Long-Term Outcomes of the Pull-Back Technique for Genicular Nerve Ablation

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ABSTRACT

Purpose: To test the hypothesis that the pull-back genicular nerve ablation (pbGNA) technique provides superior 12-month pain relief and functional improvement compared with traditional genicular nerve ablation (tGNA) for knee osteoarthritis, as measured by visual analog scale (VAS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores.

Materials and Methods: A single-center, nonrandomized retrospective analysis of a prospectively collected cohort of patients undergoing genicular nerve block and ablation between September 2022 and February 2024 was performed. Technique selection was based on operator preference. Baseline and 12-month VAS and WOMAC scores were compared between groups. Demographics including age, gender, and body mass index (BMI) were analyzed. Univariate and multivariate linear regressions assessed associations between technique and score changes, adjusting for clinical and demographic covariates.

Results: Sixty-eight patients were included (male, 19%; median age, 67 years; median BMI, 35 kg/m^2). Twenty-six underwent pbGNA, and 41 underwent tGNA, with no significant baseline differences. In the pbGNA group, VAS score improved by 2.92 ($P < .001$), and WOMAC score improved by 12.65 ($P = .001$) at 12 months. On multivariate analysis, pbGNA was not associated with greater VAS improvement ($\beta = 0.71$, $P = .435$) but was associated with greater WOMAC improvement ($\beta = 15.39$, $P = .040$).

Conclusions: pbGNA appears safe and may improve functional outcomes compared with tGNA without compromising pain relief. However, findings should be interpreted cautiously given the modest effect size, wide CI, and small single-center sample in this retrospective nonrandomized study.

ABBREVIATIONS

BMI = body mass index, cRFA = cooled radiofrequency ablation, GN = genicular nerve, GNA = genicular nerve block and ablation, IMGN = inferomedial genicular nerve, IQR = interquartile range, IRB = Institutional Review Board, MR = magnetic resonance, OA = osteoarthritis, pbGNA = pull-back genicular nerve ablation, RFA = radiofrequency ablation, SLGN = superolateral genicular nerve, SMGN = superomedial genicular nerve, SPGN = suprapatellar genicular nerve, tGN = traditional genicular nerve ablation, TKA = total knee arthroplasty, US = ultrasound, VAS = visual analog scale, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index

The current approach to treatment for knee osteoarthritis (OA) often begins with nonpharmacologic options such as exercise, weight management, and physical therapy (1). However, in recent years, minimally invasive interventions have emerged as fruitful options for pain control in patients whose OA-related pain has continued to progress despite conservative management (2). One of these percutaneous interventions is genicular nerve block and ablation (GNA), which involves the directed application of energy to disrupt nociceptive signals from the knee joint (3). Conventional radiofrequency ablation (RFA) uses probes to create frictional heat of 60–90 °C to create an elliptical focus of ablation around the target nerve. In contrast, cooled RFA utilizes circulating saline to maintain a probe temperature of 60 °C, producing a larger spherical area of tissue destruction compared with traditional GNA RFA, eliminating the need for probe placement in parallel to the target (4).

Initially described by Tran et al (5) from cadaveric dissections, there are potentially 11 genicular nerve (GN) targets for effective pain management in knee OA, emphasizing the anatomical importance of these structures in treatment (6). The knee receives sensory innervation from over eleven nerves originating from the sciatic,

J Vasc Interv Radiol 2026; 37:108920
https://doi.org/10.1016/j.jvir.2026.108920

RESEARCH HIGHLIGHTS

- The pull-back genicular nerve ablation (pbGNA) technique increases lesion coverage to address known anatomical variability of genicular nerves (GNs).
- pbGNA was associated with functional improvement at 12 months, with larger reductions in Western Ontario and McMaster Universities Osteoarthritis Index scores compared with the traditional technique (P = .04).
- Pain reduction measured by visual analog scale was similar between pbGNA and traditional GN ablation.
- No procedure-related adverse events were observed in either cohort.
- pbGNA represents a safe technique associated with potentially superior functional outcomes for GN ablation in knee osteoarthritis.

