Transcatheter Arterial Embolization of Abnormal Neovessels for Patellar Tendinopathy: A Safety Evaluation

A Proof-of-Concept Study

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Background: Patellar tendinopathy (PT) is common among athletes, and the current care is largely palliative.

Purpose: To evaluate the safety of transcatheter arterial embolization (TAE) in patients with PT refractory to nonoperative treatments.

Study Design: Case series; Level of evidence, 4.

Methods: This was a multicenter, retrospective study in which recalcitrant PT was treated using TAE. TAE was performed by infusing temporary embolic material through a catheter inserted into the targeted genicular artery. Complications, numeric rating scale (NRS) for pain, Victorian Institute of Sport Assessment for the patella (VISA-P), time to return to training, and ultrasound findings were reported.

Results: Between March 2017 and February 2023, a total of 98 patients with PT underwent TAE. Nine patients were lost to follow-up, and the remaining 89 patients (69 male; mean age, 26.1 ± 11.9 years) were followed up for 1 to 7 years (mean, 31.2 ± 16.1 months) after TAE. No major complications were observed. Mean VISA-P score improved from 24.9 ± 15.3 at baseline to 43.2 ± 21.6, 55.2 ± 22.3, and 67.4 ± 24.7, at 1, 3, and 6 months of follow-up, respectively. Mean NRS for pain improved from 7.6 ± 1.4 at baseline to 4.5 ± 2.3, 3.5 ± 2.4, and 2.7 ± 2.4 at the corresponding time points. VISA-P and NRS scores were 74.6 ± 26.2 and 2.3 ± 2.7, respectively, at the final follow-up. Mean times for return to light and full training were 7.8 ± 8.7 and 14.3 ± 11.5 weeks, respectively. Ultrasound demonstrated decreased patellar tendon thickness (9.5 ± 1.8 mm at baseline vs 6.6 ± 1.3 mm at the final follow-up) without tendon ruptures.

Conclusion: TAE can be considered a safe alternate to existing treatment options for recalcitrant PT. A randomized controlled trial is required to elucidate its efficacy.

Keywords: patellar tendinopathy; jumper's knee; transcatheter arterial embolization; TAE

Patellar tendinopathy (PT) is a major cause of chronic anterior knee pain in athletes participating in sports with high demand on the knee extensor mechanism. The prevalence of PT in jumping sports, such as elite basketball or volleyball players, reaches 32% to 50%.[16,17] The management of PT presents a challenge as the treatments currently available are palliative. Eccentric loading is frequently the first-line treatment option for PT.[40] In cases of unresponsiveness to nonoperative options, an operative treatment is considered despite the limited evidence.[36]

Ultrasound (US) is commonly used to establish an imaging diagnosis of PT. Sonographic findings of PT include decreased echogenicity, disorganized echotexture, and intratendinous calcification. Neovascular proliferation can also be seen with the use of color Doppler mode.[32]

The Orthopaedic Journal of Sports Medicine, 13(6), 23259671251337093
DOI: 10.1177/23259671251337093

Alfredson et al[1] demonstrated vascular/neural ingrowth in areas of painful tendon by demonstrating the presence of substance P–positive nerves located near the newly formed blood vessels. These findings indicate that the area with neovessels and the accompanying nerves might be of significant importance and possibly a source of pain in patients with PT.

Recent investigations have demonstrated the therapeutic benefits of transcatheter arterial embolization (TAE) in addressing inflammation and pain by occluding aberrant blood vessels that proliferate in chronic inflammatory tissues. Both safety and efficacy have been reported for frozen shoulder,[21] lateral epicondylitis,[3,11] and knee osteoarthritis.[35,37] The mechanism is believed to involve the occlusion of neovascularization resulting from inflammation, leading to a reduction in the number of inflammation-induced neovessels, infiltration of inflammatory cells, and alleviation of inflammation severity.[9,31,34] TAE can be performed without ischemic complications owing to the use of temporary embolic substances. Although existing reports attest to the safety and efficacy of TAE, the safety and long-term efficacy of applying this technique to PT remain unexplored.

The aim of the present study was to evaluate the long-term safety and outcomes of TAE in athletic patients with PT refractory to nonoperative management.

