MSK Embolization: From the Established to the Emerging

Emerging evidence supporting integration of embolization into contemporary care for musculoskeletal conditions.

By Yuji Okuno, MD, PhD

Embolization therapy has recently been adapted for nonmalignant, pain-related disorders, reflecting advancements in interventional radiology and an increasing emphasis on nonsurgical treatment strategies. In particular, embolization has emerged as a novel treatment option for various musculoskeletal (MSK) conditions, including adhesive capsulitis (AC), overuse sports injuries, and knee osteoarthritis (OA).

This article explores the emerging evidence supporting its integration into contemporary MSK care. As a rapidly evolving field, embolization therapy represents a paradigm shift in managing refractory joint pain and dysfunction, warranting further investigation and broader clinical application.

KNEE OA

Knee OA is a leading cause of disability worldwide, affecting > 250 million people and imposing a significant economic burden.[1] With aging populations and increasing obesity rates, its impact is expected to grow, highlighting the need for effective interventions.

Over the past 2 decades, pharmaceutical companies have made significant investments in developing novel drugs for knee OA, underscoring the vast market potential of this condition. Among these efforts, nerve growth factor inhibitors emerged as a promising avenue in 2010.[2] However, despite substantial financial backing and extensive research over a decade, the development of nerve growth factor inhibitors was ultimately halted due to significant safety concerns.[3] This reflects the high stakes and challenges associated with advancing the treatment landscape for knee OA. As a result, the field has seen limited breakthroughs beyond well-known interventions, such as physical therapy and corticosteroid injections, the latter of which has been in clinical use for > 40 years.

Recently, a novel, minimally invasive procedure—genicular artery embolization (GAE)—has gained traction as a promising treatment for knee OA. GAE, which targets and embolizes inflammatory blood vessels in the knee, received FDA approval in 2022 and is becoming increasingly popular.

Reported Outcomes

The technical success rate of GAE for knee OA is reported to be high—99.7%.[4] Clinical success, which varies depending on its definition, has been summarized in recent meta-analyses as reaching up to 78%.[4] The pooled mean reduction in visual analog scale (VAS) scores has been reported as -39 mm at 6 months.[4] For patients with mild to moderate degenerative changes (Kellgren-Lawrence grade 1-3), these therapeutic effects are maintained in many cases over a 2-year follow-up period.[5] This information is particularly valuable for younger patients seeking to delay the timing of total knee arthroplasty.

Regarding safety, common complications include subcutaneous hematomas at the puncture site and allergic reactions. Specific adverse effects of GAE have also been reported, such as mild skin ulcers and transient nerve injuries, including numbness and foot drop. These complications have been associated with the use of permanent spherical embolic agents. Notably, nerve injuries are more likely to occur when embolic agents smaller than 100 µm are used.[6,7]

ADHESIVE CAPSULITIS

AC of the shoulder is a common condition marked by pain and restricted glenohumeral motion, affecting

2% to 5% of the general population.[8] Previously regarded as a self-limiting disease resolving within 18 to 24 months,[9] recent studies indicate a less optimistic outlook. Long-term follow-up reveals that 30% to 40% of patients experience persistent pain after 3 years, and 30% report residual pain even after 7 years.[10] These findings underscore the need for effective minimally invasive treatments for patients unresponsive to standard therapies.

Abnormal hypervascularity in AC has been well-documented through contrast-enhanced MRI,[11,12] surgical observation,[13,14] and histologic studies.[14,15] Sasanuma et al found dynamic contrast-enhanced MRI enhancement in 100% of AC patients compared to 53% with symptomatic rotator cuff tears.[11] Histopathologic analyses further revealed increased abnormal vascularization and associated nerve growth within capsular tissues in AC,[15] highlighting its role in the disease's pathophysiology.

Reported Outcomes of Transarterial Embolization

In a multicenter, prospective study of 100 cases, 80% of patients reported significant nocturnal pain relief within 1 month post–transarterial embolization (TAE).[16] Another study reported that significant improvement in night pain was observed in 67% of patients within 1 week and in 87% within 1 month. Additionally, range of motion markedly improved at 1 year, with forward elevation increasing from 77° to 165° and external rotation from 8° to 58°, with most patients achieving near-normal mobility.[17]

Similar outcomes were reported in three Spanish studies. A study of 20 patients found significant pain reduction and functional improvement, with only one case of transient wrist/forearm edema.[18] Another study of secondary stiff shoulders reported a median VAS pain reduction from 8 to 2 and increased range of motion (flexion/abduction from 70° to 150°), with transient erythema in four cases.[19] A larger study of 40 patients showed that median VAS scores decreased from 8 to 0.5, with significant gains in flexion (79.5° to 133°) and abduction (72.4° to 129.7°) and without major complications.[20]

These findings confirm that TAE is an effective and safe treatment for AC, offering substantial pain relief and improved mobility.