femoral, and obturator nerves (7). In the context of GNA, the primary targets are the superomedial genicular nerves (SMGNs), superolateral genicular nerves (SLGNs), inferomedial genicular nerves (IMGNs), and suprapatellar genicular nerves (SPGNs). However, according to recent cadaveric and magnetic resonance (MR) imaging studies, there are variations in the location of SMGN and SLGN relative to bony and radiographic landmarks and even duplicated nerves (8). Cadaveric and imaging studies, particularly those by Fonkoue et al (9,10), have shown inconsistent localization of GNs using conventional bony landmarks and have proposed revised, anatomically validated targets to improve procedural accuracy. Specifically, for the SMGN, the revised technique drastically reduced the mean distance from the active tip to the target nerve compared with classical methods (0.7 mm vs 17.8 mm) (11). These findings underscore the limitations of standard landmark-based approaches and highlight the need for strategies that better account for anatomical variability. In this manuscript, the term anatomical variability refers to inter-individual differences in nerve course, rather than systematic inaccuracies of classical fluoroscopic landmarks.

Hence, to address the variability in the SMGN and SLGN, the pull-back genicular nerve ablation (pbGNA) technique for GNA has been developed. This technique involves performing an initial ablation at two-thirds femoral shaft depth at all GN locations. After the initial ablation, the SMGN and SLGN probes are "pulled back" to one-third trocar depth, and the ablation is repeated. This approach increases the ablation area, helping to ensure comprehensive treatment of the targeted nerves and improve pain relief outcomes for patients, regardless of anatomical variability.

Although no anatomical, cadaveric, imaging, or simulation-based validation is provided to demonstrate that a pull-back technique could capture the nerve trunks more reliably, to date, there are no published studies that compare the clinical outcomes between the pull-back technique and the traditional needle placement technique.

This study assessed the safety profile of the "pull-back" technique (pbGNA) for the management of anatomical heterogeneity and compare its effectiveness versus the traditional needle approach (traditional genicular nerve ablation [tGNA]) using the visual analog scale (VAS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain scale. The authors hypothesize that pbGNA would result in superior pain and functional outcomes compared with tGNA at 12-month follow-up.

MATERIALS AND METHODS

An Institutional Review Board (IRB) (MedStar Health Research Institute) approved nonrandomized retrospective study was conducted for patients who underwent GN cooled RFA (cRFA) using CooLief probes (Avanos Medical, Alpharetta, Georgia) between September 2022 and February 2024. The patient population consisted of individuals with chronic knee OA who were deemed nonsurgical candidates, declined total knee arthroplasty (TKA), sought a "bridge" for pain management prior to TKA, or experienced persistent pain following TKA. Inclusion criteria mandated that patients be aged $\geq$18 years, with a documented diagnosis of OA based on either radiographic imaging or MR imaging. Eligible patients also had to demonstrate a positive response ($\geq$50% subjective pain relief) to prognostic GN blocks. Exclusion criteria included active infections, inflammation at the target site, and prior knee surgeries, excluding TKA.

Participants underwent fluoroscopic-guided cRFA utilizing either the tGNA or pbGNA technique, as determined by the operator's preference. In the tGNA technique, ablation probes were strategically positioned to target the SMGN, SLGN, and IMGN at the junction of the long-bone metaphysis and epicondyles, with a probe insertion depth of 60% as seen in **Figure 1**. The suprapatellar GN was accessed by advancing the ablation probe to the mid-femoral diaphysis, approximately 4–5 cm proximal to the patella. In the pbGNA technique, the SMGN and SLGN were targeted similarly; however, ablation commenced at two-thirds shaft depth, followed by a second ablation after retracting the probe to one-third depth as seen in **Figure 2**. These landmarks were defined according to commonly used fluoroscopic conventions. The IMGN and SPGN were treated following the tGNA method.

Ablation was conducted at a target temperature of 80 °C for a total of 90 seconds of ablative time, in accordance with the manufacturer's recommendations. Patients were monitored for adverse events for 30 minutes after the procedure, with follow-up assessments scheduled at 12 months after cRFA. VAS and WOMAC scores were obtained during follow-up and compared with baseline scores.

