Validation of a new protocol for ultrasound-guided genicular nerve radiofrequency ablation with accurate anatomical targets: cadaveric study

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ABSTRACT

Introduction Ultrasound (US)-guided radiofrequency ablation (RFA) of genicular nerves (GNs) is increasingly performed to manage chronic knee pain. The anatomical foundations supporting the choice of original targets for US-guided GN-RFA have been thoroughly improved by recent anatomical studies. Therefore, this study aimed to provide a new protocol with revised anatomical targets for US-guided GN-RFA and to assess their accuracy in a cadaveric model.

Materials and methods Fourteen fresh-frozen cadaveric knees were used. After a pilot study with 4 knees, five consistent nerves were targeted in the other 10 knees with revised anatomical landmarks: superior medial genicular nerve (SMGN), superior lateral genicular nerve (SLGN), inferior medial genicular nerve (IMGN), recurrent fibular nerve (RFN) and the infrapatellar branch of the saphenous nerve (IPBSN). For each nerve, the lumen of radiofrequency (RF) cannula was prefilled with non-diffusible black paint, and then the cannula was inserted at the target site under US guidance. After US verification of correct placement, the stylet was introduced in the cannula to create a limited black mark on the tissues at the top of the active tip. Anatomical dissection was performed to assess for accuracy.

Results The proportion of nerves directly found in contact with the black mark was 7/10, 8/10, 10/10 and 9/10 for the SMGN, SLGN, IMGN and RFN, respectively. The proportions of nerve captured by the theoretical largest monopolar RF lesions were 100% for the SMGN, IMGN and RFN, and IPBSN and 95% for SLGN. The mean distances from the center of the black mark to the targeted nerve were 2.1±2.2 mm, 1.0±1.4 mm, 0.75±1.1 mm and 2.4±4.5 mm for the SMGN, SLGN, IMGN and RFN, respectively.

Conclusion US-guided GN-RFA with revised anatomical targets resulted in accurate capture of the five targeted nerves. This protocol provides precise sensory denervation of a larger panel of nerves, targeting those whose constancy regarding anatomical location has been clearly demonstrated. It is expected to improve the clinical outcomes.

INTRODUCTION

Radiofrequency ablation (RFA) of genicular nerves (GNs) has demonstrated some efficacy in the management of chronic knee pain.[1–8] While the original procedure involved fluoroscopy-guided needle placement, the ultrasound (US)-guided technique is gaining interest.[2 9–14] In addition to bony landmarks used in fluoroscopy-guided procedures, US allows the visualization of surrounding soft tissues, that is, tendons, muscles, ligaments and fasciae, as well as arteries running alongside the GNs,[14–17] which could improve the precision of the cannula placement during RFA.[3 15 18] Moreover, US is free of radiation, more easily accessible, reliable and cheaper.[14 17]

The anatomical bases supporting the original targets for image-guided (fluoroscopy or US) GN-RFA have been thoroughly improved, thanks to recent anatomical studies providing sound targets.[15 18–21] To date, the large majority of the studies assessing US-guided GN-RFA have used targets which are based on the original description of GNs,[2 9–14 22–24] but there is evidence that these classical targets fail to accurately capture the trunk of two out of three commonly treated GNs.[25] Since direct visualization of the GN is challenging, most described US-guided techniques are based on the identification of genicular arteries running alongside the targeted nerves.[9 12 14 22 24] However, it has been shown that some of the GNs do not run alongside nor in the same direction with the currently targeted genicular arteries.[18 25] This highlights the need for new US-guided GN-RFA protocols, based on updated and more precise anatomical landmarks.

Therefore, this study aimed to provide revised anatomical targets for US-guided GN-RFA and to assess their accuracy in a cadaveric model.

METHODS

Fourteen knees from 10 fresh-frozen adult cadavers (6 women, mean age 81.9±5.7 years), without evidence of surgery or major knee trauma, were used in this study conducted at UCLouvain Laboratory of Human Anatomy. Donation procedures and the use of the human cadavers were in accordance with national laws and regulations. Four knees were used for the pilot trials and 10 were used for the main study.

