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Genicular Artery Embolization as a Treatment Option for Refractory Knee Pain Post Total Knee Arthroplasty: A Prospective Series

Nishanth Konduru[1] · Anton Hnatov[1] · Samuel Pravin Joshua[1] · Merna Metry[1] · Hardayal Singh[2] · Siddhartha Rao[1]

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Abstract

Purpose This study examines the efficacy of genicular artery embolization (GAE) as a treatment to reduce chronic knee pain in patients who have previously undergone total knee arthroplasty (TKA).

Materials and Methods Thirty-seven consecutive patients (13 men and 24 women) with a history of persistent pain for at least one year after TKA underwent GAE at a single center. The mean age across all patients was 72.8 ± 9.7 years, and the mean BMI was 29.3 ± 6.1 kg/m^2. Imipenem cilastatin particles and/or microspheres were delivered through a microcatheter to the targeted arteries by a board-certified interventional cardiologist. Clinical success was determined by degree of improvement in patient response to the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Visual Analog Scale (VAS) pain questionnaires at one-month and three-month intervals following successful embolization of targeted arteries.

Results Among 37 patients, WOMAC scores at the preliminary, one-month, and three-month follow-up appointments were 64% ± 6%, 39% ± 8%, and 36% ± 8%, respectively (95% CI). VAS scores were 8.1 ± 0.6, 3.2 ± 1.1, and 3.1 ± 1.0 (95% CI). A paired t-test showed a statistically significant improvement at both one-month and three-month post-procedure evaluations. ($p < 0.05$). Overall, 64.9% (n = 24) of patients achieved at least a 50% improvement in pain scores by the end of the study term.

Conclusion GAE shows efficacy as an adjunct treatment in patients with TKA and long-standing pain (> 1 year). Further research is needed to assess long-term outcomes and broader applicability.

✉ Siddhartha Rao
srao@vascularsolutions.org

[1] Rao Clinic, Cary, USA

[2] Carolina Regional Orthopaedics, Rocky Mount, USA

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Graphical Abstract

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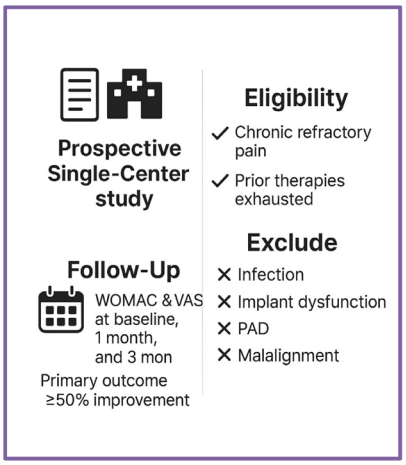
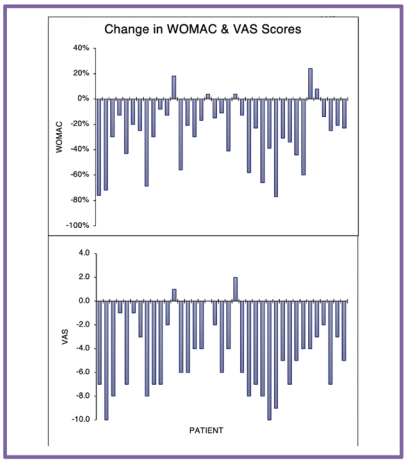
Genicular Artery Embolization as a Treatment Option for Refractory Knee Pain Post Total Knee Arthroplasty: A Case Series



Step	Action	Key Tool / Material
1.	**Access** (US-guided)	Retrograde or Antegrade
2.	**Angiography**	4F RIM/Berenstein Catheter
3.	**Sub-selection**	1.4F Caravel Microcatheter
4.	**Target Confirmation**	Pathologic blush under angiography
5.	**Embolization**	Imipenem-Cilastatin + Microparticles
6.	**Closure**	Angioseal/Celt/ Safeguard
7.	**Post-Care**	Celecoxib and tapered methylprednisolone



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Keywords Osteoarthritis · Pain · Arthroplasty · Embolization

Introduction

Total knee arthroplasty (TKA) is a surgical intervention performed for advanced cases of knee osteoarthritis (OA) [1], offering long-term pain relief and improvement in quality of life [2,3]. Despite its effectiveness, some patients report increasing pain within three months of their procedure [4,5]. Numerous studies have shown that approximately 20–25% of patients who undergo TKA have substantial chronic knee pain years after surgery [3,6–8]. Knee pain after TKA results in poor quality of life and general health, which can be attributed to multiple factors [5,9]. Treatment for these patients is complex, and there are typically few therapies which have not already been exhausted. Given the prevalence of TKA as one of the most commonly performed surgical interventions in the United States, and the proportion of patients who experience little improvement in pain [10], there is a clear need for adjunctive treatments that directly target chronic knee pain post-arthroplasty.