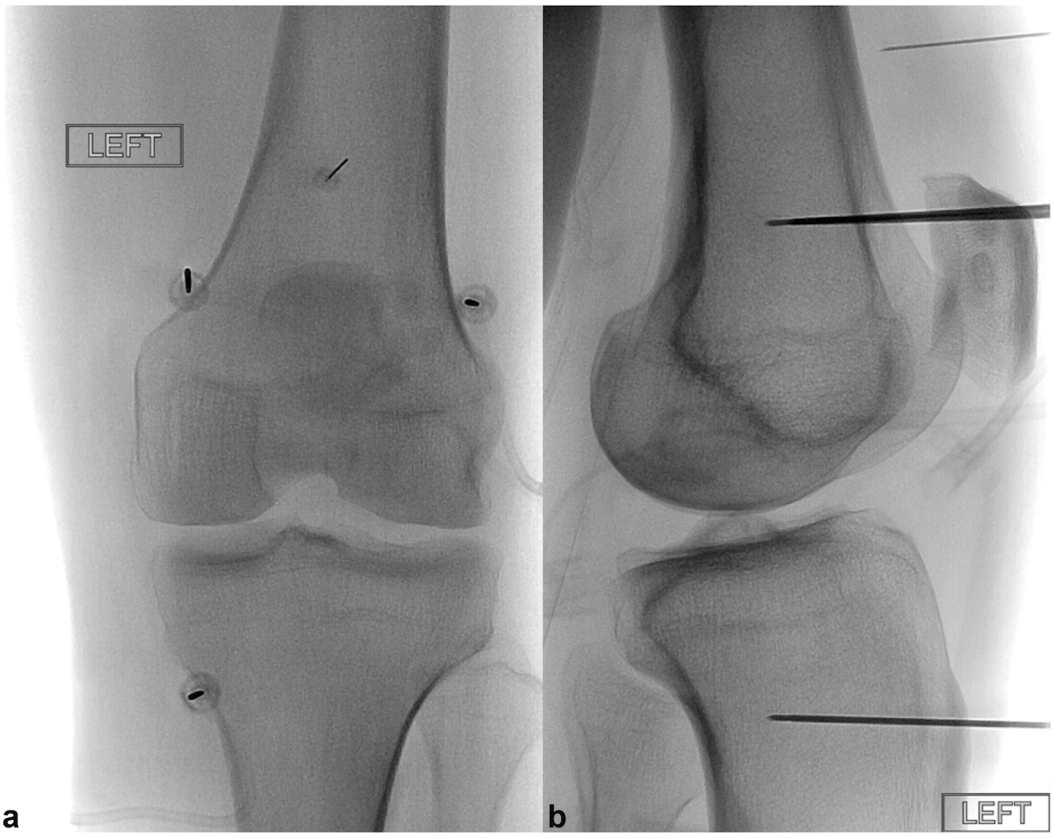

Figure 1. (a) Anteroposterior and **(b)** lateral fluoroscopic views of the left knee demonstrating ablation probe placement using the traditional genicular nerve ablation technique. The probes were positioned to target the superomedial, superolateral, and inferomedial genicular nerves at the junction of the long-bone metaphysis and epicondyles, with a probe insertion depth of 60%. The suprapatellar genicular nerve was accessed by advancing the ablation probe to the mid-femoral diaphysis, approximately 4–5 cm proximal to the patella.