OVERUSE SPORTS INJURIES

Overuse injuries, defined as MSK chronic conditions without a single traumatic event,[21] are common among professional athletes, often causing missed playtime and career setbacks.[22] Tendinopathy, a frequent overuse injury, results from excessive tendon loading, leading to structural degeneration.[23] These injuries rarely resolve with rest or physical therapy,[23,24] highlighting the need for effective treatments to ensure rapid recovery and return to peak performance. Therapeutic interventions, including nonsteroidal anti-inflammatory drugs, taping, cryotherapy, shockwave therapy, platelet-rich plasma injections, and surgery, offer varying success.[24] However, challenges like limited effectiveness, tissue damage risks, and extended recovery times remain.[23]

Patient Selection and Informed Consent

Imaging plays a crucial role in selecting patients for TAE in overuse sports injuries by identifying hypervascular regions through ultrasound or MRI. Key findings include edema, swelling, thickening, increased Doppler signals on ultrasound, and contrast enhancement on MRI. In patellar tendinitis, a tendon thickness ≥ 7 mm on ultrasound is considered an indication for TAE, while in plantar fasciitis, a fascia thickness ≥ 4 mm at its attachment site is used as a criterion.[25] For proximal hamstring tendinopathy, MRI is preferred, with findings such as peritendinous edema, tendon thickening, or high signal intensity within the bone marrow of the ischial tuberosity indicating eligibility. Severe cases, as characterized by significant thickening or increased Doppler signals throughout the tendon, may require informing patients about the possibility of two treatment sessions, as reported in some cases of tennis elbow and plantar fasciitis.[25,26]

Reported Outcomes

A systematic review and meta-analysis on TAE for painful and refractory tendinopathy of the rotator cuff, elbow extensor and flexor, Achilles, and patellar tendons reported a decline in the VAS ratio of means at various time points: 0.53 (95% CI, 0.31-0.88) at 1 day, 0.51 (95% CI, 0.32-0.79) at 1 week, 0.45 (95% CI, 0.29-0.71) at 1 month, 0.33 (95% CI, 0.22-0.48) at 3 to 4 months, and 0.18 (95% CI, 0.13-0.26) at 6 months following embolization.[27] In our recent data, the majority of patients with refractory patellar tendinopathy resistant to conservative treatments returned to full training after TAE (unpublished data, 2025; submitted for publication).

HAND OA

Hand OA commonly affects the distal and proximal interphalangeal (DIP/PIP) joints, with a 40% lifetime risk for symptomatic OA in at least one hand.[28] Symptoms such as pain, stiffness, and limited movement significantly impair daily activities and quality of life.[29] The trapeziometacarpal (TM) joint is another frequently affected site in the hand, with radiographic OA present in 15% of adults aged > 30 years and one-third of postmenopausal women, often causing debilitating functional limitations.[30] Conservative treatments, including

education, exercise, orthotics, and analgesics, are first-line approaches for hand OA, with surgery reserved for severe cases unresponsive to these methods.[31]

Reported Outcomes

Recent studies highlight the potential of minimally invasive intra-arterial treatments for refractory hand OA. A TM OA study reported significant improvements in QuickDASH (49.2 to 19.5) and numeric rating scale (NRS) scores (7.2 to 2.5) over 24 months, with 77% of patients reporting improvement.[32] In DIP/PIP joint OA, intra-arterial injections reduced NRS scores (7.8 to 4.0) and improved QuickDASH scores (27 to 19) at 12 months, with a 77% clinical success rate.[33] A TAE study for hand OA demonstrated significant pain relief (VAS, 76 to 18 mm) and functional improvement (AUSCAN [Australian Canadian Osteoarthritis Hand Index], 22.0 to 9.3) at 6 months.[34] These studies reported no major adverse events, suggesting that minimally invasive treatments can effectively relieve pain and restore function in refractory hand OA.

CONCLUSION

Although current evidence supports the efficacy and safety of embolization therapy for symptom management in various MSK conditions, further research is necessary to define optimal patient selection criteria, procedural protocols, and long-term outcomes. Large-scale, randomized controlled trials will be critical for validating its role within clinical practice and establishing standardized guidelines for its application.