METHODS

This retrospective, multicenter, case series was performed by analyzing medical records. Written informed consent was obtained from all patients before the procedure, and an opt-out method was used to secure opportunities for referral from the patients. Our institutional review board approved this retrospective study (OC 2024-014).

Population

The study included patients with PT who underwent TAE at 4 outpatient clinics between March 2017 and February 2023. The diagnosis of PT was confirmed through physical examination showing tenderness localized to the inferior pole of the patella and a patellar tendon thickness of $\geq$7 mm on US.[19] Eligible patients were 16 years or older, had a pain score $\geq$4 on a 0- to 10-point numeric rating scale (NRS), and were resistant to nonoperative therapy for $\geq$3 months. Patients with a history of advanced atherosclerosis, local infection, malignancy, mental illness, pregnancy, rheumatoid arthritis, or previous knee tendon surgery were excluded.

Procedures

All procedures were performed in the outpatient clinic. An ipsilateral femoral artery puncture was performed under US guidance, and a 3F angiographic catheter was inserted intra-arterially toward the target lesion. Digital subtraction angiography was then performed for the popliteal artery, inferior lateral genicular artery, descending genicular artery, and inferior medial genicular artery. Once the abnormal neovessels were localized, a microcatheter (Asahi Veloute; Asahi Intecc Co) was inserted coaxially through the 3F catheter and selectively placed in the targeted abnormal neovessels to infuse embolic materials. Abnormal neovessels were characterized by a "tumor blush"–type enhancement that appeared during the arterial phase and was often accompanied by early venous drainage. Imipenem/cilastatin sodium (IPM/CS) (Primaxin; Merck & Co) or NBGM200 (Nexsphere-F; NextBiomedical Co) was used as temporary embolic material. IPM/CS comprises crystalline compounds that are slightly soluble in water; when suspended with a contrast agent, they form particles that exert temporary embolic effects.[41] A suspension of 1.0 g of IPM/CS in 10 mL of iodinated contrast agent was prepared and then injected in 0.2-mL increments until near stasis of contrast media was achieved in the targeted artery. NGBM200 is a short-dissolution gelatin spherical embolic material, with 90% volume dissolution within 8 hours. NBGM200 was administered in 0.1- to 0.2-mL doses with 200 mg mixed with 10 mL of saline and 10 mL of contrast medium. IPM/CS was used from March 2017 to July 2021, whereas NBGM200 was used from August 2021 to February 2023. Postprocedure angiography was performed to confirm the proper temporary occlusion of the neovessels evidenced by the disappearance of aberrant vessels at the proximal patellar tendon. If an abnormal pattern was still present, additional embolic material was injected through the same catheter. Figures 1 and 2 show examples of the angiographic images.

After the disappearance of the abnormal neovessels was confirmed, the catheter was removed. Hemostasis was achieved via manual compression for 10 minutes and patients rested for 1 hour after the procedure. The patients were discharged on the same day.

Two procedures were planned at the study entry, with the second procedure scheduled 1 to 2 months after the

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Final revision submitted November 6, 2024; accepted January 6, 2025.
One or more of the authors has declared the following potential conflict of interest or source of funding: Y.O. has received consulting fees from Asahi Intecc Co, Terumo Corporation, Shimadzu Corporation, and Guerbet and is an advisory board member of Clearfynamic Inc and Nextbiomedical Co. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from Medical Corporation Yuyu-kai (OC 2024-014).