Demographics including gender, age, and body mass index (BMI) were collected. Prior medical and surgical history of the patients for history of fibromyalgia and prior surgery (total or unilateral knee arthroplasty) were also reviewed and utilized for analysis. The primary outcomes included changes in pain and functional scores, assessed using VAS and WOMAC. Secondary outcomes focused on safety and complication rates associated with the procedure. Statistical analyses were performed in R version 4.4.2 (R Foundation for Statistical Computing, Vienna, Austria) by a professional biostatistician. Categorical variables were summarized as counts and percentages, and continuous variables were summarized at medians with interquartile ranges (IQRs). Categories were compared using chi-square analysis and Fisher exact test for categorical variables and Wilcoxon rank sum exact test for continuous variables. Univariate and multivariate linear regressions were used to assess relationships between clinical variables of interest and differences in scores, adjusting for clinical covariates and demographic confounders. Because some patients underwent bilateral GN ablations, knees from the same patient may not be fully independent. This potential unit of analysis issue was not modeled explicitly and should be considered when interpreting the results.

RESULTS

A total of 68 patients were included in the study, 13 male (19%), 54 female (81%), and 1 unknown. Median age was 67 years (IQR, 59–72 years), and median BMI was 35 kg/m^2 (IQR, 30–43 kg/m^2) as shown in **Table 1**.

Twenty-six patients underwent pbGNA, 4 male (15%) and 22 female (85%), whereas 41 patients underwent tGNA, 9 male (22%) and 32 female (78%), which has a *P* value of .500. There was a 100% technical success rate in both the pbGNA and tGNA groups. Using the Society of Interventional Radiology (SIR) adverse event classification system, no safety events occurred. The median ages of the pbGNA cohort were 68 years (IQR, 60–73 years) and 64 years (IQR, 58–69 years) with a *P* value of .200. The BMI of the pbGNA group was 35 kg/m^2 (IQR, 31–47 kg/m^2),

