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Transcatheter Arterial Embolization Using Imipenem/Cilastatin Sodium for Chronic Low Back Pain Resistant to Conservative Treatment: A Pilot Study with 2-Year Follow-Up

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Abstract

Purpose To evaluate the safety and 2-year follow-up clinical outcomes of transcatheter arterial embolization (TAE) using imipenem/cilastatin sodium for chronic low back pain resistant to conservative treatment.

Materials and Methods A retrospective review identified 14 patients who underwent TAE for chronic low back pain between October 2017 and August 2018. Patients with low back pain related to the facet or sacroiliac joint, lasting $\geq$ 6 months, refractory to $\geq$ 3 months of conservative treatment were eligible for TAE. Each patient received embolization of feeding arteries of painful regions. The changes in brief pain inventory (BPI) scores, adverse events, and the Oswestry Disability Index (ODI) were evaluated at baseline and 1, 3, and 24 months after TAE. Clinical success was defined as BPI maximum pain intensity decrease of $\geq$ 2 and ODI decrease of $\geq$ 10 points from baseline.

Results Follow-up data were available in 13 and 11 patients, at 3 and 24 months after embolization, respectively. Intention-to-treat clinical success was obtained in 11/14 (79%) of patients at 3 months and 8/14 (57%) of patients at 24 months after TAE. Mean BPI maximum pain intensity and ODI scores decreased significantly from baseline to 1, 3, and 24 months after treatment (7.6 vs.. 4.3, 3.4, and 4.1; 40.8 vs 21.5, 20.0, and 23.8, respectively; all $P < 0.01$). No major adverse events were associated with the procedures.

Conclusion TAE is one possible treatment option for patients with chronic low back pain refractory to conservative treatment.

Keywords Chronic low back pain · Transcatheter arterial embolization · Brief pain inventory score · Oswestry disability index

Abbreviations

TAE	Transcatheter arterial embolization
BPI	Brief pain inventory
ODI	Oswestry disability index

Introduction

Low back pain affects people of all ages and is a leading contributor to disease burden worldwide [1]. The effects of chronic low back pain on patients vary substantially, from those who experience minimal disruption to their life through to people who are severely disabled and for whom participation in work, social, and family roles is severely restricted. For chronic low back pain, the use of brief education about the problem, advice to stay active, non-steroidal anti-inflammatory drugs, weak opioids (short-term use), exercise therapy (of any sort), and spinal manipulation are recommended in most guidelines [2]. It

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has been reported that in 85–90% of patients with chronic low back pain, the problem is non-specific without any surgically treatable lesions including fracture, herniation, or spinal canal stenosis [3]. Lumbar facet joint and sacroiliac joint are well-recognized sources of non-specific low back pain [4, 5]. These sources of pain were classified as mechanical low back pain [5]. There is no strong evidence for the use of injection therapy (i.e., corticosteroids, anesthetics, or other drugs administered into epidural sites, facet joints, or sacroiliac joints) in the treatment of these conditions [6]. Radiofrequency denervation was a commonly used treatment in pain clinics for these conditions. However, a randomized controlled trial resulted in either no improvement or no clinically important improvement compared to a control group [7]. One explanation of this condition is a low-grade inflammation of facet joint or sacroiliac joint [8]. Hypothetically, improvements in chronic inflammation may have a therapeutic effect on this condition.

The emergence of new techniques in the field of interventional radiology has enabled the embolization of new vessels and has attracted attention as a treatment for chronic painful conditions based on the idea that a number of increased blood vessels and associated nerves is a possible cause of chronic pain with occlusion of such new vessels possibly alleviating the pain. In previous studies performed by our group, transcatheter arterial embolization (TAE) was applied for tendinopathy [9], osteoarthritis of the knee [10], and adhesive capsulitis [11], and we reported good results without any major complications. In addition, TAE is undergoing clinical trials around the world, reporting the same therapeutic efficacy and safety as we have obtained [12–15]. However, TAE for chronic low back pain has not yet been reported. So far, TAE has been documented to be effective for synovitis pain [10, 11], and so we speculated that it might be useful to treat patients with chronic low back pain related to the chronic inflammation of facet or sacroiliac joints.

The purpose of the present study was to evaluate the safety and short-term clinical outcomes of transcatheter arterial embolization (TAE) using imipenem/cilastatin sodium (IPM/CS) for chronic low back pain resistant to conservative treatment.