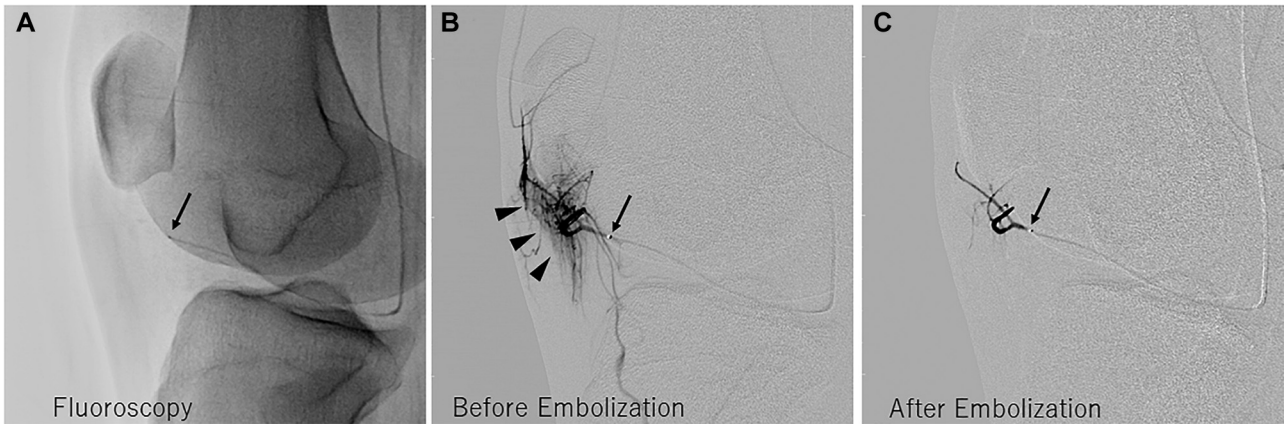

Figure 1. Fluoroscopic findings in a 19-year-old man with patellar tendinopathy. Digital subtraction angiography from the right inferior genicular artery before (b) and after (c) embolization. Abnormal neovessels (''tumor blush''–type enhancement; black arrowheads, b) disappeared after embolization. Black arrow: catheter tip.