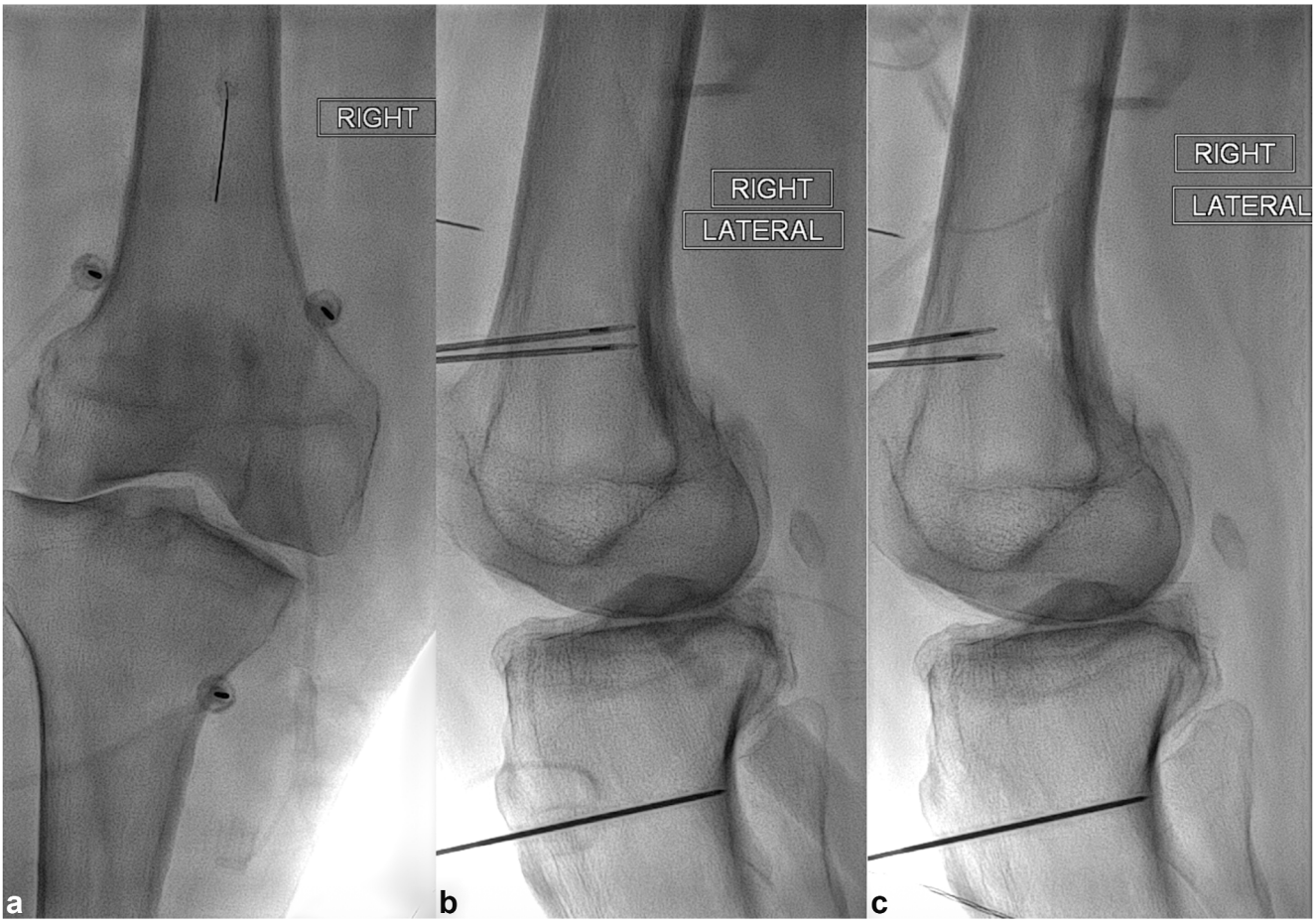

Figure 2. **(a)** Anteroposterior and **(b)** lateral fluoroscopic views of the right knee demonstrating ablation probe placement similar to the traditional genicular nerve ablation technique. **(c)** Lateral fluoroscopic view of the second ablation of the superomedial and superolateral genicular nerves after retracting the probe to one-third depth.

Table 2. Demographic Variables Stratified by Pull-Back Genicular Nerve Ablation

Characteristic	No, n = 41*	Yes, n = 26*	*P* value†
Gender			.5
Male, n (%)	9 (22%)	4 (15%)	
Female, n (%)	32 (78%)	22 (85%)	
BMI, kg/m^2	36 (29–42)	35 (31–47)	.8
Unknown	5	7	
Age, y	68 (60–73)	64 (58–69)	.2
Unknown, n (%)	2	1	

BMI = body mass index.
*n (%) or median (interquartile range).
†Pearson chi-square test or Wilcoxon rank sum exact test.

while the BMI of the tGNA group was 36 kg/m^2 (IQR, 29–42 kg/m^2), with a *P* value of .800. The demographic variables stratified by technique are demonstrated in Table 2.

History of fibromyalgia was also evaluated. In the pbGNA group, 0 patients reported yes to having fibromyalgia, and 25 patients (100%) reported no, whereas in the tGNA group, 2 patients (5%) reported yes and 95% reported no, with a *P* value of .500. In the pbGNA sample, 4 patients (16%) had prior surgery, and 21 patients (84%) did not, whereas in the tGNA sample, 14 patients (37%) reported yes and 24 (63%) reported no, with a *P* value of .07 as demonstrated in Table 3.

The mean baseline preprocedural VAS score was 8.52, and the 12-month postprocedural VAS score was 5.61, with a mean VAS change of −2.92 (95% CI, 2.01–3.82), with a statistically significant *P* value ($P < .001$). The mean baseline preprocedural WOMAC score was 64.76, and the 12-month postprocedural WOMAC score was 53.39, with a mean WOMAC change of 12.65 (95% CI, 5.38–19.91), with a statistically significant *P* value ($P = .001$), as demonstrated in Table 4.

Multivariate linear regressions with the difference in pain scores as the outcome and pull-back technique, BMI, age, and gender as covariates were performed to assess their relationship to the difference in pain scores for VAS and WOMAC, assuming that normality and pain scores are

Table 3. Clinical Variables Stratified by Pull-Back Genicular Nerve Ablation

Characteristic	No, n = 41*	Yes, n = 26*	*P* value†
History of fibromyalgia			.5
No, n (%)	37 (95%)	25 (100%)	
Yes, n (%)	2 (5.1%)	0 (0%)	
Unknown, n (%)	2	1	
Prior surgery			.073
No, n (%)	24 (63%)	21 (84%)	
Yes, n (%)	14 (37%)	4 (16%)	
Unknown, n (%)	3	1	

*n (%) or median (interquartile range).