Materials and Methods

Study Design

This study is a retrospective analysis of patients who previously underwent TAE for low back pain. The study population was selected by searching the available medical records of patients who had undergone this procedure between October 2017 and August 2018. Our institutional review board approved this retrospective study.

Because this was the first application of TAE for low back pain, the treatment was approved by our institutional review board on one-by-one basis for each individual. Patients with low back pain, considered to be related to the facet joint or sacroiliac joint, lasting more than 6 months, with 3 months or more of conservative treatment composed of anti-inflammatory drugs (NSAIDs), opioids, physical therapy, acupuncture, or local steroid injection were considered eligible for TAE. The possible sources of pain were assumed by physical examination by an interventional radiologist and those who showed local tenderness over the area of the facet and/or sacroiliac joints and reproduced pain with deep pressure were eligible. Patients with vertebral compression fracture, local infection, malignancy, disk herniation or spinal canal stenosis on MRI, pain after surgery, or age > 80 years were not considered eligible. There were 24 eligible patients. They were given a thorough explanation regarding previously established outcomes and complications of TAE for other regions including frozen shoulder or knee OA and the novelty of TAE application for chronic low back pain. Fourteen of 24 patients provided written informed consent and underwent TAE (Fig. 1).

Procedure Details

Under local anesthesia, percutaneous arterial access was gained using a 3-Fr introducer sheath (Super Sheath, Medikit Co., Ltd., Tokyo, Japan) from the femoral artery. A 3-Fr angiographic catheter (JR2.5; Medikit Co, Ltd) was inserted intra-arterially. The feeding arteries related to the possible sources of pain assumed by physical findings were selected as targets for embolization (Table 1) and digital subtraction angiography (DSA) was captured. Anterior segmental medullary arteries can be derived from spinal branches of lumbar arteries [16]. Mostly, these arteries form a hairpin turn. In order to avoid spinal cord infarction, when these vessels are recognized in the case of embolization of a lumbar artery, we did not treat it.

A 1.7-F microcatheter (ASAHI Veloute; Asahi Intecc, Nagoya, Japan) was inserted coaxially through the 3F catheter and positioned at the origin of the target arteries (i.e., the same position previously used for diagnostic angiography) to infuse embolic materials. Imipenem/Cilastatin Sodium (IPM/CS; Primaxin, Merck & Co., Inc., Whitehouse Station, NJ, USA) was used as an embolic material. This compound is slightly soluble in water, and when suspended with a contrast agent, it forms crystalline particles with particle size smaller than 40 μm and exerts an temporary embolic effects for days to weeks [17]. A suspension of 0.5 g of IPM/CS in 10 mL of contrast agent