Literature suggests that angiogenesis contributes to synovitis in patients with OA, and inhibiting angiogenesis may be utilized as a potential treatment option [11,12]. Furthermore, evidence indicates that pain due to knee OA is influenced by inflammation of the synovium [11,13,14]. This pathology has prompted genicular artery embolization (GAE) to emerge as a form of knee pain management, given its specificity in treating the inflamed synovium [15,16]. GAE is a minimally invasive procedure in which embolic agents are used to block targeted blood vessels, reducing blood flow to the joint and alleviating inflammation [17,18]. Patients who continue to experience pain despite prior treatments such as pain medications, steroid injections, physical therapy, and/or TKA may benefit from undergoing GAE [14,19].

The objective of this study was to evaluate the clinical efficacy of GAE in treating post-operative knee pain persisting for over one year in patients who have undergone TKA. Disability and pain were measured using two metrics: The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), a comprehensive questionnaire designed to assess severity and treatment response in patients with knee or hip osteoarthritis [20], and the Visual Analog Scale (VAS), a 0–10 scale that allows patients to rate the level of pain they feel in their knee [21]. This study serves as a preliminary analysis of

GAE outcomes and efficacy post-TKA in relieving pain and improving disability.

Methods and Materials

This is a single-center prospective study with IRB approval. Participants in the study were referred by orthopedic specialists, pain management clinics, or self-referred. Patients were eligible for inclusion if they were over the age of 18, had already undergone TKA for OA, and continued to experience persistent, life-limiting pain for at least one year following surgery. These patients had not undergone GAE prior to their TKA procedure and had exhausted other treatment options for pain such as medications, steroid injections, and physical therapy. All patients who presented, independently or referred, with persistent pain underwent a detailed history, physical exam, and X-rays to rule out prosthetic joint infection and dysfunction by their orthopedic specialists. Patients with significant peripheral arterial disease and joint malalignment were also excluded based on examination, X-rays, and arterial duplex ultrasound when clinically indicated. After enrollment, baseline WOMAC and VAS scores were obtained from each participant to assess pain severity and functional status. WOMAC scores were normalized to a 0–100% scale, and VAS scores were measured on the 1–10 scale. The sample consisted of 37 consecutive patients who all returned for follow-up at one-month and three months post-GAE.

Procedures in this study were performed by a board-certified interventional cardiologist with additional fellowship training and certification in endovascular medicine from the American Board of Vascular Medicine. Ultrasound-guided arterial access was obtained using either a retrograde approach through a tibial vessel or an antegrade approach through the superficial femoral artery. A retrograde approach was primarily used due to the risk of complications associated with antegrade access. Antegrade access was used only when a retrograde approach was not feasible due to complete arterial occlusions. Selective popliteal artery angiography was then performed with a 4F 65 cm RIM or Berenstein catheter (Merit Medical). Target genicular arteries were sub-selected with a 1.4F 135 cm Caravel microcatheter (Asahi Intecc). Branches of the genicular arteries that fed regions of the synovium were targeted for embolization, with special consideration given to areas where patients reported the most pain during physical assessment. Additionally, branches that revealed significant blush with angiography were targeted. All genicular arteries were attempted to be cannulated and embolized. Embolization was not performed solely in cases where genicular arteries were diffusely diseased or did not

Table 1 Demographics for patients of the study cohort

Patient Demographics			
	Male	Female	Total
Count	13	24	37
BMI (kg/m^2)	29.3 ± 4.3	29.2 ± 6.9	29.3 ± 6.1
Age (years)	68.9 ± 10.1	74.9 ± 8.9	72.8 ± 9.7
Ethnicity			
White	9	17	26
Black	4	2	6
Asian	0	1	1
Hispanic	0	1	1
Other	0	3	3