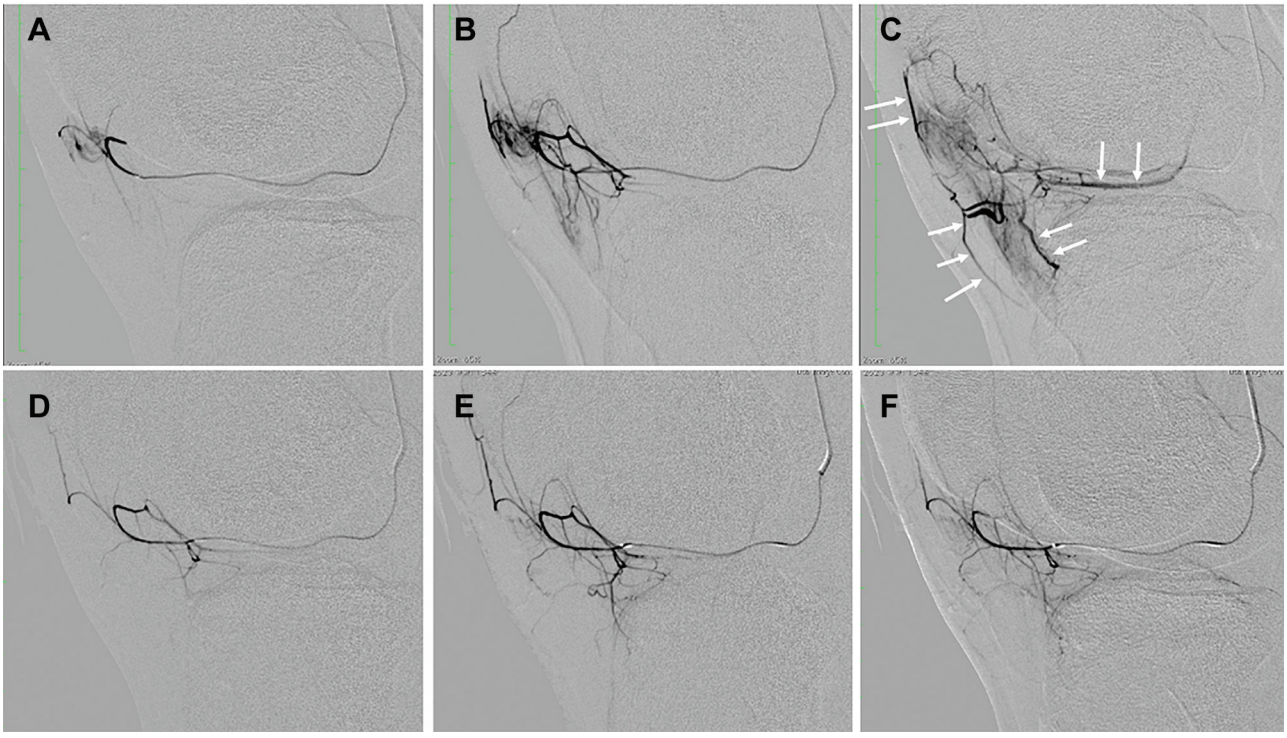

Figure 2. Selective angiography in a 21-year-old woman with patellar tendinopathy before and after embolization. Digital subtraction angiography from the right inferior genicular artery before (a-c) and after (d-f) embolization. Abnormal neovessels and early venous return (white arrows, c) disappeared after embolization.

first. If the patients' pain was sufficiently relieved by the first procedure, they were allowed to skip the second procedure. Patients were encouraged to gradually resume training, starting at an intensity that they could comfortably perform without experiencing pain, and were instructed to keep their pain level <3 out of 10 while increasing the intensity of their training. Patients were allowed to continue with previous nonoperative therapies except for corticosteroid injections, and the use of these nonoperative therapies was recorded at every follow-up visit.

Outcomes

Adverse events, as defined by the Society of Interventional Radiology classification, were recorded.[13] Additionally,

TABLE 1
Patient Characteristics[a]

	Data
Age, y	26.1 ± 11.9 [16-56]
Female sex	20 (22)
Body mass index, kg/m^2	23.5 ± 3.4 [18-40]
Affected side, right/left/both	27/32/30
Duration of symptoms, mo	23.3 ± 28.5 [6-120]
Level of sport, professional/college/high school/recreational	16/17/29/27
Sports type	
Soccer	27 (30)
Basketball	13 (15)
Track and field	12 (13)
Volleyball	9 (10)
Baseball, softball	8 (9)
Badminton	3 (3)
Rugby	3 (3)
Others (football, ice hockey, weightlifting, gymnastics, judo, trampoline, cheerleading, climbing, handball, figure skating, fencing, boxing, lacrosse)	1 each

[a]The data are presented as n, n (%), or mean ± SD [range].

patients were asked whether they experienced any of the following symptoms: newly occurring pain, peripheral paresthesia, knee instability, or muscle weakness. Patients were encouraged to report any other symptoms at each visit.

All patients completed the Victorian Institute of Sport Assessment for the patella (VISA-P), the NRS for maximum pain, and the modified Blazina score. The modified Blazina score is a pathology-specific outcome measure that uses a 5-stage scoring system depending on the symptoms (0 = no pain, 1 = pain after intense sports activity, 2 = pain at the beginning of and after sports activity, 3 = pain during activity at a satisfactory level, 4 = pain during sports activity at a nonsatisfactory level, and 5 = pain during daily activity).[39] These assessments were conducted at baseline before the procedure and then at 1, 3, and 6 months and at the final follow-up.

Return to training was defined as the point in recovery when a patient was able to resume playing sports or engaging in an activity. The number of weeks until patients could perform light-intensity and full-intensity training was also recorded. Full-intensity training was defined as the same practice in which uninjured teammates were performing, whereas light-intensity training was defined as the patient performing anything less than their uninjured counterparts.

All patients were examined before treatment and at the final follow-up with US, measuring tendon thickness, tendon structure scores, and neovascularization scores (ie, modified Ohberg scores). Tendon structure was scored on a 4-point scale of 0 to 3 based on previous reports.[32] In brief, 0 indicated normal structure (homogeneous echogenicity), 1 indicated light structural changes (discrete hypo-echogenic areas), 2 indicated moderate structural changes (some well-defined hypo-echogenic areas), and 3 indicated severe structural changes (extended hypo-echogenic areas). Neovascularity was scored as follows: 0 for no neovascularization, 1 for mild neovascularization (a few solitary blood vessels), 2 for moderate neovascularization (moderate quantity, mostly transversal blood vessels), and 3 for severe neovascularization (several, mostly horizontal blood vessels spread throughout the depth of the tendon). Other qualitative findings were also recorded during these US examinations.

