the cooled technique.		Charcot's neuropathy (only a theoretical risk and for this reason not recommended for decompensated diabetes)
Safer technique compared with continuous technique, which uses greater temperatures.		

USG, ultrasonography.

Chen et al.[8] evaluated the outcome of cooled RF (CFR) versus hyaluronic acid (HA) in OA of the knee in a multicenter, randomized study. They compared the effect of CFR of the 3 genicular nerves (88 patients) in relation to HA Synvisc-One (87 patients), which has proven efficacy in treating knee OA.[8] They reported superiority of the use of CFR in the rate of pain reduction more significant than 50% at the assessment after 6 months (CFR 71% vs HA 38%; $P < .001$), in the WOMAC score at 6 months (48.2 CFR vs 22.6% AH; $P < .001$), and in the improvement to the perception of global improvement score at 6 months (72 CFR vs 40% HA; $P < .01$).[8]

In 2020, Arıcan et al.[9] published a study analyzing 20 patients with knee OA equal to or greater than Kellgren—Lawrence II submitted to pulsed RF. All analyzed patients were previously submitted to a test block with anesthetic of the genicular nerves, being included in the study only if the pain improved by at least 50% after the test block. Pulsed RF was performed on the superomedial and lateral and inferior medial genicular nerves. The authors found an improvement of at least 50% in the VAS and the WOMAC score within 3 months of FU. In addition, they found no side effects from the procedure. They concluded that pulsed RF of the genicular nerves is a safe and effective technique for patients with chronic OA of the knee.[9]

Elawamy et al.[10] carried out a prospective randomized study comparing pain improvement, analyzed by the VAS questionnaire, between patients with Kellgren— Lawrence III or IV OA between 2 groups of 100 patients each. Group I underwent pulsed RF in the genicular nerves guided only by ultrasound, and group II underwent intra-articular injection of platelet-rich plasma into the affected knee, also guided by ultrasound. The authors evaluated patients at 3, 6 and 12 months of FU. The group submitted to pulsed RF obtained better results, with statistical significance in the 6th and 12th month. Elawamy et al.[10] concluded that pulsed RF has better pain relief results when compared to infiltration with platelet-rich plasma.

In 2021, Chou et al.[11] carried out a systematic review and meta-analysis, analyzing the effectiveness of the 3 types of RF by ablation, conventional, pulsed, and cooled for the treatment of patients with OA. Twenty articles met the inclusion criteria, including 605 patients. The 3 techniques evaluated showed statistically significant improvements in pain in the first 6 months of FU. Chou et al. did not find differences between the 3 techniques in the 1st, 3rd, 6th, and 12th month of FU.[11]

We observed satisfactory results in the literature with pulsed, refrigerated, and conventional RF ablation techniques.[5-8] The refrigerated (cooled) technique can reach a larger area of the nerve by releasing a fluid that, in addition to cooling, increases the RF range; however, its cost is much greater, limiting its use. The conventional, although effective, because it uses greater temperatures, increases the risk of iatrogenic damage to structures peripheral to the nerve.[3] The best cost—benefit seems to be the pulsed one, which is affordable and works with low pulse temperatures. Cooled and continuous techniques generate thermal damage to the nerve, as they work at higher temperatures. The pulsed technique is based on the principle of neuromodulation, with regulation of neurotransmission, inhibiting afferent pathways and stimulating pain inhibitory pathways.[12]

Radiographic control with imaging apparatus is very useful for locating the needles in relation to anatomical bone references in the coronal and sagittal planes, and USG adds precision to this location, especially when using the Doppler feature, visualizing the arteries along the nerves. Bioimpedance analysis and sensory and motor electrostimulation ensures that the sensory nerve has actually been reached and ensures that no iatrogenic damage to motor nerves occurs.

We believe that RF rhizotomy is a very promising technique, but its results depend on the correct location of the nerves and that the combination of radiographic and ultrasound control and impedance analysis plus sensory-motor stimulation helps to achieve this goal with greater accuracy.

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