Pilot trial

The pilot study was conducted for sonographic exploration of the anatomical landmarks and confirmation of feasibility of our technical protocol to assess the position of the RF cannulas. US

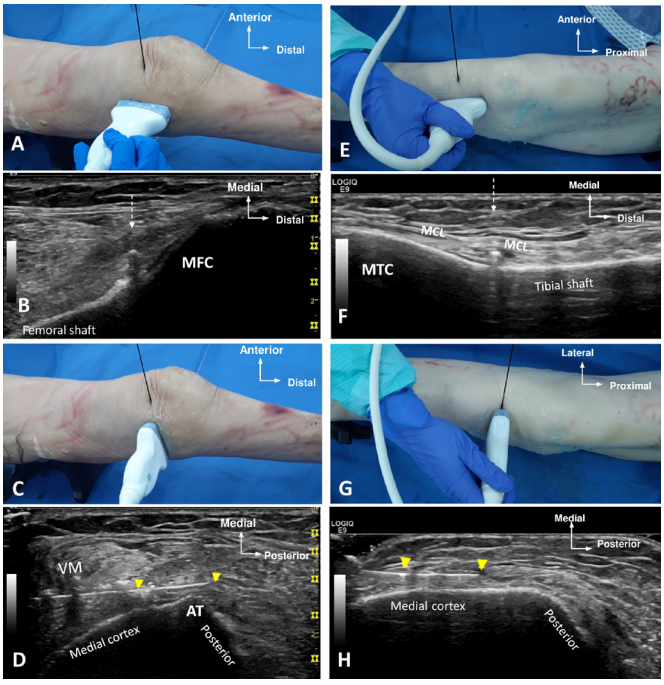

Figure 1 Cannula placement and ultrasound landmarks for SMGN and IMGN in cadaveric knee. (A,B) Coronal plane: target point for SMGN. (C,D) Axial plane: final position of the RF cannula for SMGN (with the active tip highlighted with two yellow arrowheads). (E,F) Coronal plane: target point for IMGN. (G,H) Axial plane: target point for IMGN. Vertical dashed arrows indicate target level on coronal view; yellow arrowheads indicate limits of the active tip. AT, adductor tubercle; IMGN, inferior medial genicular nerve; MCL, medial collateral ligament; MFC, medial femoral condyle; MTC, medial tibial condyle; SMGN, superior medial genicular nerve; VM, vastus medialis.

examination of the cadaveric knees was performed by a sonographer (MSS) with more than 10 years' experience in musculoskeletal US using a high-resolution US (General Electrics Logic E9; GE Medical Systems, USA), equipped with two multifrequency linear array transducers, an 18 MHz transducer for superficial areas (8–18 MHz hockey stick probe) and a 6–15 MHz transducer (ML6-15) for medium and deep areas. According to the revised anatomical targets from recent studies,[15 18–21] RF cannulas were inserted to fit the target of each of the five consistent GNs. Bones, tendons, vessels, enthesis and superficial landmarks were used to increase US accuracy and needle positioning. The localization of the tip of the cannula was demonstrated on two perpendiculars planes. A needle was redirected under US guidance in order to reach the target, if needed.

For the simulation of RF lesions, since the injection of even a very small volume (0.1 mL) of dyed solution is likely to diffuse beyond the limits of RF lesions, we marked the tissue at the top of the active tip with non-aqueous black paint. The stylet of the 18-gage 10 mm active tip, 10 cm-long RF cannula (Cosman Medical, Burlington, Massachusetts, USA) was removed and the cannula was prefilled with a syringe containing the black paint. Then, the cannula was detached from the syringe and its tip was cleaned. Under direct US guidance, the anatomical landmarks for each nerve were identified and the cannula was advanced to the target. After verification of the correct cannula placement, the stylet was reintroduced into its cannula while ensuring that it did not move from its final position. The stylet and then the cannula were removed from the knee. After completion of the procedure and subsequent meticulous anatomical dissection, we found a clear limited black mark (mean 5.36 mm (SD 2.61)×3.69 mm (SD 1.49)) at all the targeted points. We concluded that the method was reliable for accessing the accuracy of lesions produced by US-guided RFA.

During dissection, we securely fixed a thick echoic stainless-steel wire on each targeted nerve. The distal end of the steel wire was bent over itself and fixed on the nerve at its target point by strong sutures to avoid secondary displacement during handling. Then, the anatomical structures were carefully repositioned and sutured layer by layer before skin closure. A second US exploration was performed the day after the anatomical dissection. The reverberation US artifact generated by metals was used to identify the position of the steel wire in order to refine US landmarks.

Main study

In the other 10 lower limbs, US-guided RF lesions were simulated as described earlier, targeting five nerves, in accordance with previous anatomical studies and the current pilot trial. All the procedures were performed in supine position with the knee extended.