Statistical Analysis

All data were statistically analyzed using IBM SPSS Advanced Statistics 20.0 software. Baseline and outcome variables were compared using Dunnett post hoc test to determine changes in NRS scores, VISA-P scores, and range of motion examination at each time point. $P < .05$ was considered to indicate a statistically significant difference.

RESULTS

A total of 98 patients with PT were treated with TAE between March 2017 and February 2023. Nine patients were lost to follow-up and the remaining 89 patients (69 male; mean age, 26.1 ± 11.9 years) were followed for 1 to 7 years (mean 31.2 ± 16.1 months) after TAE (Table 1).

Of 89 patients, 16 were professional athletes, 17 were collegiate athletes, 29 were high school athletes, and 27 were recreational athletes. No significant differences were found between these 4 groups in pretreatment NRS, pain duration, modified Blazina score, tendon thickness, tendon structure score, or tendon neovascularization scores. All TAE procedures were performed successfully. Abnormal vessels were identified in all 89 patients (Figures 1 and 2). Early venous drainage (Figure 2; see the online Video Supplement for this technique) was

evident in 79 of the 89 patients. In total, 56 patients were treated with IPM/CS and 33 patients with NBGM200. No significant differences were noted in pretreatment NRS, pain duration, Blazina score, or tendon thickness between the 2 groups, but the NBGM200 group had a significantly higher neovascularization score than the IPM/CS group (2.63 ± 0.69 vs 2.15 ± 0.64, respectively; $P = .0048$).

Of the 89 patients, 41 patients underwent a second TAE. During the second procedures, abnormal neovessels were identified although the vascularity scores were lower than those found during the first TAE in all patients.

No major adverse events were related to the procedures. A temporary increase in pain at the treatment site was observed in 5 patients, and a transient subcutaneous hematoma at the punctured area was observed in 4 patients, all of whom improved spontaneously within a week. Tissue necrosis, dermal ulcers, muscle weakness, or peripheral paresthesia did not occur in any embolized territory during the follow-up period.

The mean VISA-P scores before treatment and at 1, 3, and 6 months after treatment and the final follow-up were 24.9 ± 15.3, 43.2 ± 21.6, 55.2 ± 22.3, 67.4 ± 24.7, and 74.6 ± 26.2, respectively (all $P < .001$). NRS pain scores at the corresponding time points were7.6 ± 1.4, 4.5 ± 2.3, 3.5 ± 2.4, 2.7 ± 2.4, and 2.3 ± 2.7 (all $P < .001$). The reduction in NRS pain score from pretreatment to 6 months after treatment for patients at each sport level was 5.7 ± 2.2 for professionals, 4.7 ± 3.0 for college students, 5.0 ± 2.7 for high school students, and 4.0 ± 3.1 for recreational athletes, with the largest improvement seen in the professional athletes. Although the NBGM200 group had a greater mean NRS reduction at 6 months than the IPM/CS group, the difference did not reach statistical significance (5.5 ± 2.9 vs 4.4 ± 2.7, respectively; $P = .093$). No significant differences were observed between the IPM/CS and NBGM200 groups at other time points. Figure 3 shows the modified Blazina scores at pretreatment, 1, 3, and 6 months after treatment, and the final evaluation.

Of the 89 patients, 80 were able to return to full training within 1 year of the initial treatment. The mean times for return to light training and full training were 7.8 ± 8.7 weeks and 14.3 ± 11.5 weeks, respectively. The mean time from the initial TAE to return to full training by sport level was shortest for professional athletes (8.9 ± 4.7 weeks) and longest for recreational athletes (21.9 ± 16.9 weeks), with significant differences between the 2 groups (Figure 4).

US images demonstrated decreased thickness of the patellar tendon from baseline to the final follow-up (9.5 ± 1.8 vs 6.6 ± 1.3 mm, respectively; $P < .001$) (Figure 5). Structure scores improved from a preoperative mean of 2.10 ± 0.59 to 0.65 ± 0.79 at the final follow-up. Neovascularity scores decreased from a preoperative mean of 2.34 ± 0.70 to 0.73 ± 0.86 at the final follow-up. No sonographically visible tendon tear was found during the follow-up US examinations.