As interventional radiology continues to evolve, embolization therapy can potentially transform the management of MSK disorders. It could offer patients a less invasive and highly effective treatment alternative. Ongoing collaboration between clinicians, researchers, and industry stakeholders will be essential to fully harness its potential and integrate it seamlessly into multidisciplinary care models. ■

1. Centers for Disease Control and Prevention (CDC). Prevalence and most common causes of disability among adults—United States, 2005. MMWR Morb Mortal Wkly Rep. 2009;58:421-426.
2. Schnitzer TJ, Marks JA. A systematic review of the efficacy and general safety of antibodies to NGF in the treatment of OA of the hip or knee. Osteoarthritis Cartilage. 2015;23(suppl 1):S8-S17. doi: 10.1016/j.joca.2014.10.003
3. Hochberg MC. Serious joint-related adverse events in randomized controlled trials of anti-nerve growth factor monoclonal antibodies. Osteoarthritis Cartilage. 2015;23(suppl 1):S18-S21. doi: 10.1016/j.joca.2014.10.005
4. Taslakian B, Miller LE, Mabud TS, et al. Genicular artery embolization for treatment of knee osteoarthritis pain: systematic review and meta-analysis. Osteoarthr Cartil Open. 2023;5:100342. doi: 10.1016/j.ocarto.2023.100342
5. Little MW, O'Grady A, Briggs J, et al. Genicular artery embolisation in patients with osteoarthritis of the knee (GENESIS) using permanent microspheres: long-term results. Cardiovasc Intervent Radiol. 2024;47:1750-1762. doi: 10.1007/s00270-024-03752-7
6. van Zadelhoff TA, Bos PK, Moelker A, et al. Genicular artery embolisation versus sham embolisation for symptomatic osteoarthritis of the knee: a randomised controlled trial. BMJ Open. 2024;14:e087047. doi: 10.1136/bmjopen-2024-087047
7. Bagla S, Piechowiak R, Hartman T, et al. Genicular artery embolization for the treatment of knee pain secondary to osteoarthritis. J Vasc Interv Radiol. 2020;31:1096-1102. doi: 10.1016/j.jvir.2019.09.018
8. Manske RC, Prohaska D. Diagnosis and management of adhesive capsulitis. Curr Rev Musculoskelet Med. 2008;1:180-189. doi: 10.1007/s12178-008-9031-6
9. Grey RG. The natural history of "idiopathic" frozen shoulder. J Bone Joint Surg Am. 1978;60:564.
10. Hand C, Clipsham K, Rees JL, Carr AJ. Long-term outcome of frozen shoulder. J Shoulder Elbow Surg. 2008;17:231-236. doi: 10.1016/j.jse.2007.05.009
11. Sasanuma H, Sugimoto H, Iijima Y, et al. Blood flow evaluation by dynamic magnetic resonance imaging of symptomatic rotator cuff tears and frozen shoulders. J Shoulder Elbow Surg. 2018;27:e372-e379. doi: 10.1016/j.jse.2018.05.042
12. Song KD, Kwon JW, Yoon YC, Choi SH. Indirect MR arthrographic findings of adhesive capsulitis. AJR Am J Roentgenol. 2011;197:W1105-1109. doi: 10.2214/AJR.10.6099
13. Yamaguchi K, Sethi N, Bauer GS. Postoperative pain control following arthroscopic release of adhesive capsulitis: a short-term retrospective review study of the use of an intra-articular pain catheter. Arthroscopy. 2002;18:359-365. doi: 10.1053/jars.2002.32311
14. Bunker TD, Anthony PP. The pathology of frozen shoulder. A Dupuytren-like disease. J Bone Joint Surg Br. 1995;77:677-683.
15. Xu Y, Bonar F, Murrell GAC. Enhanced expression of neuronal proteins in idiopathic frozen shoulder. J Shoulder Elbow Surg. 2012;21:1391-1397. doi: 10.1016/j.jse.2011.08.046
16. Okuno Y, Yasumoto T, Koganemaru M, et al. Transarterial embolization of neovascularity for refractory nighttime shoulder pain: a multicenter, open-label, feasibility trial. J Vasc Interv Radiol. 2022;33:1468-1475.e8. doi: 10.1016/j.jvir.2022.08.016
17. Okuno Y, Iwamoto W, Matsumura N, et al. Clinical outcomes of transcatheter arterial embolization for adhesive capsulitis resistant to conservative treatment. J Vasc Interv Radiol. 2017;28:161-167.e1. doi: 10.1016/j.jvir.2016.09.028
18. Lanciego C, Puentes-Gutierrez A, Sánchez-Casado M, et al. Transarterial embolization for adhesive capsulitis of the shoulder: midterm outcomes on function and pain relief. J Vasc Interv Radiol. 2024;35:550-557. doi: 10.1016/j.jvir.2023.12.572
