Original Research

HAND
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DOI: 10.1177/15589447261467939
journals.sagepub.com/home/HAN

Prospective Analysis of Transarterial Embolization in Treating Hand Osteoarthritis

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Abstract

Background: The first carpometacarpal (CMC) joint of the hand is among the most commonly affected sites of osteoarthritis (OA). Treatment options for CMC OA have remained largely unchanged over the years. This therapeutic, prospective cohort study aims to establish the significance of transarterial embolization (TAE) to treat persistent hand pain caused by CMC OA.

Materials and Methods: Fourteen patients presented with a history of persistent pain from the CMC joints. Eaton classification system was used to determine the severity of OA. Embolic agents were delivered through a microcatheter into the radial artery by a board-certified endovascular specialist. Clinical success was determined using a Wilcoxon signed-rank test to determine statistical significance in visual analog scale (VAS) scores reported by patients. Procedural success was determined by abolition of arterial blush following embolization. After the procedure, patients returned to the clinic for 1- and 6-month follow-up appointments.

Results: Among 14 patients, average VAS scores at preliminary and follow-up appointments were 8.0, 3.1, and 2.6. A Wilcoxon signed-rank test showed statistical significance in observed improvement at both treatment checkpoints. Overall, 79% of patients experienced at least a 50% improvement in VAS scores by the end of the study period.

Conclusion: Transarterial embolization significantly improved pain among this patient cohort both at 1-month and 6-month postembolization appointments, with no major adverse outcomes reported. The findings within this study pose TAE as a safe, minimally invasive treatment for OA-induced hand pain across an extended time period when conservative measures have failed. Future studies surrounding this procedure should aim to assess generalizability of study findings across a larger patient population.

Keywords

carpometacarpal, osteoarthritis, blush, pain, embolization

Introduction

Osteoarthritis (OA) is a leading cause of chronic joint disability worldwide.[1] The hand is one of the most commonly affected sites of OA, particularly among women.[2] Life-limiting hand pain is a typical symptom of OA which affects quality of life for many patients. Hand OA primarily affects the first carpometacarpal (CMC) and the interphalangeal joints and is traditionally characterized by progressive cartilage erosion due to repetitive use.[3-5] Conservative treatments include analgesics, physical therapy, and steroid injections, and severe cases may require arthroplasty.[5,6] However, studies have found conservative treatments may not always provide adequate pain relief, and surgical interventions carry notable risks including infection and decreased mobility in the CMC joints.[3,7] This highlights the need for adjunctive therapies to treat hand OA.

Recent research emphasizes the role of joint inflammation in the progression of OA.[3,8-10] As such, transarterial embolization (TAE) has emerged as a minimally invasive alternative for treating joint pain.[11,12] TAE is a procedure in

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which embolic agents are delivered through a microcatheter, blocking targeted arteries and interrupting blood supply that causes inflammation. TAE has been widely adapted to treat OA in the knee,[13,14] with studies showcasing application of the technique to treat hand OA.[11,15]

The objective of this study is to evaluate the clinical significance of TAE in treating hand pain associated with OA. Pain is assessed using the visual analog scale (VAS), a 0 to 10 metric on which patients report their perceived pain level.[16] This study analyzes the sustained outcomes of TAE in treating hand pain and establishes the relevance of the procedure in treatment planning.

Methods

This is an open-label, nonrandomized, single-center prospective study with institutional review board (IRB: 20241915) approval. Participants in this study were either referred by orthopedic specialists or self-referred. Patients were eligible for inclusion if they were over the age of 18, presented with OA of the CMC joint, and previously failed to improve with conservative treatments for at least 1 year. After inclusion criteria were satisfied, patients were consecutively enrolled into the study, and a baseline VAS score was obtained to assess severity of pain. Progression of arthritis in the first CMC joint was evaluated during pretreatment assessment using the Eaton radiographic classification system, which provides a structured framework for evaluating the severity of joint degeneration. This system ranges from stage I, indicating early synovitis with preserved joint space, to stage IV, which includes total degeneration of the scaphotrapezial joint.[17] Radiographic features were assessed using x-ray imaging to assign Eaton stage for each patient. All patients returned to the clinic for 1- and 6-month follow-up appointments after embolization. All patients embolized and presented for 1-month and 6-month follow-up were included in the sample.