The changes in concomitant therapy during study period are shown in Table 2.

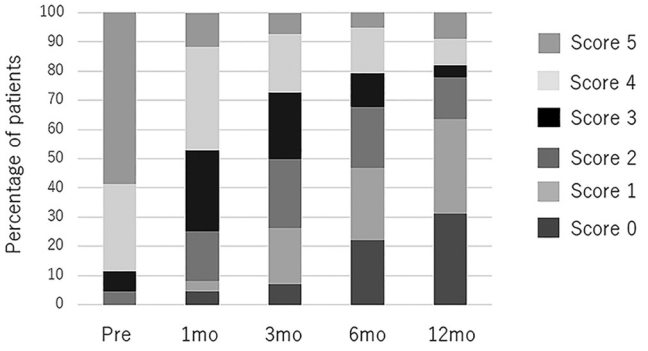

Figure 3. Bar graph showing the percentage change in modified Blazina scores before transcatheter arterial embolization (TAE); at 1, 3, and 6 months after TAE; and at the final evaluation.

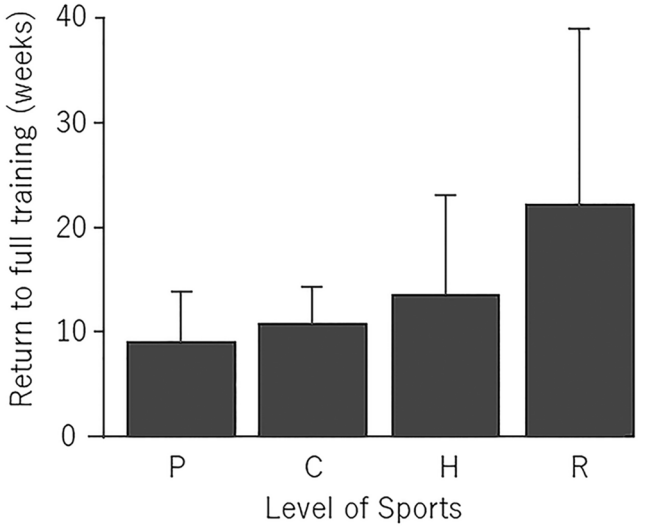

Figure 4. Bar graph showing the mean time from the initial transcatheter arterial embolization to return to full training by sport level. The duration was shortest for professional athletes (8.9 ± 4.7 weeks) and longest for recreational athletes (21.9 ± 16.9 weeks), with significant differences between the 2 groups. C, college athletes; H, high school athletes; P, professional athletes; R, recreational athletes.

DISCUSSION

The present study revealed a high safety profile for TAE when used for recalcitrant PT in athletic patients, with significant reductions in pain and functional improvements persisting up to 7 years. A statistically significant change was seen from baseline to the last observed value in both pain NRS and VISA-P scores. The mean time to return to light and full training was 7.8 and 14.3 weeks, respectively, with professional athletes returning to full training earlier than those in other groups. Additionally, US

TABLE 2
Number of Patients Who Used Other Nonoperative Treatments During the Study Period[a]

Treatment Option	Before Treatment	1-mo Follow-up	2-mo Follow-up	6-mo Follow-up	Final Assessment
Physical therapy	74	11	6	5	3
Hyaluronic acid injection	29	0	0	0	0
Steroid injection	22	0	0	0	0
Platelet-rich plasma injection	10	0	0	2	1
Extracorporeal shock wave therapy	35	0	0	1	1
Oral NSAIDs daily	18	4	0	0	0
Oral NSAIDs as needed	21	6	5	2	3

[a]NSAID, nonsteroidal anti-inflammatory drug.