Superior medial genicular nerve (SMGN)

The US transducer was aligned in a coronal plane over the medial femorotibial joint line and move cephalad and posteriorly to identify the adductor tubercle (AT) and the insertion of the adductor magnus tendon. The skin was marked transversally at the level of the AT. Then, the transducer was turned into the axial orientation at that level and translated posteriorly to identify the posterior cortex of the femoral metaphysis. With the probe in that position, a RF cannula was inserted about 2–3 cm medially from the superior medial angle of the patella and was advanced in an in-plane position from front to back (90° from the coronal plane) until the posterior cortex, on or above the AT, about 1 mm from the periosteum (figure 1A–D).

Superior lateral genicular nerve (SLGN)

The transducer was aligned in a coronal plane (figure 2A) over the lateral femoro-tibial joint line and moved cephalad to identify the junction between the lateral femoral condyle and the shaft. This corresponded to a transitional area, and we marked the junction between the convexity and concavity (figure 2B). The skin was marked transversally at that level. Then the transducer was positioned into the axial plane according to this transversal skin mark (figure 2C) and translated posteriorly to identify the posterior edge of the lateral femoral cortex, which is easily identifiable as a crest separating the lateral and posterior sides (figure 2D). The skin was marked at the point corresponding to the junction between the posterior edge of the lateral femoral cortex and the superior edge of the lateral condyle, which was the target (figure 2E). As we observed in the pilot study that the correct approach for cannula placement was at about 45° from the coronal plane, the skin entry point was placed about 3 cm anterior and 3 cm proximal to that skin marking point (figure 2F). Under direct US guidance, an RF cannula was inserted obliquely, about 45° from the coronal plane, and advanced obliquely from anterior to posterior toward the target (figure 2G,H). Then, the transducer was repositioned in the axial plane (figure 2K), centered on the skin mark of the target point, and the active tip position was adjusted to fit the target (figure 2L), about 2–3 mm from the periosteum.

Inferior medial genicular nerve (IMGN)

The US transducer was aligned in a coronal plane over the medial femorotibial joint line and translated distally to identify

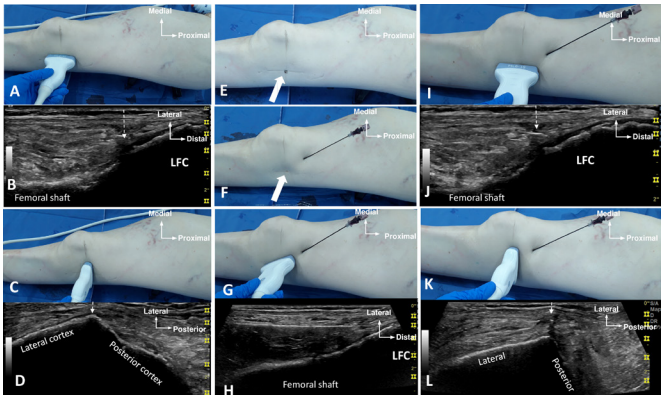

Figure 2 Cannula placement and US landmarks for SLGN in the cadaveric knee. (A,B) Coronal plane: target point for SLGN and transversal skin mark. (C,D) Axial plane: target point for SLGN. (E) Target skin point. (F) Cannula introduction at 45°. (G,H) Oblique in-plane insertion of the cannula. (I,J) Coronal plane: final position of the cannula tip. (K,L) Axial plane: final position of the cannula tip. Vertical dashed arrows indicate the US target point. LFC, lateral femoral condyle; SLGN, superior lateral genicular nerve; US, ultrasound.

the metaphyseal–diaphyseal junction of the tibia and the distal insertion of the medial collateral ligament (MCL). We tried to visualize the short-axis view of the nerve, running on the periosteum with the inferior medial vessels. The skin was marked transversally at that level. The US transducer was turned into an axial orientation, at the level of the transversal skin mark. An RF cannula was inserted (with the entry point on the skin mark, 1 cm medially to the tibial tuberosity) in an in-plane approach and advanced from anterior to posterior to fit at the midpoint of the tibial width, close to the periosteum. A supplementary coronal view allowed checking of the position of the active tip beneath the MCL, close to the vessels and the nerve (figure 1E-H).