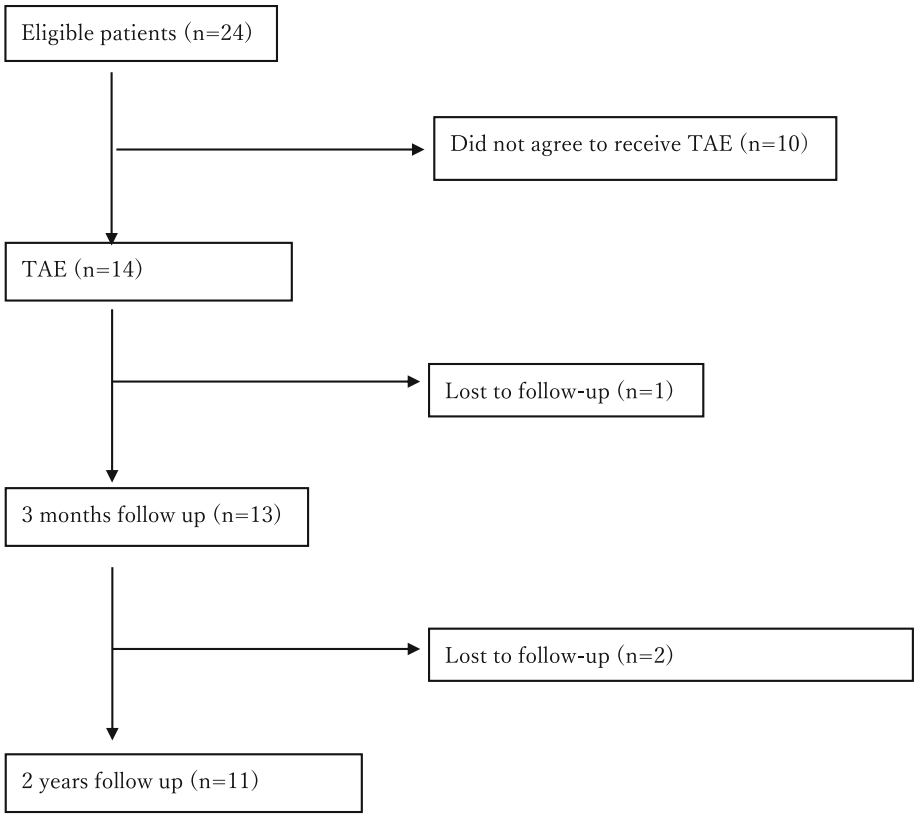

Fig. 1 Diagram illustrating the patient flow

Table 1 Target region and target artery to be embolized

Target region	1st target artery	2nd target artery	3rd target artery
L2/3 Facet joint	L2 Lumbar A	L1 Lumbar A	
L3/4 Facet joint	L3 Lumbar A	L2 Lumbar A	
L4/L5 Facet joint	L4 Lumbar A	Iliolumbar A	L3 Lumbar A
L5/S Facet joint	Iliolumbar A	L4 Lumbar A	Median sacral A
Sacroiliac Joint	Iliolumbar A	Median/Lateral sacral A	Superior Gluteal A
Buttock region	Superior Gluteal A	Inferior Gluteal A	Obturator A

A Artery

was prepared. For each artery, a prepared suspension of IPM/CS of 0.5 mL was infused with minimal manual pressure followed by saline infusion. During infusion of the IPM/CS suspension, patients felt pain, itching, or a hot sensation at the site where they usually feel symptoms if the infused region was responsible for their pain (namely evoked pain). When such pain was observed, 0.5 mL of IPM/CS suspension was additionally infused incrementally. The endpoint of catheter treatment was determined when the patient experienced attenuation of the evoked pain and/or near-stasis of arterial blood flow for 3–5 heart beats in the target arteries. Figures 2 and 3 show angiographic images obtained during the procedure.

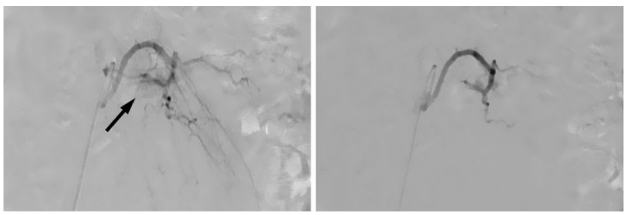

Fig. 2 Angiographic findings of the L3 level lumbar artery before (**A**) and after (**B**) transcatheter embolization in a 52-year-old patient with chronic low back pain. The lumbar artery before embolization shows pale staining of abnormal neovessels (arrow). Abnormal neovessels are located at the L3 facet joint. Angiography after embolization (**B**) shows that the pale stain has become unclear

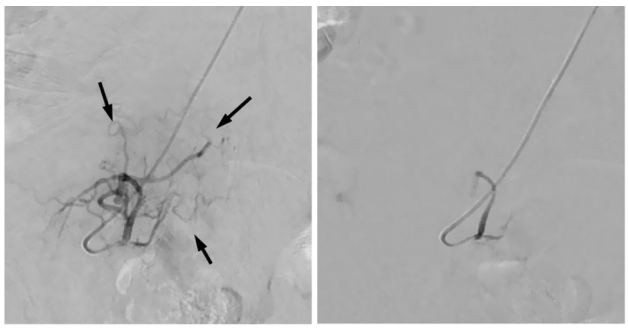

Fig. 3 Angiographic findings of a lateral sacral artery before (**A**) and after (**B**) transcatheter embolization in a 72-year-old patient with chronic low back pain. The lateral sacral artery before embolization shows pale staining of abnormal neovessels (arrow). Abnormal neovessels are located at the sacroiliac joint. Angiography after embolization (**B**) shows that the pale stain has become unclear