All embolization procedures were performed by a board-certified endovascular specialist with over 14 years of experience. Ultrasound-guided arterial access into the radial artery was obtained in an antegrade manner. Selective radial artery angiography was performed with the dilator of a 2.9F pedal access micro puncture kit (Cook). Subsequently, 50 to 100 mcg of nitroglycerin was injected, followed by contrast dye injection to elicit inflammatory capillary blush from branches of the radial artery at the CMC joint. Subselection of dorsal radial carpal and metacarpal arteries was then performed depending on the presentation of abnormal angiogenesis. Treatment was performed using 100- to 300-µm Embospheres (Merit Medical), 125- to 275-µm Hydropearls (Terumo), and/or a 30- to 70-µm imipenem/cilastatin suspension (Primaxin) particles at operator discretion. Hemostasis was maintained with ultrasound-guided manual pressure. Patients were discharged within 30 minutes after the procedure.

Clinical success of TAE was defined as a statistically significant reduction in VAS scores by the end of the study period. Statistical significance was determined using a Wilcoxon signed-rank test. A result of $P < 0.05$ indicated a statistically significant difference. Moreover, a statistical power test with an alpha level of 0.05 and power level 0.9 was conducted for this sample size, which indicated a minimum effect size of 1.1 standard deviations. Due to the small sample size, averages were not stratified by Eaton classification as it would not have provided meaningful insights between groups. Furthermore, any procedures in the study that did not result in greater than 50% improvement in pain scale scores were considered an unintended treatment outcome.

Results

All 14 patients were classified according to the Eaton classification system (Table 1). Out of 14 patients, 7 were classified as stage IV, 4 were classified as stage III, and 3 were classified as stage II. Average patient age was 68 $\pm$ 2.5 years (range: 49-89 years). Average TAE procedure time (from infiltration of lidocaine into the skin to application of hemostatic device) was 21.3 $\pm$ 2.5 minutes. All patients had either their right or left radial artery accessed, depending on the location of their pain. Embolization successfully eliminated inflammatory blush in all treated arteries (Figure 1).

No major complications, such as digital ischemia, nail bed changes, or numbness, were observed during or after the procedure. Complications included minor pseudoaneurysms and bruising at the access site. One patient had a pseudoaneurysm at the access site, which was treated and resolved immediately after the procedure using 7 minutes of ultrasound-guided pressure. Two patients reported minor bruising, which had resolved within 1 month after the procedure. All patients were discharged home safely after confirming patent hemostasis with bedside Duplex immediately prior to discharge.

Among the 14 patients, VAS scores across the study group demonstrated significant improvement 1 month and 6 months after the procedure. Mean VAS scores fell from 8.0 $\pm$ 0.4 to 3.1 $\pm$ 0.6 (95% CI, $P \approx 0.002$) 1 month after the procedure and decreased further to 2.6 $\pm$ 0.8 (95% CI, $P \approx 0.001$) 6 months after the procedure. These reductions were statistically significant, indicating sustained pain relief throughout the follow-up period ($P < 0.05$). Statistical power analysis indicated a minimum effective effect size of 3.4, which is exceeded by the mean difference in scores. Notably, all patients reported a decrease in VAS scores by the end of the study period, with 11 (79%) patients achieving more than a 50% reduction in VAS scores. These findings demonstrate substantial clinical improvement and highlight the effectiveness of the procedure in reducing pain symptoms throughout the duration of the study period (Figure 2).

Table 1. Demographic Characteristics, Classification of OA Severity, Treated Hand, and Total Change in VAS Score of Each Patient Who Underwent Embolization in This Study.