Recurrent fibular nerve (RFN)

The US transducer was aligned in a coronal plane over the lateral femorotibial joint line and translated distally to identify Gerdy's tubercle (GT) and the insertion of the iliotibialis tract. The transducer was translated about 2 cm distally to visualize the short-axis view of pedicle containing the RFN and the anterior tibial recurrent artery, located just below the GT, beneath the tibialis anterior muscle (figure 3A,B). The skin was marked

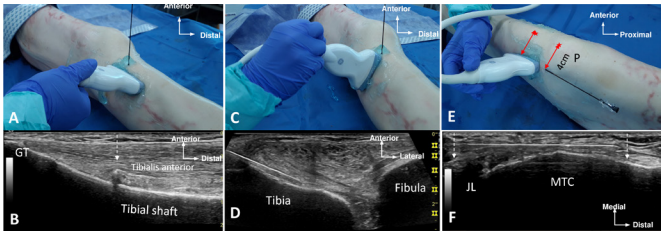

Figure 3 Cannula placement and US landmarks for RFN and IPBSN in the cadaveric knee. (A,B) Coronal plane: target point for RFN. (C,D) Axial plane: final position of the RF cannula for the RFN. (E,F) Coronal plane: RF cannula placement on the treatment line for the IPBSN. Red stars indicate the patella apex and tibial tuberosity; vertical dashed arrows indicate the target levels on US view. GT, Gerdy's tubercle; IPBSN, infrapatellar branch of the saphenous nerve; JL, medial femorotibial joint line; MTC, medial tibial condyle; P, patella; RF, radiofrequency; RFN, recurrent fibular nerve; US, ultrasound.

transversally at that level. The US transducer was turned 90° into an axial orientation at the level of the transversal skin mark. A RF cannula was inserted (with the entry point on the skin mark, just lateral to the tibial tuberosity) in an in-plane approach and advanced close to the bone, from the anterior to posterior to fit at midpoint of the tibial width (figure 3C,D), far from the common fibular nerve (CFN).

Infrapatellar branch of the saphenous nerve (IPBSN)

We drew the IPBSN treatment line, that is, a longitudinal line, 4 cm medially to the patella apex, connecting both transversal lines passing by the patella apex and the top of the tibial tuberosity. We investigated direct US visualization and indirect targeting of the IPBSN.

- Direct visualization of the IPBSN at the level of the knee: the probe was aligned in the coronal plane throughout the treatment line to try to visualize the short-axis view of the nerve as hypoechogenic ovoid structure in the subcutaneous tissue, lying on the MCL, running with its small artery. If the nerve was not identified there, the probe was translated posterior-medially, and cephalad to search for it (retrograde US exploration). In the case where the IPBSN was not identified at the inferior medial aspect of the knee, the saphenous nerve was identified at a mid-femoral level, and we tried to identify the emergence of the IPBSN and to follow its course until the knee (anterograde US exploration).
- Indirect targeting of the IPBSN: if the nerve was not directly identified, the transducer was placed in coronal view on the treatment line, and the RF cannula was inserted through a skin point located at the superior edge of the treatment line, advanced from proximal to distal along the line, deep in subcutaneous tissue, just superficial to the MCL (figure 3E,F).

For each nerve, after verification of correct cannula placement, one RF lesion was simulated as described previously. For the SLGN, three consecutive contiguous lesions were performed: at the level of the target area described earlier, then the cannula was advanced (1 cm distally) and the second lesion was performed, and the cannula was withdrawn (1 cm proximally) for the third lesion. For the IPBSN, if the nerve was directly identified, the lesion was performed directly on the nerve. If not, a black mark was made at both extremities of the treatment line.

After the completion of all the simulated RF lesions, the limbs were dissected by an experienced anatomist to assess the nerve capture rate, which was our primary outcome. The midpoint of the black mark was considered the final location of the top of the active tip. Therefore, according to this black mark and considering the direction of the cannula and its final position, we traced the location of the 10 mm active tip and the theoretical limits of the largest RF lesion volume (transversal distance 7.4 mm, longitudinal distance 12.9 mm and distance beyond the tip 2.4 mm).[26] The anatomical targets for cannula placement were considered accurate either if the nerve was in contact with black mark or if it was included within the limits of the presumed RF lesion. Using a sliding digital caliper, we measured the shortest distance from center of the black mark to the nerve and the distance from limits of the presumed RF lesion to the nerve. We also measured the distance from the edge of the RF lesions for RFN to the CFN.