Table 4. Comparison of the Means of Both Visual Analog Scale and Western Ontario and McMaster Universities Osteoarthritis Index Scores before and after Genicular Nerve Ablation Using the Paired t-Test

Test	Mean score before survey	Mean score after survey	Mean difference in score	95% CI	*P* value
VAS	8.52	5.61	2.92	2.01–3.82	<.001
WOMAC	64.76	53.39	12.65	5.38–19.91	.001

VAS = visual analog scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

continuous. Patients who underwent pbGNA had a 0.71 (CI, −2.51 to 1.10; $P = .435$) higher change in VAS score after adjusting for baseline VAS score, age, gender, and BMI; however, this was not statistically significant. Table 5 demonstrates linear regression with difference in VAS score as the dependent variable. Patients who underwent the pbGNA had a 15.39 (CI, −30.09 to −0.70; $P = .04$) higher change in WOMAC score after adjusting for baseline WOMAC score, age, gender, and BMI. Table 6 demonstrates linear regression with difference in WOMAC score as the dependent variable.

A subgroup analysis for patients with prior arthroplasty was performed with the same regression as above to assess the effect of prior surgery (TKA or unicompartmental knee arthroplasty) on the pain scale scores. Patients who underwent pbGNA had a 0.88 (CI, −2.79 to 1.04; $P = .360$) higher change in VAS score after adjusting for baseline prior surgery, baseline VAS score, age, gender, and BMI. Patients who underwent pbGNA had a 15.52 (CI, −30.58 to −0.46; $P = .040$) higher change in WOMAC score after adjusting for baseline prior surgery, baseline WOMAC score, age, gender, and BMI. The coefficients of the multivariate analysis for VAS and WOMAC did not change significantly in this subanalysis as shown in Tables 7 and 8.

Table 5. Linear Regression with Difference in Visual Analog Scale Score as the Dependent Variable

diffVAS		Coefficient (univariate)	Coefficient (multivariate)
Pull back	No		
	Yes	0.36 (–1.52 to 2.23, *P* = .704)	–0.71 (–2.51 to 1.10, *P* = .435)
Baseline VAS score		–0.90 (–1.25 to –0.56, *P* < .001)	–0.91 (–1.33 to –0.49, *P* < .001)
Age		–0.02 (–0.12 to 0.07, *P* = .617)	–0.00 (–0.09 to 0.09, *P* = .976)
Gender	Male		
	Female	–1.76 (–3.93 to 0.41, *P* = .110)	–0.33 (–2.61 to 1.94, *P* = .770)
BMI		0.10 (–0.01 to 0.20, *P* = .074)	0.10 (0.00 to 0.20, *P* = .042)

Note–Patients who underwent pull-back genicular nerve ablation had a 0.71 (CI, –2.51 to 1.10; *P* = .435) higher change in VAS score after adjusting for baseline VAS score, age, gender, and BMI; however, this was not statistically significant.
BMI = body mass index; VAS = visual analog scale.

Table 6. Linear Regression with Difference in Western Ontario and McMaster Universities Osteoarthritis Index Score as the Dependent Variable

diffWOMAC		Coefficient (univariate)	Coefficient (multivariate)
Pull-back	No		
	Yes	–13.46 (–28.00 to 1.07, *P* = .069)	–15.39 (–30.09 to –0.70, *P* = .040)
Baseline WOMAC score		–0.59 (–0.90 to –0.29, *P* < .001)	–0.44 (–0.79 to –0.09, *P* = .016)
Age		–0.07 (–0.80 to 0.66, *P* = .848)	–0.13 (–0.88 to 0.63, *P* = .732)
Gender	Male		
	Female	–6.61 (–26.47 to 13.25, *P* = .508)	–3.04 (–23.96 to 17.87, *P* = .771)
BMI		0.45 (–0.36 to 1.26, *P* = .271)	0.49 (–0.34 to 1.32, *P* = .241)

