Selective Arterial Embolization

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ABSTRACT
Knee osteoarthritis is the most prevalent degenerative arthropathy and one of the leading causes of chronic pain and disability. Its pathophysiology involves chondral wear, synovial inflammation, pathological angiogenesis, and sensory neoinnervation. Treatment options range from conservative measures to arthroplasty; a subset of patients who are not yet surgical candidates would benefit from minimally invasive alternatives. Genicular artery embolization has emerged as a promising option by reducing neovascularization and, consequently, pain. Clinical improvements greater than 70% and a favorable safety profile have been reported. Its indications have also been extended to persistent pain after arthroplasty and to other chronic musculoskeletal entities (e.g., adhesive capsulitis), with encouraging results. Despite this promising early evidence, controlled trials and long-term follow-up are needed to define its role in the management of osteoarthritis and other musculoskeletal diseases and, in turn, to support its inclusion in treatment guidelines.
Keywords: Embolotherapy; selective arterial embolization; genicular artery embolization; osteoarthritis; knee osteoarthritis; painful total knee arthroplasty; adhesive capsulitis.
Level of Evidence: IV

Embolización arterial selectiva

RESUMEN
La osteoartritis de rodilla es la artropatía degenerativa más prevalente y una de las causas principales de dolor crónico y discapacidad. Su fisiopatología involucra desgaste condral, inflamación sinovial, angiogénesis patológica y neoinervación sensorial. El tratamiento varía desde medidas conservadoras hasta la artroplastia. un grupo de pacientes aún no candidatos quirúrgicos se beneficiarían de opciones mínimamente invasivas. La embolización arterial genicular surge como una alternativa prometedora al reducir la neovascularización y, de este modo, el dolor. Se han comunicado mejoras clínicas superiores al 70% y un perfil de seguridad favorable. Su indicación se ha extendido al dolor persistente después de una artroplastia y a otras entidades nosológicas musculoesqueléticas crónicas (capsulitis adhesiva), con resultados alentadores. Pese a la evidencia inicial prometedora, se necesitan ensayos controlados y un seguimiento prolongado para definir su rol en el manejo de la osteoartritis y otras enfermedades musculoesqueléticas y, de esta manera, poder incluirla en guías de tratamiento.
Palabras clave: Emboloterapia; embolización arterial selectiva; embolización de arterias geniculares; osteoartritis; gonartrosis; reemplazo total de rodilla doloroso; capsulitis adhesiva.
Nivel de Evidencia: IV

INTRODUCTION

Osteoarthritis is the most common degenerative joint disease worldwide and represents one of the leading causes of chronic pain and disability, especially among older adults. The knee is the most frequently affected joint in people from developed countries. This condition increasingly impacts healthcare systems due to population aging and the sustained rise in obesity.[1,2]

Traditionally, osteoarthritis was considered a purely degenerative disease, attributed to the progressive "wear and tear" of the articular cartilage. However, in recent decades, it has been recognized that chronic inflammation, particularly of the synovial membrane, plays a central role in its pathophysiology. Mechanical damage triggers a

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synovial inflammatory response that stimulates pathological angiogenesis and fosters a persistent inflammatory microenvironment, accelerating joint degeneration. Added to this process is sensory neoinnervation associated with neovascularization, which contributes to the persistent pain characteristic of the disease.[3,4]

Therapeutic strategies range from conservative measures, such as lifestyle modification, physical therapy, analgesics, anti-inflammatory agents, and intra-articular treatments (hyaluronic acid, corticosteroids, or platelet-rich plasma), to surgical procedures. Among these, total knee arthroplasty remains the treatment of choice for advanced, refractory cases.

However, in patients with mild to moderate osteoarthritis who do not adequately respond to conservative management but are not yet surgical candidates, a significant therapeutic gap persists, prompting the search for minimally invasive alternatives.

Case of Symptomatic Knee Osteoarthritis

A 68-year-old male surgeon presented with degenerative joint disease and symptomatic genu varum (Figure 1). Recently, he had to increase his analgesic medication and limit walking.

Figure 1. Weight-bearing radiographs of both knees showing grade II/III knee osteoarthritis according to the Alhbäck classification.

In previous consultations, intra-articular hyaluronic acid injection and prosthetic arthroplasty had been proposed.

At the time of evaluation, the patient reported having declined both options: a) he refused injection therapy because of progressive malalignment of the knee, and b) he was not yet willing to undergo prosthetic arthroplasty, as he did not perceive a significant limitation in his daily or professional activities.

Selective arterial embolization was therefore proposed (Figure 2).

Figure 2. A. Access to the inferomedial genicular artery. **B.** Digital subtraction angiography showing focal inflammatory "blush" (arrows). **C.** Post-embolization control showing resolution of the inflammatory focus (circle).

The patient reported marked symptomatic relief following embolization (Figure 3).