Statistical analysis was performed using SPSS V.25.0 (Chicago, Illinois, USA). For each nerve, the accuracy rate of the cannula placement was described as proportions. The various distances were described as mean (SD). Analysis of variance test was used

Table 1 Distances from the nerves to the marks

Distance measured (in mm)	Mean (SD)	Median	Range
SMGN distance 1	2.1 (2.2)	2.0	0.0–8
SMGN distance 2	0 (0.0)	0	0
IMGN distance 1	1.0 (1.4)	0	0–4
IMGN distance 2	0 (0.0)	0	0
RFN distance 1	0.75 (1.1)	0	0–3
RFN distance 2	0 (0.0)	0	0
SLGN distance 1	2.4 (4.5)	0	0–14
SLGN distance 2	0.5 (1.2)	0	0–4

Distance 1 : distance from the center of the black mark to the nerve.
Distance 2: distance from the edge of the theoretical RF lesion to the nerve.
IMGN, inferior medial genicular nerve; RFN, recurrent fibular nerve; SLGN, superior lateral genicular nerve; SMGN, superior medial genicular nerve.

to compare the mean distances from the black mark between the different nerves. We considered a p value of <0.05 as statistically significant.

RESULTS

The mean distances from the center of the black mark to the targeted nerve were 2.1±2.2 mm, 1.0±1.4 mm, 0.75±1.1 mm and 2.4±4.5 mm for the SMGN, SLGN, IMGN and RFN respectively (table 1). We did not find a statistical difference in these distances between the nerves (p=0.31).

The mean distances from the edge of the simulated RF lesion to the targeted nerve were mm for the SMGN, IMGN and RFN, and 0.5±1.2 mm for the SLGN (table 1).

The mean distance from the edge of the RF lesions to the CFN was 37.33 [range 30–42] mm

The proportion of nerves directly in contact with the black mark was 7/10, 8/10, 10/10 and 9/10 for the SMGN (figure 4), SLGN (figure 5), RFN (figure 6A,B) and IMGN (figure 6C,D), respectively (table 2).

The proportions of nerve capture (accuracy rate) with the theoretical largest monopolar RF lesions were 100% for the SMGN, IMGN and RFN (table 2). For the SLGN, the trunk of the nerve was captured before its bifurcation in 9/10 cases; in 1/10 case, only the transversal branch was captured, resulting in an overall accuracy rate of 95%.

The IPBSN was directly visualized in 2/10 cases, with a successful direct capture (figure 6E). In the eight remaining cases, the IPBSN was found within the black marks at both extremities of the treatment line (figure 6F), giving an accuracy rate of 100% with this indirect technique.

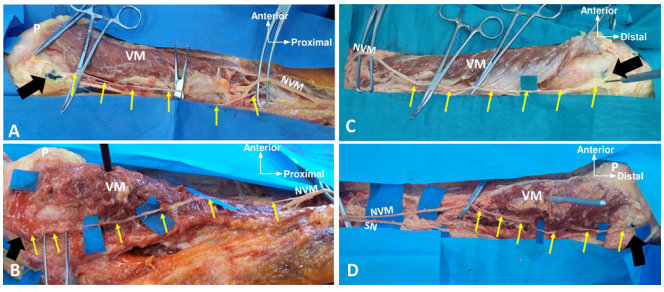

Figure 4 Postprocedural anatomical dissections, medial view: superior medial genicular nerve (yellow arrows). (A,B) Right knees and (C,D) left knees. Tick black arrows show the black mark. NVM, nerve to the vastus medialis; P, patella; SN, saphenous nerve; VM, vastus medialis muscle.