Outcomes Measured

To assess the severity and impact of pain, the brief pain inventory (BPI) was obtained at baseline and 1, 3, and 24 months after TAE. The BPI was originally developed to assess cancer pain and was extended for use in patients with chronic nonmalignant pain [18]. In addition, to evaluate patients' disability and function, the Oswestry Disability Index (ODI) was used. This is considered an important tool for assessing chronic low back pain and functional outcomes [18]. Technical success was defined as selective catheterization and embolization of all arteries feeding the affected area. Based on the previous determination of the minimally clinical important change for chronic low back pain, clinical success was defined as improvement of both BPI pain intensity > 2 and of the ODI score > 10 points at 3 months and 2 years after the procedure compared to baseline [19]. Adverse events (AEs), as defined by the Society of Interventional Radiology classification, were recorded. Patients were allowed to continue with previous conservative therapies. The use of these conservative therapies was recorded at every follow-up visit. Patients were also asked whether they had any of the following symptoms: new-onset pain, peripheral paresthesia, numbness, or muscle weakness. At every visit, patients were encouraged to mention any symptoms.

Statistical Analysis

Statistical software (JMP Pro, version 12, SAS Institute) was used to process the data and perform the statistical analysis. Significance was accepted at $P < 0.05$. Baseline and outcome variables were compared using Friedman's test to determine the changes in BPI and ODI scores before and after the procedure at every follow-up visit. The proportion of cases of clinical success at 6 months after TAE was assessed with binomial responses and corresponding two-sided exact 95% confidence intervals (CIs).

Results

During October 2017 to August 2018, 14 patients (eight females and six males; mean age, 55.6 years; age range, 24–77 years) underwent TAE for chronic low back pain. Table 2 shows baseline demographic data of the patients. Technical success was obtained in all patients. All patients were treated according to the protocol, and the procedure was performed successfully, with evoked pain observed in 14 of 14 (100%) cases. The mean and standard deviation of the volume of embolic material were 7.4 mL ($\pm$ 3.7). Follow-up data were available in 13 patients at 3 months and 11 patients at 24 months after embolization. Details of treated vessels for each patient are summarized in Table 3.

Clinical outcomes

Details of the change in BPI and ODI scores before and after the treatment and the use of other treatments were summarized in Table 4. Mean BPI maximum pain intensity scores decreased significantly at 1, 3 and 24 months after TAE compared to those at baseline (7.6 vs. 4.3, 3.4, and 4.1, respectively; all $P < 0.01$). Mean ODI scores also decreased significantly at 1, 3 and 24 months after TAE compared to those at baseline (40.8 vs. 21.5, 20.0, and 23.8, respectively; all $P < 0.01$). The intention-to-treat clinical success rate at 3 months after TAE was 78.5% (11/14), and 10 patients showed more than a 50% decrease of pain. The intention-to-treat clinical success rate at 2 years was 57.1% (8/14), and 7 patients experienced a more than 50% decrease of pain.

Safety

There were several minor adverse events. These included pain sensation during the procedure (strong evoked pain), the most frequently in the lateral sacral artery ($n = 5$, 38.4%) and which resolved during the procedure or within 1 h thereafter, and puncture site pain for one week ($n = 1$, 6.7%). Mild subcutaneous hemorrhage at the puncture site in one patient resolved within 1 week, and no hospitalization was required. No major AEs were reported. No patients reported peripheral paresthesia or muscle weakness during the follow-up period. No obvious complications in the late period, three months or two years after the procedure, were identified.

Table 2 Baseline demographic data

No	Age	Sex	Pain duration (months)	Prior treatment	Baseline maximum pain	Baseline ODI	PMH
1	47	F	60	Tramadol, NSAIDs, PT	10	68	–
2	43	M	12	Tramadol, Pregabalin, PT, steoid injection	8	48	–
S	72	M	36	NSAIDs PT	8	18	–
4	63	F	48	NSAIDs PT	10	42	Uterine cancer
5	77	M	156	PT Tramadol, Acupuncture	4	42	–
6	46	F	10	NSAIDS, PT, Tramadol	7	22	–
7	36	M	120	NSAIDs PT, steroid injection, Acupuncture	8	34	–
8	69	M	6	Tramadol, PT	4	66	–
9	55	F	60	Tramadol, Pregabalin	8	68	–
10	68	F	12	PT tramadol, steroid injection	8	44	Breast cancer
11	50	M	120	NSAIDs, PT, Acupuncture	10	30	–
12	76	F	96	Tramadol, NSAIDs	8	30	DM
13	52	M	120	NSAIDs, PT	5	40	–
14	24	F	96	NSAIDs, PT, steroid injection	8	65	–

PMH Past medical history, *NSAIDS* nonsteroidal anti-inflammatory drug, *PT* physical therapy, *DM* diabetes mellitus, *ODI* oswestry disability index

Discussion

In the current study, TAE improved symptoms in patients with chronic low back pain refractory to prior conservative treatment. During the 2 years of follow-up, the analgesic effect of the treatment was maintained in most available cases, and no severe AEs were observed.