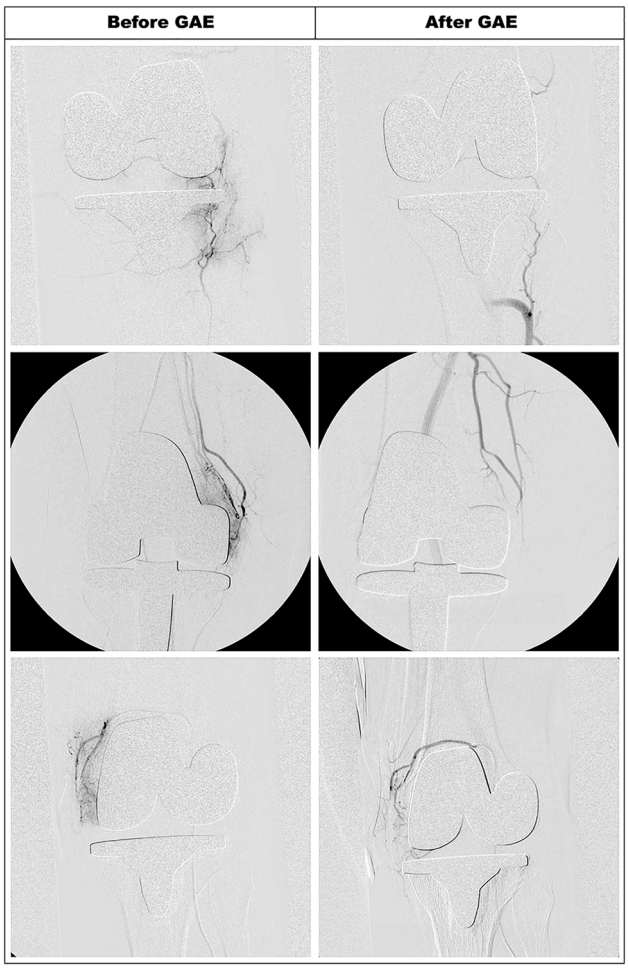

Fig. 1 Pre- and post-procedural angiographic imaging depicting reduced arterial blush following embolization accessed through a retrograde manner. Arteries depicted are as follows: Anterior tibial recurrent genicular artery (top), descending genicular artery (middle), superior medial genicular artery (bottom)

Table 2 Summary of outcomes and complications observed in study cohort. Pain scale scores were reported with mean and standard error (95% CI). Complications were resolved within 4 weeks post-procedure

Outcomes and Complications	
WOMAC Scores	
Pre-GAE	64% ± 6%
1-month post-GAE	39% ± 8%
3-month post-GAE	38% ± 8%
p-value	< 0.0001
VAS Scores	
Pre-GAE	8.1 ± 0.6
1-month post-GAE	3.2 ± 1.1
3-month post-GAE	3.1 ± 1.0
p-value	< 0.0001
Complications	
Joint stiffness	5 (13.5%)
Tenderness	1 (3.0%)
Total	6 (16.2%)
Treatment Efficacy	
>50% improvement	24 (64.9%)
<50% improvement	13 (35.1%)

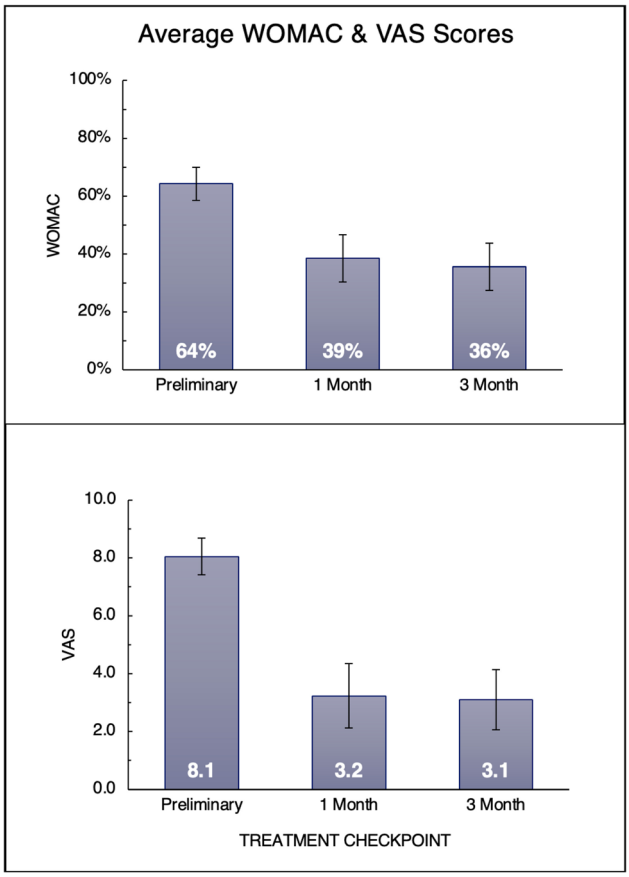

Fig. 2 Average WOMAC and VAS Scores pre- and post-GAE procedure. Error indicates a 95% confidence interval (CI). $p < 0.05$ at each post-procedure follow-up