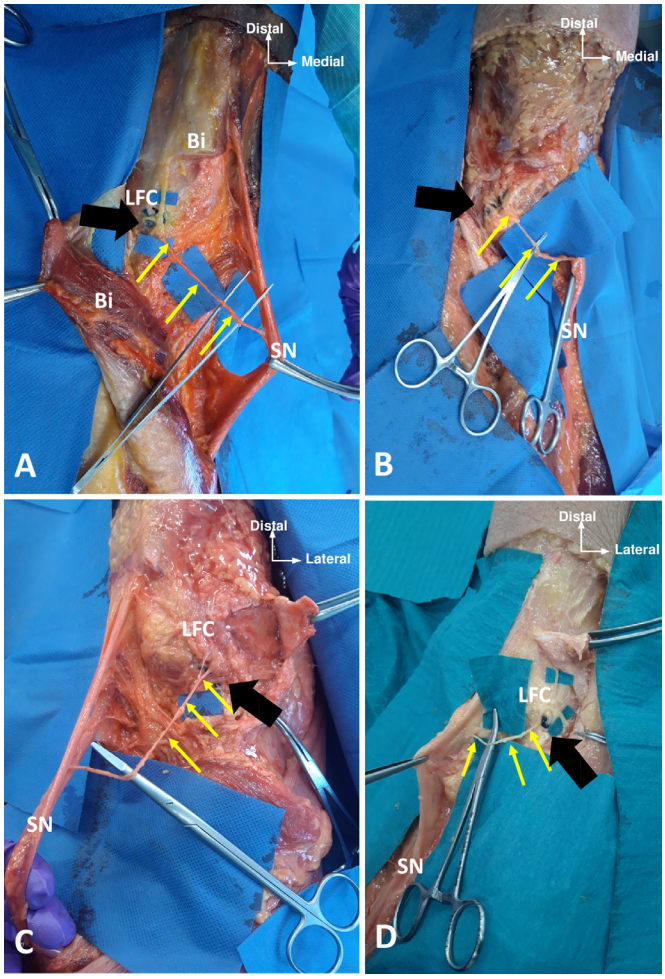

Figure 5 Postprocedural anatomical dissections, posterior lateral view: superior lateral genicular nerve (yellow arrows). (A,B) Right knees and (C,D) left knees. Tick black arrows show the black marks. Bi, biceps femoris muscle (cut and reflected); LFC, lateral femoral condyle; SN, sciatic nerve.

DISCUSSION

This cadaveric study was designed to provide updated anatomical targets for US-guided GN blockade and RFA, and assess for accuracy of a new protocol. According to our results, US-guided GN-RFA using revised anatomical targets is feasible and accurately captures the five most consistent sensory nerves of the knee joint capsule: SMGN, SLGN, IMGN, RFN and IPBSN.

The increasing number of publications on the use of US-guided GN blockade and RFA to alleviate chronic knee pain reflects the growing interest of pain physicians for this technique.[2 11–14 22 24 27] However, very few anatomical studies have assessed the accuracy of targets used for US-guided intervention.[16 17] Moreover, the anatomical targets commonly used are based on the original anatomical descriptions, which have since then been improved. Therefore, revised targets, based on updated and accurate anatomical data, are paramount to expect improving outcomes. While using anatomical landmarks based on original description of GNs, a recent cadaveric study[16] found that the commonly used targets for US-guided RFA on SMGN, SLGN, and IMGN were accurate. Two major methodological differences may explain the discrepancies between both studies. First, they injected a dyed solution – even 0.1 mL of soluble dyed solution diffuse beyond the limits of RF lesions[25] - to visualize

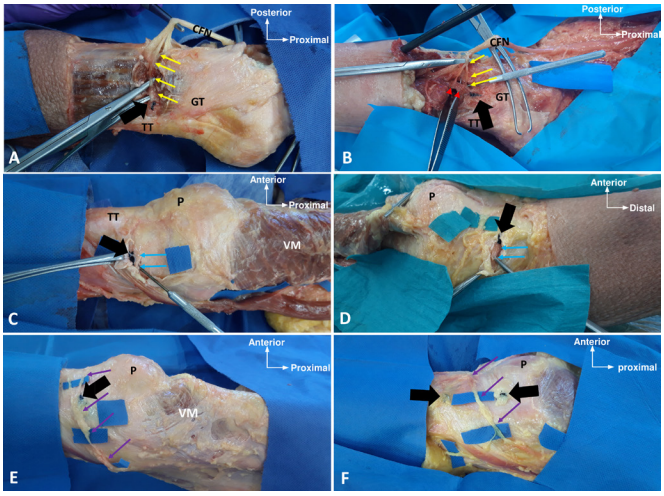

Figure 6 Postprocedural anatomical dissections. (A,B) Recurrent fibular nerve (yellow arrows) accompanied by anterior tibial recurrent vessels (red arrowheads). (C,D) Inferior medial genicular nerve (blue arrows) with accompanying vessels. (E) IPBSN (purple arrows) captured under direct ultrasound visualization. (F) IPBSN passing within the two extremities of the treatment line. Tick black arrows show the black marks; CFN, common fibular nerve; GT, Gerdy's tubercle; IPBSN, infrapatellar branch of the saphenous nerve; P, patella; TT, tibial tuberosity; VM, vastus medialis muscle.