Case no.	Hand	Eaton's stage	Sex	BMI (kg/m^2)	Age (years)	Procedure time (min)	Change in VAS score
1	Left	III	Female	21.1	78	12	−10
2	Left	III	Male	24.9	78	13	−5
3	Right	II	Female	26.2	72	12	−9
4	Right	IV	Female	25.6	63	12	−10
5	Right	II	Female	26.3	49	20	−1
6	Left	IV	Female	26.6	67	36	−1
7	Right	IV	Female	24.9	72	19	−6
8	Left	III	Female	21.1	62	10	−4
9	Left	IV	Male	36.8	65	33	−1
10	Left	IV	Female	28.5	75	40	−5
11	Right	IV	Female	24	58	15	−3
12	Right	III	Female	23.9	89	24	−8
13	Right	II	Female	33.5	66	24	−8
14	Right	IV	Male	24.4	68	25	−4

All demographics are exact values recorded at the time of treatment.
Abbreviations: OA, osteoarthritis; VAS, visual analog scale; BMI, body mass index.

Discussion

These study findings support TAE as an effective treatment method for CMC OA in patients who have exhausted all other conservative measures. All patients in the study experienced inflammation and pain of the CMC joint, indicated by significant blush identified through angiography. Studies have shown a correlation between synovitis and pain reported in hand OA.[18] As such, vascular embolization is found to be effective in reducing abnormal angiogenesis and halting the inflammatory response.[19] Embolization provided significant pain relief for 11 (79%) out of 14 patients by the end of the study period, signifying the efficacy of TAE in treating this pathology. It is worthwhile to note that within this study cohort, patients with Eaton stage II and III disease saw on average a decrease of 6.0 and 6.7, respectively, in VAS scores, whereas patients with Eaton stage IV arthritis saw, on average, a decrease of 4.3. While this discrepancy may be due to the increased severity of OA in stage IV patients, this variance should not be taken as a formal analysis as the sample size for each subset is very small.

Of note, pain levels within the study group saw a statistically significant improvement in VAS scores verified by a Wilcoxon signed-rank test. All patients in this study cohort experienced persistent hand pain for over 2 years. On average, TAE resulted in a 67.5% decrease in pain scale scores 6 months after the procedure. In addition to pain reduction, patients reported functional improvement in day-to-day activities, such as enhanced grip strength and ability to perform previously limited activities like playing the piano or carrying weights. The qualitative and statistical changes observed in this study indicate the applicability of arterial embolization in treatment planning for hand OA.

Recent research suggests that although conservative therapy can provide symptomatic relief for OA patients, a sizeable subset continues to experience persistent pain despite treatment.[20] In a meta-analysis of treatments for hand OA, Veronese et al. found nonpharmacological, nonsteroidal anti-inflammatory drug, and steroid treatments had statistically insignificant improvement of pain.[21] In addition, studies examining OA across various joints have found that intra-articular corticosteroids may, in some cases, increase risk of joint degradation.[22,23] The sustained reduction of pain observed in this study demonstrates the importance of recognizing TAE as a viable treatment option for patients with hand OA, particularly when nonsurgical treatments are found to be ineffective.

No patient experienced major complications because of the TAE procedure. In the study cohort, 1 patient experienced a minor pseudoaneurysm at the access site, which was resolved almost immediately after the procedure using manual pressure. The lack of persisting postprocedural complications underscores the safety of the intervention. The use of permanent embolic agents may cause minor skin ulceration and irritation, as observed in a limited number of genicular artery embolization cases.[24] To mitigate these effects, the use of an imipenem/cilastatin solution was implemented into treatment protocol. The impermanent effect of this solution likely contributes to the minimal complications observed in the study.[25]

In the present study, 3 patients had unintended treatment outcomes, as they experienced less than a 50% decrease in pain scale scores. Further analysis of these patients showed

Figure 1. Angiographic imaging obtained before and after the procedure demonstrated a reduction in arterial blush following embolization. Both images display left distal radial arteries.

that these patients did experience pain relief, but to a degree lower than the rest of the study cohort. In addition, underlying comorbidities were identified among these patients, including neuropathy in 2 patients and rheumatoid arthritis in 1 patient. These findings suggest that distinctive chronic conditions may limit the effectiveness of artery embolization in achieving optimal pain reduction. As such, comprehensive evaluation is needed to refine patient selection and drive treatment planning.