Thanks to a better understanding of the pathophysiological mechanisms of osteoarthritis, strategies aimed at modulating inflammation and synovial neoangiogenesis have been developed in recent years. Within this context, the hypothesis has emerged that embolization of synovial neovessels could reduce pain by interrupting pathological blood flow and the associated sensory stimulation. Moreover, interruption of the inflammatory cycle might delay the structural progression of the disease.[5-12]

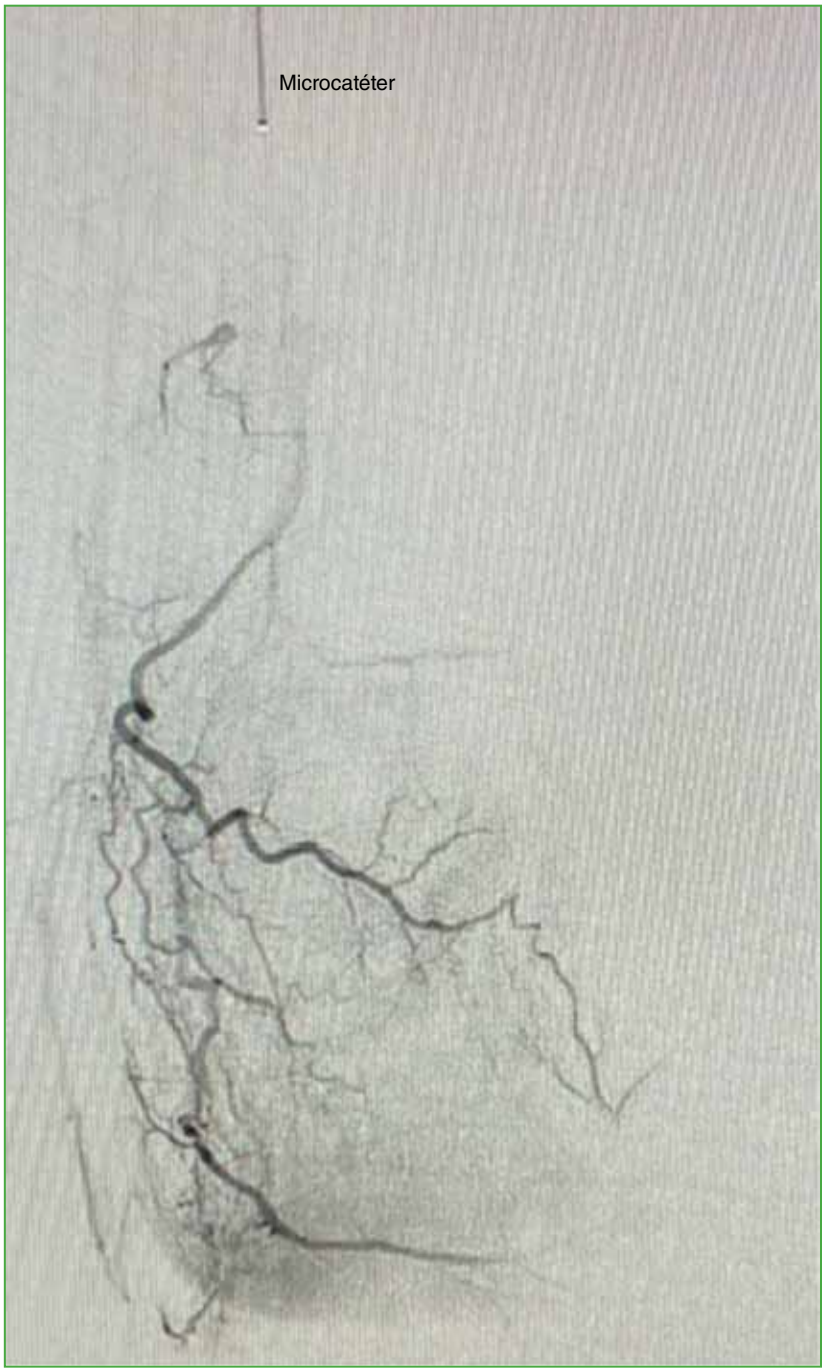

Figure 3. Selective embolization (genicular artery embolization) performed to achieve symptomatic relief. Pre-embolization image showing inflammatory focus characterized by neovascularization (“blush”).

GENICULAR ARTERY EMBOLIZATION

Genicular artery embolization has emerged as a minimally invasive therapeutic alternative for patients with symptomatic osteoarthritis who do not respond to conventional treatment but are not immediate candidates for prosthetic surgery.