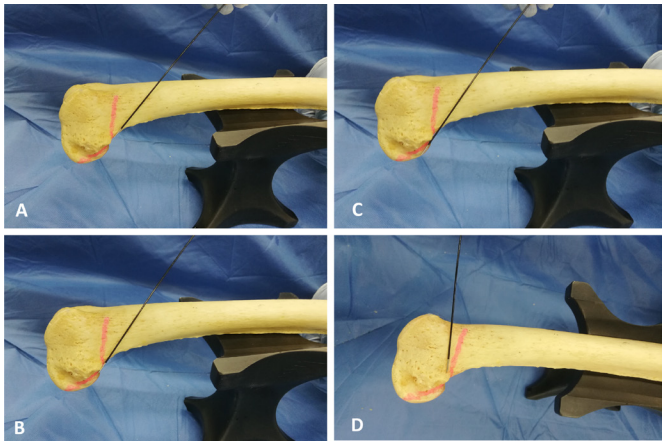

Figure 7 Targeting approach for the SLGN, illustration on a real human femur skeleton, lateral view. (A) Oblique approach with the three contiguous lesions proposed to capture the terminal branches of SLGN: proximal lesion (see the position of the active tip). (B) Central lesion: the active tip fit exactly at the junction between the posterior edge of the lateral cortex and the lateral condyle. (C) Distal lesion: the RF cannula is advanced 1 cm from central position. (D) Anterior–posterior vertical approach: the proximal expansion of the lateral epicondyle prevents the tip to fit properly the target area; in addition, the three contiguous lesions are not feasible. Red lines represent transverse and longitudinal terminal branches of SLGN. RF, radiofrequency; SLGN, superior lateral genicular nerve.

the final position of cannula. In the current study, to assess the precision of cannula placement, we simulated the RF lesion by creating a limited black mark on the tissues at the top of RF cannula using a non-diffusible paint. Second, we performed a systematic anterograde dissection of GNs from origin to ending, to ensure that we really visualized nerves. Indeed, small GNs can be confused with small vessels on a cadaver (especially an embalmed specimen) if the nerve is not dissected since its origin (which is big and easily identifiable), or the vessels are not injected before dissection.[25] Therefore, in cadaveric validation studies, post interventional dissections and illustrations of the nerves should allow the researcher and the reader to discriminate between the very thin GNs and vessels. Dissection of the GN trough a distal "window" could be misleading.

Our target for SMGN is different from that of the commonly described technique,[14 16 22 28] which relies on the course of the vessels running transversally forward at the junction between epiphysis and diaphysis. This does in fact not correspond to the superior medial genicular artery (SMGA), but to the upper transverse artery from the articular branch of the descending genicular artery (DGA), which does not run with SMGN.[25 29] Recent studies have found that the SMGN has a descending course, along with its artery from the DGA.[18 20 21 29] Its transversal terminal branch runs forward with SMGA at the level of medial epicondyle, and not at junction between medial femoral condyle and diaphysis,[29] as targeted in classical technique. In our proposed protocol, the active tip of the RF cannula should be advanced totally posteriorly on the medial femoral axial view (figure 1D), to cross the course of the nerve. To capture the trunk of the nerve, the cannula should not be distal to the AT. We observed that in all our specimens, the base (superior pole) of the patella corresponded to the correct level of cannula insertion. Identification of the distal end of the adductor magnus tendon and the artery running on its surface with the SMGN could be complementary landmarks to improve capture of the SMGN in patients.

Due to the anatomical conformation on the lateral femoral condyle and epicondyle, we observed that it is difficult to reach the target area of the SLGN when the cannula is at 90° from the coronal plane, because the proximal part of lateral epicondyle prevents the tip from reaching the target (figure 7). We found that a 45° approach provided a better trajectory to the target area (figure 7). Due to the variability of the SLGN position, we propose a palisade of three contiguous lesions (figure 7A–C). Our results show that this technique improved the capture rate of that nerve from 65% in a previous study with single lesion[25] to 95% in the current study. While this would prolong the procedural time for about 5 min, we believe it is worth it. The needle should not be too close from the bone, but at 2–3 mm from the periosteum. In our proposed technique, while the needle insertion technique was extremely simple and basic for the other targeted nerves, the needle proper positioning for the SLGN was the less easy to achieve. That is why we provided a more detailed description of the procedure, which could be reproduced by any pain physician (figure 2). Fluoroscopy could be used to confirm the needle position, especially during the learning phase of this technique. Some physicians use both devices (fluoroscopy and US) to confirm the needle positioning during GN-RFA. For those who are very experienced sonographers, an alternative

Table 2 Staining and accuracy rates for different targeted nerves

Targeted nerves	Contact of the black mark with the nerve n (%)	Nerve within the limits of the RF lesion n (%)
SMGN	7 (70)	10 (100)
SLGN	8 (80)	9+½ (95)
IMGN	10 (100)	10 (100)
RFN	9 (90)	10 (100)
IPBSN	Non applicable	10 (100 %)

IMGN, inferior medial genicular nerve; IPBSN, infrapatellar branch of the saphenous nerve; RFN, recurrent fibular nerve; SLGN, superior lateral genicular nerve; SMGN, superior medial genicular nerve.

technique to identify the target area could be as follow: coronal view to determine the junction between lateral femoral condyle and shaft and note the depth; then turn the probe 90° to see the junction between the posterior and lateral cortex with the same depth, while paying attention to make sure that the probe is in the true lateral plane.