19. Fernández-Martínez AM, Alonso-Burgos A, López R, et al. Clinical outcomes of transcatheter arterial embolization for secondary stiff shoulder. J Vasc Interv Radiol. 2021;32:489-496. doi: 10.1016/j.jvir.2020.11.006
20. Fernández Martínez AM, Baldi S, Alonso-Burgos A, et al. Mid-term results of transcatheter arterial embolization for adhesive capsulitis resistant to conservative treatment. Cardiovasc Intervent Radiol. 2021;44:443-451. doi: 10.1007/s00270-020-02682-4
21. Chéron C, Le Scanff C, Leboeuf-Yde C. Association between sports type and overuse injuries of extremities in adults: a systematic review. Chiropr Man Therap. 2017;25:4. doi: 10.1186/s12998-017-0135-1
22. Ekstrand J, Hägglund M, Waldén M. Injury incidence and injury patterns in professional football: the UEFA injury study. Br J Sports Med. 2011;45:553-558. doi: 10.1136/bjsm.2009.060582
23. Abate M, Silbernagel KG, Siljeholm C, et al. Pathogenesis of tendinopathies: inflammation or degeneration? Arthritis Res Ther. 2009;11:235. doi: 10.1186/ar2723
24. Aicale R, Tarantino D, Maffulli N. Overuse injuries in sport: a comprehensive overview. J Orthop Surg Res. 2018;13:309. doi: 10.1186/s13018-018-1017-5
25. Sasaki T, Shibuya M, Miyazaki K, et al. Clinical results of ultrasound-guided intra-arterial embolization targeting abnormal neovessels for plantar fasciitis: 66 cases with up to 4 years of follow-up. Foot Ankle Surg. Published online July 27, 2024. doi: 10.1016/j.fas.2024.07.009
26. Iwamoto W, Okuno Y, Matsumura N, et al. Transcatheter arterial embolization of abnormal vessels as a treatment for lateral epicondylitis refractory to conservative treatment: a pilot study with a 2-year follow-up. J Shoulder Elbow Surg. 2017;26:1335-1341. doi: 10.1016/j.jse.2017.03.026
27. Epelboym Y, Glaser C, Lan Z, et al. Transcatheter arterial tendinopathy embolization as a treatment for painful and refractory tendinopathy: a systematic review and meta-analysis. Skeletal Radiol. 2024;53:2429-2435. doi: 10.1007/s00256-024-04649-9
28. Qin J, Barbour KE, Murphy LB, et al. Lifetime risk of symptomatic hand osteoarthritis: the Johnston County Osteoarthritis Project. Arthritis Rheumatol. 2017;69:1204-1212. doi: 10.1002/art.40097
29. Marshall M, Watt FE, Vincent TL, Dziedzic K. Hand osteoarthritis: clinical phenotypes, molecular mechanisms and disease management. Nat Rev Rheumatol. 2018;14:641-656. doi: 10.1038/s41584-018-0095-4
30. Haara MM, Heliövaara M, Kröger H, et al. Osteoarthritis in the carpometacarpal joint of the thumb. Prevalence and associations with disability and mortality. J Bone Joint Surg Am. 2004;86:1452-1457. doi: 10.2106/00004623-200407000-00013
31. Kolasinski SL, Neogi T, Hochberg MC, et al. 2019 American College of Rheumatology/Arthritis Foundation guideline for the management of osteoarthritis of the hand, hip, and knee. Arthritis Rheumatol. 2020;72:220-233. doi: 10.1002/art.41142
32. Inui S, Yoshizawa S, Shintaku T, et al. Intra-arterial infusion of imipenem/cilastatin sodium through a needle Inserted into the radial artery as a new treatment for refractory trapeziometacarpal osteoarthritis. J Vasc Interv Radiol. 2021;32:1341-1347. doi: 10.1016/j.jvir.2021.06.024
33. Kubo T, Miyazaki K, Shibuya M, et al. Intra-arterial injection of temporary embolic material through a needle inserted into the radial or ulnar artery for distal and proximal interphalangeal joint osteoarthritis: a retrospective study of 92 patients. Cardiovasc Intervent Radiol. 2023;46:1375-1382. doi: 10.1007/s00270-023-03514-x
34. Lee SY, Lim WX, Wu KT, et al. Short-term clinical outcomes of transarterial embolization for symptomatic hand osteoarthritis refractory to conservative treatment. Diagn Interv Radiol. 2024;30:65-71. doi: 10.4274/dir.2023.232350

Yuji Okuno, MD, PhD
Chief Director
Okuno Clinic
Tokyo, Japan
okuno@okuno-y-clinic.com

Disclosures: Consultant to Asahi Intecc Co., Ltd; advisory board for Nextbiomedical Co., Ltd.