Chronic low back pain collectively encompasses a spectrum of diseases of miscellaneous etiologies. Deyo and Weinstein estimated that of patients with low back pain, about 4% would have a compression fracture, 3% would have spinal stenosis, 2% would have visceral disease 0.7% a tumor or metastasis and 0.01% an infection [20]. Suzuki et al. investigated 320 patients with low back pain, whose etiologies were inflammation of facet joints and sacroiliac joints accounting for 27%, while vertebral herniation, compression fracture, and ankylosing spondylarthritis were observed in only 7%, 3%, and 0%, respectively [8]. From these results, inflammations of facet joints or sacroiliac joints presumably constitute a substantial portion of this condition. Therefore, it was speculated that inflammation of synovial tissues of these joints might be treatable by TAE like in the case of frozen shoulder or OA as previously reported [10, 11].

The mechanism of pain alleviation by catheter treatment is not fully understood. Pathological studies have reported abnormal vessels and accompanying nerve growth in Achilles tendinosis [21], osteoarthritis of the knee [22], and adhesive capsulitis [23]. We have reported the efficacy of TAE in such diseases [9–11]. In the latest report, on histopathology, the numbers of microvessels and mononuclear inflammatory cells in the synovial membrane of the joint capsule were significantly higher compared with the control group [24]. Given that embolization often results in an immediate decrease in pain, there could be a mechanism by which embolization inhibits potential activity of the nerves near the abnormal vessels. A previous report showed perivascular nerve-like structures that stained more intensely than the rest of the tissue in plical synovial tissue of chronic low back pain in a facet joint [25]. Another explanation is alleviation of inflammation in synovial tissues as Taguchi et al. reported in an animal study, in which they showed a decrease in the angiogenesis and inflammatory infiltration in a rat frozen shoulder model after TAE [24].

The weaknesses of this study need to be mentioned. First, we were unable to localize the source of pain on MRI. In this study, MRI was used to exclude to surgically treatable conditions i.e., vertebral herniation, spinal canal stenosis, and compression fracture. However, the presence/absence of inflammation in the soft tissue with the use of STIR sequence should have been considered for proper patient selection. Second, sociopsychological status was not evaluated, although it may have an influence on symptom severity and response to treatment [26].

Table 3 Procedural details

No	Main pain site	Target arteries	Embolic volume (mL)	CS*at 3 M	CS at 2Y
1	Bil L3/4, 4/5 level facet joints Bil sacroiliac joints	Bil L3,4,ILA,LSA, SGA, MSA	13	Success	–
2	Bil sacroiliac joints	Bil ILA, SGA	8	Success	Success
3	Bil L3/4, 4/5 level facet joints Lt sacroiliac joint	Bil L3,4, Lt ILA, LSA, SGA	8	Success	Success
4	Bil sacroiliac joints	Bil ILA, SGA, Lt LSA	7	Success	Success
5	Bil L2/3, 3/4 level facet joints	Bil L2, 3	3	Failure	Failure
6	Bil sacroiliac joints	Bil ILA, MSA, LSA,	7	Success	Success
7	Bil L4/5 level facet joints	Bil L3,4, ILA	4.5	Success	–
8	Bil L3/4, 4/5 level facet joints and Bil buttocks	Bil L3,4, ILA, LSA, SGA, IGA, ObA	17.5	Success	Success
9	Bil sacroiliac joints	Bil LSA, SGA, Rt ILA, MSA	4	Failure	Failure
10	Rt L3/4, 4/5 level facet joints Rt sacroiliac joint	Rt L3,4, ILA, LSA	7	Success	Success
11	Rt L3/4, 4/5 level facet joints Rt sacroiliac joint	Rt L3,4, ILA, LSA, MSA	6	Success	Success
12	Lt 4/5 level facet joint Bil sacroiliac joints	Lt L4, Bil ILA, LSA,	5	Success	Failure
13	Bil L3/4 level facet joint Bil sacroiliac joints	Bil L3,4, ILA, LSA, MSA	10	Success	Success
14	Bil L3/4, 4/5 level facet joints	Bil L3,4, ILA	3.5	–	–