This study utilizes a prospective approach to avoid selection bias experienced by previous retrograde investigations of this treatment.[19,26] Transarterial embolization demonstrated sustained efficacy as an interventional procedure for hand OA. However, the limited sample size of this study cohort must be considered when interpreting the observed improvement in patient outcomes. Large-scale trials are needed to assess the generalizability of the result found in this study. Moreover, this study did not utilize functional scales to assess limitation of

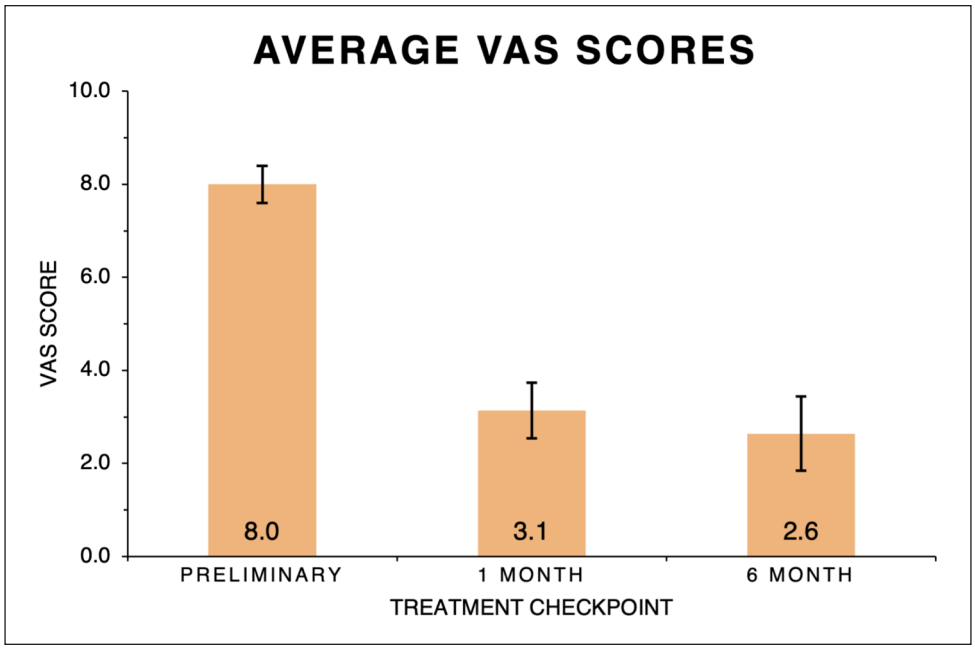

Figure 2. Average VAS scores before and after the transarterial embolization procedure. Error indicates a 95% confidence interval. Scores indicate statistical significance ($P < 0.05$) at each postprocedural follow-up.
VAS indicates visual analog scale.

hand function. As a result, the results found position this study to show effect on pain more than hand functionality. While this study serves as a pilot to help establish the importance of this treatment, further research is required to ensure results are replicated across a larger, diverse patient population.

Acknowledgments

Dr. Siddhartha Rao is the Principal Investigator. The authors thank Amer Iqbal (Clinical Operations Director) and Merna Metry (Clinical Research Coordinator) for their support.

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Ethical Considerations

This study was approved by WCG institutional review board.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). Informed consent was obtained from all patients for being included in the study.

Statement of Informed Consent

Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

Clinical Trials Number

NCT06477965

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