Note–Patients who underwent the pull-back genicular nerve ablation had a 15.39 (CI, –30.09 to –0.70; *P* = .04) higher change in WOMAC score after adjusting for baseline WOMAC score, age, gender, and BMI.
BMI = body mass index; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

Table 7. Subgroup Linear Regression Analysis to Evaluate the Effect of Prior Surgery with Difference in Visual Analog Scale Score as the Dependent Variable

diffVAS		Coefficient (univariate)	Coefficient (multivariate)
Pull-back	No		
	Yes	0.36 (–1.52 to 2.23, P = .704)	–0.88 (–2.79 to 1.04, P = .360)
Baseline VAS score		–0.90 (–1.25 to –0.56, P < .001)	–0.93 (–1.36 to –0.50, P < .001)
Prior arthroplasty	No		
	Yes	0.01 (–1.87 to 1.88, P = .995)	–0.53 (–2.35 to 1.29, P = .560)
Age		–0.02 (–0.12 to 0.07, P = .617)	–0.00 (–0.09 to 0.09, P = .990)
Gender	Male		
	Female	–1.76 (–3.93 to 0.41, P = .110)	–0.20 (–2.54 to 2.13, P = .862)
BMI		0.10 (–0.01 to 0.20, P = .074)	0.10 (0.00 to 0.20, P = .047)

Note–Patients who underwent pull-back genicular nerve ablation had a 0.88 (CI, –2.79, 1.04; P = .360) higher change in VAS score after adjusting for baseline prior surgery, baseline VAS score, age, gender, and BMI.
BMI = body mass index; VAS = visual analog scale.

Table 8. Subgroup Linear Regression Analysis to Evaluate the Effect of Prior Surgery with Difference in Western Ontario and McMaster Universities Osteoarthritis Index Score as the Dependent Variable.

diffWOMAC		Coefficient (univariate)	Coefficient (multivariate)
Pull-back	No		
	Yes	–13.46 (–28.00 to 1.07, P = .069)	–15.52 (–30.58 to –0.46, P = .044)
Baseline WOMAC score		–0.59 (–0.90 to –0.29, P < .001)	–0.44 (–0.80 to –0.08, P = .018)
Prior arthroplasty	No		
	Yes	7.60 (–7.76 to 22.97, P = .326)	–0.79 (–15.82 to 14.23, P = .916)
Age		–0.07 (–0.80 to 0.66, P = .848)	–0.13 (–0.89 to 0.64, P = .740)
Gender	Male		
	Female	–6.61 (–26.47 to 13.25, P = .508)	–2.91 (–24.23 to 18.42, P = .785)
BMI		0.45 (–0.36 to 1.26, P = .271)	0.49 (–0.35 to 1.33, P = .246)

DISCUSSION

This retrospective study evaluated the effectiveness and safety of a novel pbGNA technique compared with the traditional approach (tGNA) in patients with chronic knee OA undergoing cRFA. Although both techniques demonstrated clinically meaningful reductions in pain as measured by the VAS pain scale and WOMAC scores, the pbGNA technique yielded a greater improvement in function as assessed by WOMAC pain index.

The comparable reductions in VAS and WOMAC scores suggest that both methods are effective in reducing subjective pain perception in patients with knee OA. This supports prior literature demonstrating the effectiveness of GN RFA as a minimally invasive modality for pain management in OA (12). However, the significant improvement in WOMAC scores seen in the pbGNA group (P = .04) could indicate that the pull-back technique may provide superior functional outcomes. WOMAC, a composite measure of pain, stiffness, and physical function, offers a more comprehensive view of patient quality of life beyond pain reduction alone (13). Even though this is statistically significant, the large confidence interval and its closeness to 0 indicate that this relationship is questionable and would need to be investigated more.