L2 L2 level lumbar artery, *L3* L3 level lumbar artery, *L4* L4 level lumbar artery, *ILA* iliolumbar artery, *SGA* superior gluteal artery, *IGA* inferior gluteal artery, *LSA* lateral sacral artery, *MSA* Median sacral artery, *ObA* Obturator artery, *Rt* right, *Lt* left, *Bil* bilateral, *CS* clinical success, – lost to follow-up

*Clinical success is defined as decreased more than 2 on BPI (brief pain inventory) maximum pain intensity and 10 points on ODI (oswestry disability index) from baseline

Table 4 BPI pain scores and ODI scores

	Baseline	1 month	3 months	2 years	*P*-value
BPI maximum	7.6 ± 2.0	4.3 ± 2.2	3.4 ± 2.2	4.1 ± 2.6	< 0.01
BPI minimum	4.3 ± 1.5	2.4 ± 1.8	1.8 ± 1.7	1.8 ± 1.3	< 0.01
BPI average	6.1 ± 1.7	3.4 ± 1.9	2.8 ± 2.0	2.7 ± 1.7	< 0.01
ODI scores	40.8 ± 16.1	21.5 ± 16.6	20.0 ± 16.2	23.8 ± 18.3	< 0.01
Opioid use (*n*)	8	4	2	3	
NSAIDs use (*n*)	8	5	1	1	
Physical therapy (*n*)	11	2	1	1	

Values are presented as the mean ± standard deviation

BPI brief pain inventory, *ODI* oswestry disability index

There may be several concerns about embolization for chronic low back pain, such as the risk of ischemic events, including muscle atrophy or peripheral paresthesia. Although all patients in the present study were repeatedly asked and encouraged to report symptoms suggestive of such pathologic conditions, none reported any. The absence of such adverse events may be related to the embolic material used in the present study, especially the use of small amounts of temporary embolic material.

This study has several important limitations, including the lack of a control group and the small sample size. In addition, the participants were not blinded to their treatment. Therefore, definitive evidence concerning the efficacy of TAE for this condition could not be obtained.

In conclusion, TAE can be a potential treatment option for the management of patients with chronic low back pain. Appropriate patient selection and rigorous pre-treatment evaluation for identification and localization of pain source

is important, and further evaluation with a control group will be needed to confirm the effects of TAE.

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Declarations

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

Ethical Approval The Institutional Review Board of Okuno Clinic approved this study (Approval Number: OC IRB 2020-0401).

Informed Consent Informed consent was obtained from all individual participants included in the study.

Consent for Publication Consent for publication was obtained from every individual whose data are included in the study.