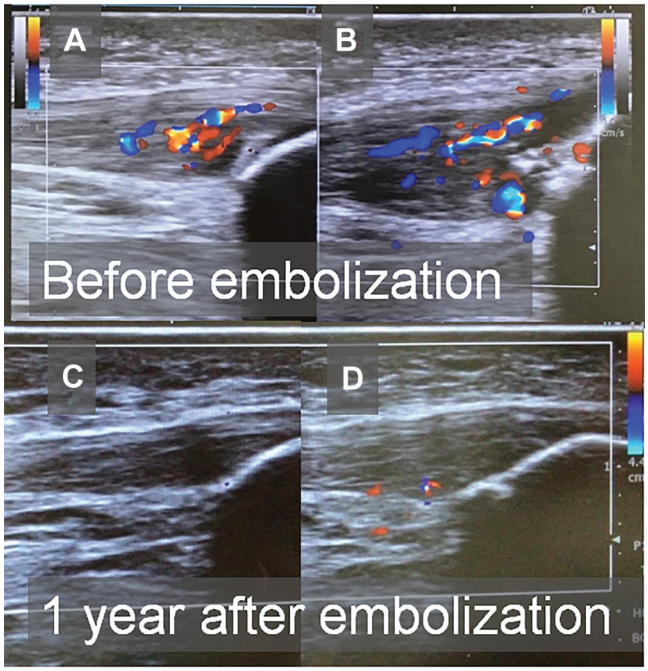

Figure 5. Ultrasound imaging of patellar tendon before and 1 year after embolization.

findings improved in terms of tendon thickness, structural score, and neovascularity score.

Existing treatments have shown limited efficacy for recalcitrant PT. Eccentric exercise using a 25° inclined board has shown benefits.[2,8,15,20,27] Various outpatient procedures have been trialed with some success, including platelet-rich plasma injection, extracorporeal shockwave therapy, sclerosing therapy/prolotherapy injection, tendon scraping/neovessel ablation, and, most recently, bone marrow concentrate aspirate.[2,5,8,15,20,27,29,38]

Surgery is generally reserved for patients who do not respond to nonoperative treatments within 3 to 6 months.[8,27,29] Studies have suggested that the outcomes of surgical intervention may not be influenced by whether surgery is performed within 1 year or after a longer duration after the onset of symptoms.[23] Given this, it seems appropriate to compare the results of the current study with those from surgical treatments, as those populations most closely resemble those included in this investigation. Pascarella et al[23] examined 64 professional athletes with Blazina stage II (41%) and stage III (59%) PT, reporting an improvement in mean VISA-P scores from 35.3 preoperatively to 69.8 at 1 year and 70.5 at 3 years after debridement/repair. Bahr et al[4] evaluated 35 athletes with Blazina stage IIIB, showing an improvement in mean VISA-P scores from 30 preoperatively to 49 at 3 months, 58 at 6 months, and 70 at 12 months after debridement. Khan et al[14] assessed 15 athletes, reporting an improvement in median VISA-P scores from 22 preoperatively to 51 at 6 months and 69 at 12 months, as well as 74.6 at the final follow-up (mean, 3.9 years) after debridement.

In the current study, which included more severe cases with Blazina stages II (4.5%), III (6.7%), and IV/V (89%), pretreatment VISA-P scores of 24.9 increased to 55.2 at 3 months, 67.4 at 6 months, and 74.6 at the final follow-up (mean, 31 months) after TAE. The baseline VISA-P scores in the above studies were relatively similar, at 35.3 (Pascella[23]), 30 (Bahr[4]), and 22 (Kahn[14]). Additionally, the current study found better outcomes at each time point, with VISA-P scores of 55.2 (current) versus 49 (Bahr) at 3 months, 67.4 (current) versus 58 (Pascella) and 51 (Bahr) at 6 months, and 74.6 (current) versus 69.4 (Pascella) and 70.7 (Peers[24]) at the final follow-up. Although this is a proof-of-concept study and has certain limitations inherent to a retrospective design, such as the absence of a control group and randomization, the findings suggest that TAE has the potential to offer treatment effectiveness comparable to surgery. A randomized trial comparing surgery and TAE is necessary to solidify the evidence and clarify the relative benefits of each.

Consistent with previously published studies on TAE,[3,11,22,35,38] our current study observed no significant adverse events. Any mild procedure-related adverse events reported were self-limited, resolving spontaneously within a week without the need for additional treatment. The absence of significant adverse events may be attributed to the specific embolic material used in this study, particularly the use of small quantities of temporary embolic material. These outcomes imply that TAE is a safe and well-tolerated treatment for PT.