The enhanced functional improvement with pbGNA is likely attributable to its design, which addresses known anatomical variability in GN distribution, particularly at the superomedial and superolateral sites (8). In 2022, Kim et al (8) reviewed 25 deidentified knee MR images and demonstrated that these nerves exhibit significant positional variation relative to standard bony landmarks, which may lead to incomplete denervation when using traditional probe placement alone (14). By adding a second ablation at a shallower depth, the pbGNA technique may increase the lesion volume and coverage of potential nerve branches that may be missed with standard probe positioning. This may allow for more thorough denervation and, consequently, improved joint function. This hypothesized mechanism remains speculative because pbGNA has not yet been validated in anatomical or imaging studies.

More broadly, GN ablation strategies are evolving alongside an improved understanding of knee joint innervation. Cadaveric and imaging studies have shown that

traditional fluoroscopic landmarks do not consistently align with the true course of the GNs, which may contribute to variable targeting and incomplete denervation (9–11). In response, revised anatomical models have highlighted a more complex and heterogeneous distribution of articular sensory branches, prompting the development of modified targeting strategies. These include ultrasound (US)-guided techniques and expanded protocols incorporating additional nerve targets beyond the classic 3-nerve paradigm (15). Collectively, this shift reflects a growing emphasis on maximizing lesion coverage and anatomical accuracy—principles that are inherently aligned with the pull-back technique and its attempt to better account for neural variability.

In the context of these evolving approaches, the present findings suggest that pbGNA may represent a practical procedural adaptation that improves functional outcomes without compromising safety. Baseline demographics such as age and BMI were similar between groups, indicating that observed differences were unlikely to be driven by patient-related factors. Additionally, the absence of reported adverse events based on the SIR adverse event classification system in either cohort further supports the safety profile of both techniques, including the novel pbGNA approach.

Although these findings are promising, this study is not without limitations. First, the retrospective nonrandomized design introduces inherent bias, including potential variability in technique due to operator preference and lack of standardized procedural training. Second, technique selection was operator-dependent, which may introduce selection bias and limits direct comparability between groups. Third, the relatively small sample size, particularly in the pbGNA group, may limit generalizability and the power to detect smaller differences in outcomes. There may also be confounding factors not accounted for, such as variations in treatment protocols or patient adherence, which could influence the observed outcomes. Although the 12-month follow-up period is clinically relevant, longer-term outcomes remain unknown, especially as OA is a chronic and progressive condition. Future prospective studies with larger cohorts with longer-term follow-up are needed to validate these findings and further explore the effectiveness of the pbGNA technique among other denervation strategies such as expanded 4- or 5- nerve targeting approaches. In addition, the pbGNA technique has not been validated anatomically, cadaverically, or using imaging surrogates; therefore, the proposed mechanistic explanation remains speculative.

Because some patients contributed bilateral GN ablations, the analyses may be affected by a unit of analysis issue, as knees from the same patient are not fully independent.

Finally, responder analyses was not performed (eg, the proportion of patients achieving ≥30% or ≥50% improvement), which would provide more clinically intuitive measures of treatment effect beyond mean score changes.

In conclusion, the pbGNA technique appears to offer improved functional outcomes compared with the traditional method, without compromising pain relief. However, given the modest effect size and borderline statistical significance, these findings should be interpreted with caution. Further prospective, adequately powered studies are needed to confirm these results and to better define the role of pbGNA in the interventional management of knee OA.

ACKNOWLEDGMENTS

The authors thank Ayah Arafat, MPH, MedStar Georgetown University Statistician.

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J.B.S. reports lecturer fees from Avanos Medical and is a consultant at Boston Scientific. K.H. reports research support from MediView. N.T. is a consultant at Boston Scientific. None of the other authors have identified a conflict of interest.

From the 2024 and 2025 SIR Annual Scientific Meetings (Abstract No. 368, "Does Pulling Back Push Outcomes Forward? A Prospective Analysis Comparing the Novel Needle Pull-back Technique versus the Traditional Needle Placement for Genicular Nerve Ablation for Knee Osteoarthritis"; Abstract No. 327, "12-Month Efficacy of the Pull-Back Technique for Genicular Nerve Ablation for Knee Osteoarthritis").

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