References

1. Maher C, Underwood M, Buchbinder R. Non-specific low back pain. Lancet. 2017;389:736–47.
2. Dagenais S, Tricco AC, Haldeman S. Synthesis of recommendations for the assessment and management of low back pain from recent clinical practice guidelines. Spine J. 2010;10:514–29.
3. Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. BMJ. 2006;332:1430–4.
4. Manchikanti L, Pampati V, Fellows B, Bakhit CE. Prevalence of lumbar facet joint pain in chronic low back pain. Pain Phys. 1999;2:59–64.
5. Bogduk N. The anatomical basis for spinal pain syndromes. J Manipulative Physiol Ther. 1995;18:603–5.
6. Staal JB, de Bie R, de Vet HC, Hildebrandt J, Nelemans P. Injection therapy for subacute and chronic low-back pain. Cochrane Database Syst Rev. 2008;2008:CD001824.
7. Juch JNS, Maas ET, Ostelo RWJG, et al. Effect of radiofrequency denervation on pain intensity among patients with chronic low back pain the mint randomized. Clin Trials. 2017;318:68–81.
8. Suzuki H, Kanchiku T, Imajo Y, et al. Diagnosis and characters of non-specific low back pain in Japan: the Yamaguchi low back pain study. PLoS ONE. 2016;11:1–13.
9. Iwamoto W, Okuno Y, Matsumura N, Kaneko T, Ikegami H. 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 Elb Surg. 2017;26:1335–41.
10. Okuno Y, Korchi AM, Shinjo T, Kato S. Transcatheter arterial embolization as a treatment for medial knee pain in patients with mild to moderate osteoarthritis. Cardiovasc Interv Radiol. 2015;38:336–43.
11. Okuno Y, Oguro S, Iwamoto W, Miyamoto T, Ikegami H, Matsumura N. Short-term results of transcatheter arterial embolization for abnormal neovessels in patients with adhesive capsulitis: a pilot study. J shoulder Elb Surg. 2014;23:e199-206.
12. Bagla S, Piechowiak R, Hartman T, Orlando J, Del Gaizo D, Isaacson A. Genicular artery embolization for the treatment of knee pain secondary to osteoarthritis. J Vasc Interv Radiol. 2020;31:1096–102.
13. Hwang JH, Park SW, Kim KH, Lee SJ, Oh KS, Chung SW, et al. Early results of transcatheter arterial embolization for relief of chronic shoulder or elbow pain associated with tendinopathy refractory to conservative treatment. J Vasc Interv Radiol. 2018;29:510–7. https://doi.org/10.1016/j.jvir.2017.11.013.
14. Little MW, Gibson M, Briggs J, et al. Genicular artery embolization in patients with osteoarthritis of the knee (GENESIS) using permanent microspheres: interim analysis. Cardiovasc Interv Radiol. 2021;44:931–40.
15. Lee SH, Hwang JH, Kim DH, So YH, Park J, Cho SB, et al. Clinical outcomes of transcatheter arterial embolisation for chronic knee pain: mild-to-moderate versus severe knee osteoarthritis. Cardiovasc Intervent Radiol. 2019;42:1530–6.
16. Yoshioka K, Niinuma H, Ehara S, Nakajima T, Nakamura M, Kawazoe K. MR angiography and CT angiography of the artery of Adamkiewicz: state of the art. Radiogr Rev Publ Radiol Soc. 2006;26(Suppl 1):S63-73.
17. Yamada K, Jahangiri Y, Li J, et al. Embolic characteristics of imipenem-cilastatin particles in vitro and in vivo: implications for transarterial embolization in joint arthropathies. J Vasc Interv Radiol. 2021;32:1031-1039.e2.
18. Tan G, Jensen MP, Thornby JI, Shanti BFJ. Validation of the brief pain inventory for chronic nonmalignant pain. J Pain. 2004;5:133–7.
19. Hägg O, Fritzell P, Nordwall A. The clinical importance of changes in outcome scores after treatment for chronic low back pain. Eur Spine J. 2003;12:12–20.
20. Deyo RA, Weinstein JN. Low back pain. N Engl J Med. 2001;344:363–70.
21. Alfredson H, Ohberg L, Forsgren S. Is vasculo-neural ingrowth the cause of pain in chronic Achilles tendinosis? An investigation using ultrasonography and colour doppler, immunohistochemistry, and diagnostic injections. Knee Surg Sports Traumatol Arthrosc. 2003;11:334–8.
22. Walsh DA, Bonnet CS, Turner EL, Wilson D, Situ M, McWilliams DF. Angiogenesis in the synovium and at the osteochondral junction in osteoarthritis. Osteoarthr Cartil. 2007;15:743–51.
23. Xu Y, Bonar F, Murrell GAC. Enhanced expression of neuronal proteins in idiopathic frozen shoulder. J Shoulder Elb Surg. 2012;21:1391–7.
24. Taguchi H, Tanaka T, Nishiofuku H, Fukuoka Y, Minamiguchi K, Taiji R, et al. A rat model of frozen shoulder demonstrating the effect of transcatheter arterial embolization on angiography, histopathology, and physical activity. J Vasc Interv Radiol. 2021;32:376–83.
25. Grönblad M, Korkala O, Konttinen YT, Nederström A, Hukkanen M, Tolvanen E, et al. Silver impregnation and immunohistochemical study of nerves in lumbar facet joint plical tissue. Spine. 1991;16:34–8.
26. Pinheiro MB, Ferreira ML, Refshauge K, et al. Symptoms of depression and risk of new episodes of low back pain: a systematic review and meta-analysis. Arthritis Care Res. 2015;67:1591–603.