Normal adult human tendons and entheses have relatively low vascularization because of limited metabolic

requirements.[18] Pufe et al[25] indicated that increased vascularity might be involved in the pathogenesis of tendinopathy. In the present study, abnormal neovessels were observed in all 89 patients and treatment was not interrupted due to a lack of abnormal neovessels. This indicates that the presence of abnormal neovessels can be observed with high frequency for patellar tendonitis. In addition, angiographic findings before embolization showed that injected contrast agent toward the pathologic site drained to a vein rather quickly, termed *early venous drainage*, in 79 of the 89 patients. This finding indicates that an arteriovenous shunt is present and that increased blood flow under these conditions does not necessarily distribute to the peripheral tissues of tendons and entheses.

Although the precise mechanism driving the therapeutic effect induced by arterial embolization on abnormal neovessels remains incompletely understood, several in vivo studies have provided insights into potential mechanisms. Ghelfi et al[9] demonstrated a reduction in abnormal neovascularization in a pig model of PT after intra-arterial administration of IPM/CS or microspheres. Similarly, Kamisako et al,[12] using a pig knee arthritis model, revealed that intra-arterial administration of IPM/CS or gelatin embolic substances led to diminished abnormal neovascularization, reduced nerve fiber stimulation, and enhanced physical activity. Hypothetically, in cases of PT, newly formed abnormal neovessels around implicated nerves might serve as a pain source. Diminishing these abnormal neovessels could potentially reduce disease-related stimulation, subsequently mitigating tenderness.

Steroid injections for PT are known to provide good pain relief in the short term at 1 month but lose their effectiveness in the mid- to long-term[15] and are therefore considered palliative. In the present study, TAE resulted in clinical efficacy for PT in both the short- and long-term, suggesting that this treatment offers continuous improvement rather than just a palliative effect. A similar course has been reported in treating common extensor tendon and Achilles tendon tendinopathy using TAE.[11,22] The strength of the current study is that it followed a longer course than previous studies to report a long-term safety and outcomes.

Return to sport or exercise after tendinopathy treatment can vary significantly, influenced by factors such as the type of tendinopathy, treatment method, patient-specific factors, and rehabilitation protocols and duration. In the current study, the duration from the initial TAE to return to full training was notably shorter for professional athletes than for recreational participants. A possible explanation is that athletes may recover to their preinjury activity levels quicker than nonathletes due to athletes' superior initial fitness levels and access to more intensive rehabilitation programs.

In the realm of sports medicine, US imaging plays a pivotal role in diagnosing and monitoring tendinopathy, a common ailment among athletes.[28] Not only does US offer cost-effectiveness and flexibility in various settings, but its high spatial resolution stands out compared with magnetic resonance imaging. US findings for tendinopathy typically include neovascularization, structural changes, and hypoechoic areas within the tendons.[10] Previous investigations have shown a compatible trend of a high probability of developing future patellar and Achilles tendinopathy if the tendons exhibit abnormalities on US at baseline.[6,30] Posttreatment US examinations after a therapeutic intervention targeting neovessels often reveal notable changes in these features, serving as a useful biomarker for favorable outcomes.[7,26,33] For example, after sclerosing therapy, most treated tendons showed reduced neovascularity, and in some cases, hypoechoic areas also diminished.[33] Our study revealed a significant reduction in the thickness of the patellar tendon, improved structure, and lower neovascularity on US after treatment. These findings suggest a potential process of tendon remodeling, aligning with previous observations made after sclerotherapy.[33]

This study has limitations. First, relative efficacy cannot be determined because this was not a randomized controlled trial. Second, the participants were not blinded to their treatment. Third, the outcomes except for return to training were self-reported and subjective.

CONCLUSION

TAE emerges as a potential treatment option for chronic PT in young athletic patients unresponsive to other treatments, showing high safety and improvements in pain and function. TEA appears to enhance their return to training with the benefits persisting for at least a mean of 31 months. A randomized controlled trial is necessary to elucidate the relative efficacy of this treatment.

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A Video Supplement for this article is available at https://journals.sagepub.com/doi/full/10.1177/23259671251337093#supplementary-materials.

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