demonstrate significant blush on angiography. Then, 50 mcg nitroglycerin was administered to prevent vasospasm from selective cannulation. A contrast injection allowed assessment of flow dynamics and demonstrated pathologic hyperemic blush prior to embolization. Saline flushing was performed before and after contrast administration. Imipenem-cilastatin was suspended in iodinated contrast to form embolic particles and embolization was subsequently performed using this suspension along with off label use of either 100–300 μm Embospheres (Merit Medical) or 125–275 μm Hydropearls (Terumo Medical) until pruning of the inflammatory blush was noted on angiography. Hemostasis was obtained using either a 26 cm Safeguard Radial (Merit Medical), Angioseal (Terumo Medical), or a Celt closure device (Vasorum). An exchange to a 5-6F 11 cm Prelude sheath introducer (Merit Medical) was performed when a femoral artery closure was necessary. Patients were discharged within 30–90 minutes post-procedure and prescribed celecoxib 200 mg orally as needed for seven days, and a six-day tapered course of oral methylprednisolone (Medrol Dosepak, 4 mg) to assist with any immediate post-procedural soreness.

For this study, treatment outcomes were determined to be clinically successful if pain scores decreased by more than 50%, as this is a widely used metric in clinical research of this nature [11,18,22,23]. Unintended treatment outcomes were defined as a reported increase in WOMAC or VAS scores. These cases were used solely to assess treatment efficacy and were not excluded from the statistical analyses. Clinical significance of GAE outcomes following the procedure was determined through statistical analysis. Statistical significance in average WOMAC and VAS scores was evaluated using a paired t-test, with a p-value threshold of 0.05. Patient data was verified to have a normal distribution through the Shapiro–Wilk test.

Results

In this study cohort, the mean age was 72.8 ± 9.7 years, and the mean BMI was 29.3 ± 6.1 kg/m^2. Patients in the clinic presented with refractory knee pain for 1 to 20 years after TKA, with a median duration of 5.0 years and a mean of 5.92 ± 5.0 years (Table 1). Average GAE procedure time was 53.6 ± 16.4 min. All patients had at least two arteries embolized during the procedure, with an average of 3.3 ± 1.1 arteries embolized. Embolized arteries resulted in cessation of arterial blush in 100% of treated arteries

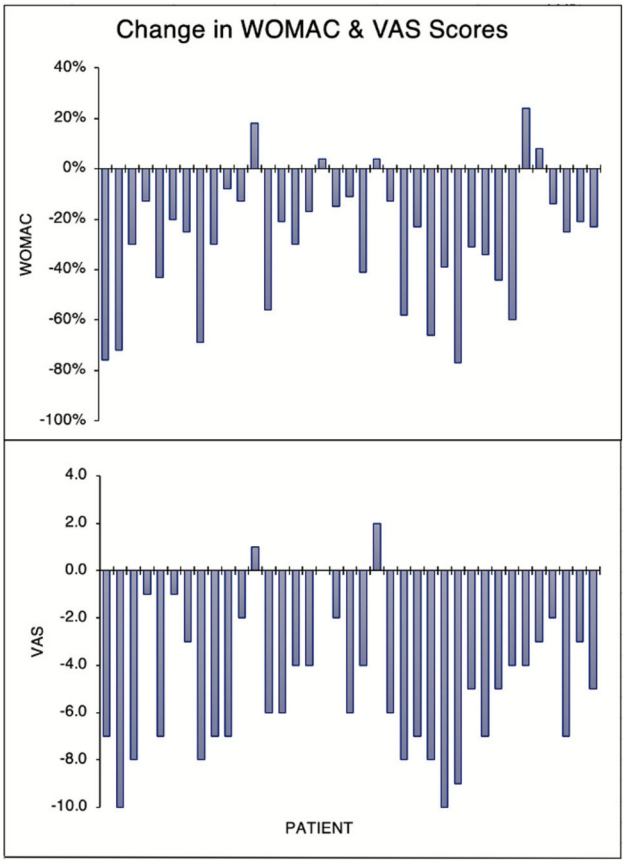

Fig. 3 Bar chart depicting change in WOMAC (top) and VAS (bottom) scores for at the end of the study period. Bars on the graph correspond to each patient and are in chronological order of treatment performed

(Fig. 1). No patients were brought back for repeat embolization in this study.

Major post-procedural complications such as hemorrhaging or pseudoaneurysms were not reported. Minor complications included joint stiffness in five patients (13.5%) and tenderness or swelling of the access site in one patient (3.0%) (Table 2). Complications were resolved within four weeks post-procedure.