The proposed technique for capture of RFN is safe and accurate. With this anterior approach under direct US guidance, the lesion is deep enough from the skin (beneath the deep surface of the tibialis anterior muscle) and far enough from the CFN, which can be visualized during the procedure. The vessels running with the nerve in a recurrent course are easily identifiable, just below GT. One may choose not to use US guidance to target this nerve as we previously described,[21 25] but the US technique has an advantage in obese patients where GT is not easy to palpate.

Some authors described direct identification of the IPBSN[15 30 31] with US, but in our specimens, we found it difficult to identify systematically. In a recent study, Gong *et al*[30] found that the IPBSN could be visualized distinctly in four out of five subjects. Their landmarks was 5 cm superior to the medial femoral condyle, and the nerve was visualized superficial to the junction between the vastus medialis and sartorius. We did not make the same observations. Moreover, we believe that even if this landmark could be used for IPBSN blockade, it seems too proximal for RFA. We found a variability in the proximal trajectory of IPBSN, but its distal course at the level of the knee is remarkably constant, crossing the proposed treatment line in 100% of cases. Therefore, for RFA of IPBSN, we propose a two-step protocol. First, try direct visualization of the nerve alongside its artery[29] at the level of the treatment line, which we succeeded in only two specimens (in patients, the arterial flow could be helpful). If direct identification fails, just perform indirect targeting as we previously described.[21 25] Introduce the cannula deep at the proximal end of the treatment line, and advance it longitudinally, deeply and progressively along the treatment line while performing sensory stimulation. A sensation in the territory of the IPBSN would confirm a close proximity between the active tip and the nerve. After ensuring that there is at least 8–10 mm between the active tip and the surface of the skin, a lesion could be performed. Due to the risk of cutaneous lesions, pulsed radiofrequency (RF) is indicated for IPBSN.

In fluoroscopy-guided intervention, only the bony landmarks are used to localize the probable position of the targeted nerves, since their trajectory is consistent. Some authors suggest that US is better than fluoroscopy for guiding needle placement during this treatment,[9 10 14] while others describe the use of both tools.[14] The proposed ultrasonographic landmarks allow the visualization of several anatomical structures, such as bony landmarks, muscles, tendons and ligaments, for each targeted nerve. In addition, since the pattern of vessels accompanying each GN has been well established, the arterial blood flow could help to better localize them, as long as we follow the correct artery. Another possible advantage of technique is the fact that the cannulas do not need to be inserted directly on the periosteum and advanced on it because this could make the procedure more painful. Moreover, it has been shown that an active tip directly placed on the bone significantly limits the volume of RF lesion.[26] Therefore, we suggest keeping a 1–2 mm distance between the tip and bone. Finally, after technical optimizing, that is, better and accurate anatomical targets, larger lesion volume, optimal use of US and/or fluoroscopy, we believe that GN-RFA appears to become very effective and widely indicated for more patients across the world.

This study has some limitations. First, the most valuable method for assessing the accuracy of needle placement for RFA is to create a true RF lesion under clinical-like conditions before performing anatomical dissection. Since studies have failed to create visually identifiable RF lesions on cadavers,[16 25] we did not use this method. However, the use of a black mark as surrogate for identifying needle position, rather than the injection of dyed solution, seems more reliable, given the limited size of RF lesions. Second, due to the absence of blood flow through the arteries of cadavers, we were unable to use the Doppler US to assess the blood flow of arteries running alongside the GNs. In a living patient, in addition to the anatomical landmarks used in this study, arterial blood flow could help increase the success rate of cannula placement, but identifying the correct artery is the key. Third, we explored only monopolar RF lesions. However, we believe that since the size of cooled RF lesions is bigger, the technique would also be accurate when using cooled RF devices. Finally, only a clinical validation study of the proposed technique will allow assessment of its efficacy and safety.

CONCLUSION

This study shows that the protocol for US-guided GNB and RFA with revised anatomical targets resulted in accurate capture of the five targeted nerves. This protocol provides more complete sensory denervation, targeting only the nerves whose constancy regarding anatomical location is clearly established. It is expected to improve the clinical outcomes. It could be directly useful for physicians who perform US-guided RFA of GNs for chronic knee pain. Clinical studies will be needed to assess the safety and efficacy of the proposed technique and to compare it to the commonly used one.

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