Among the 37 patients, WOMAC and VAS scores in the study group improved at one- and three-month post-procedure. Average WOMAC scores decreased from 64% ± 6% to 39% ± 8% and then to 36% ± 8% (95% CI) at one and three months, respectively. Average VAS scores decreased from 8.1 ± 0.6 to 3.2 ± 1.1 and then to 3.1 ± 1.0 (95% CI). In the study cohort, 64.9% (n = 24) of patients reported a clinically significant improvement (> 50%) in pain scores. This indicates a substantial reduction in perceived functional limitations and pain. WOMAC and VAS scores showed statistically significant improvements ($p < 0.05$) (Fig. 2, Fig. 3). In this study, 35 out of 37 patients reported no longer requiring analgesics to manage pain.

An unfavorable treatment outcome was defined as a less than a 50% decrease in either WOMAC or VAS scores at the end of the study period. Out of 37 patients in the study, 13 did not meet the clinical success criteria by the end of the assessment period. Within this subgroup, 10 patients reported pain relief, but to a degree less than 50%, and three patients experienced no pain relief.

Discussion

All patients in the study demonstrated significant blush on sub-selective genicular artery angiography, indicating hypervascularity contributing to inflammation and pain [11,12]. Technical success, defined as the embolization of at least two arteries in a patient, was achieved in 100% of cases. At three-month follow-up, 86.5% of patients in the study experienced pain relief, with 64.9% reporting greater than 50% reduction in pain scale scores. Furthermore, no patient reported needing to use pain medication outside of the prescribed oral celecoxib and tapered methylprednisolone for seven days post-procedure. These medications were not identified as confounding factors of pain relief, as their half-lives do not exceed one day. The significant pathological and statistical improvements observed underscore the value of integrating GAE into treatment protocols when managing refractory pain following TKA. These findings are consistent with a study which reported substantial pain reduction and improved function following GAE in 16 patients with refractory post-TKA pain [24].

A notable finding of this study is the statistically significant reduction in pain levels, which followed the observed decrease in synovial inflammation after embolization. The patients in the study cohort had endured persistent, life-limiting knee pain for 1–20 years following TKA. Follow-up subselective angiography and radiographic imaging were not performed unless clinically indicated, as this is not protocol in most studies related to GAE [11,18,19].

No patient had outcome-limiting periprocedural complications. In the study cohort, five (14.5%) cases presented with chronic total occlusions of the anterior tibial artery, which required recanalization immediately prior to GAE, demonstrating clinical variation in patient vascular anatomy. Recanalization of these arteries was not identified as a confounding variable in this study, as occlusions in the tibial artery can be either asymptomatic or associated with critical limb ischemia and foot and toe ulcers below the knee, rather than knee pain. Studies indicate that up to 65% of GAE cases experience limited skin mottling, discoloration, and skin ulceration post-procedure. [25] This center's post-arteriotomy care protocol helps limit post-procedural bleeds, hematomas, and/or pseudoaneurysms.

Skin discoloration or ulceration may result from an allergic reaction to embolic agents or from embolization of arteries near the skin, which is mitigated by distal catheter positioning and the use of an ice pack peri-procedure. Immediately before discharge and at one-month follow-up, all patients were clinically examined and found to be free of distal ischemia.

In this study, one patient reported tenderness around the knee, which had subsided by the one-month visit. The most prevalent post-procedural complication in this study was increased knee stiffness among five of 37 treated patients, which subsided by the one-month appointment. This self-limiting complication may be an interventional outcome related to post-embolization inflammation.

Future studies should focus on understanding the durability of pain relief and functional improvement following GAE with follow-up periods extending to six or twelve months. Large-scale multicenter trials are needed to assess the generalizability of the results found in this study across diverse patient populations. Although this study establishes GAE as a method for improving patient quality of life, it lacks the scope to determine its lifelong viability or generalizability across a larger population. This study also faces the risk of selection bias and unintended confounding, given its single-center, uncontrolled case series design. Alternative studies that investigate these limitations will help clarify the clinical indications and the viability of using GAE as a post-TKA intervention.

Conclusion

Findings from this study indicate that GAE may be used as an effective, safe, minimally invasive treatment adjunct for persistent post-TKA pain when revision surgery is not indicated. GAE shows efficacy as a short-term pain relief strategy in patients with TKA and long-standing pain (> 1 year). Larger, multicenter trials are needed to confirm long-term efficacy, refine patient selection, and establish the role of GAE in treating chronic post-TKA pain.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent for Publication Consent for publication was obtained for every individual person's data included in the study.

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