The technique consists of superselective embolization of genicular arterial branches supplying areas of synovial neoangiogenesis, seeking a controlled reduction—though not complete occlusion—of flow to the pathological vessels, in order to decrease inflammation and pain while minimizing the risk of ischemia in adjacent tissues (Figure 4).[13]

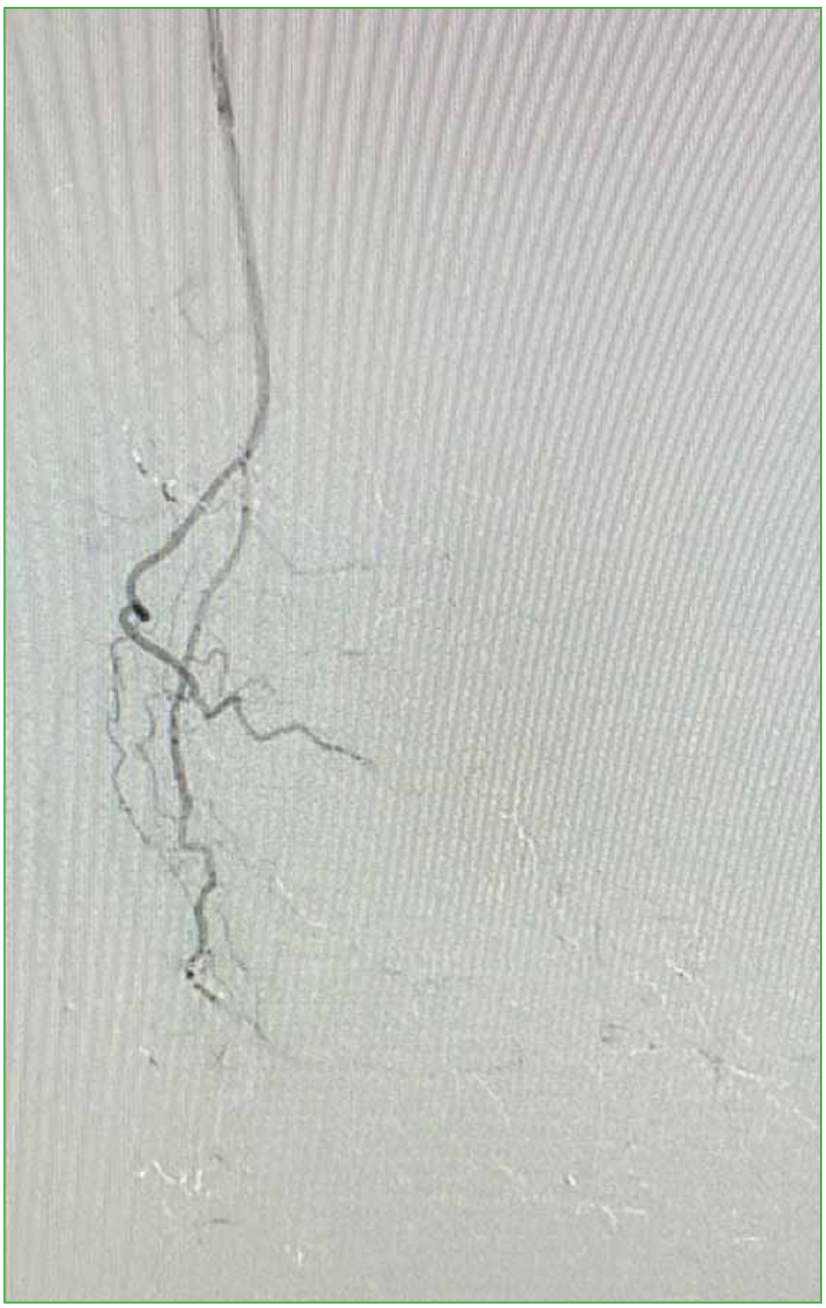

Figure 4. Post-embolization image. The "cotton-like" blush has disappeared, with preservation of collateral branches.

Okuno et al.[5,6] were pioneers in the clinical implementation of this technique. Over the past decade, they have published several case series and prospective studies documenting significant improvements in pain and function at short- and mid-term follow-up. Based on these initial experiences, genicular artery embolization has been progressively adopted by multiple international centers, consolidating its position as a promising therapeutic option.

Several subsequent studies have confirmed its efficacy, reporting clinical improvement rates exceeding 70%, along with consistent reductions in pain scales, such as the Visual Analog Scale, and in functional questionnaires, including the *Western Ontario and McMaster Universities Osteoarthritis Index.*[7,8]

In recent years, genicular artery embolization has also been used to treat: a) persistent pain after total knee arthroplasty, once mechanical and infectious causes have been ruled out as sources of symptoms,[14-20] and b) recurrent hemarthrosis, after excluding specific clinical conditions such as coagulopathies or hemorrhagic synovial disorders.[21-23]

Case of Recurrent Hemarthrosis

A 52-year-old man underwent a two-stage revision arthroplasty for periprosthetic joint infection, reconstructed with a rotating-hinge implant. He presented with recurrent hemarthrosis caused by impingement of a synovial fold (Figure 5).

Although current evidence in this context is still limited, available studies suggest that the procedure can achieve significant pain reduction and substantial improvements in quality of life, maintaining a favorable safety profile and short recovery times.

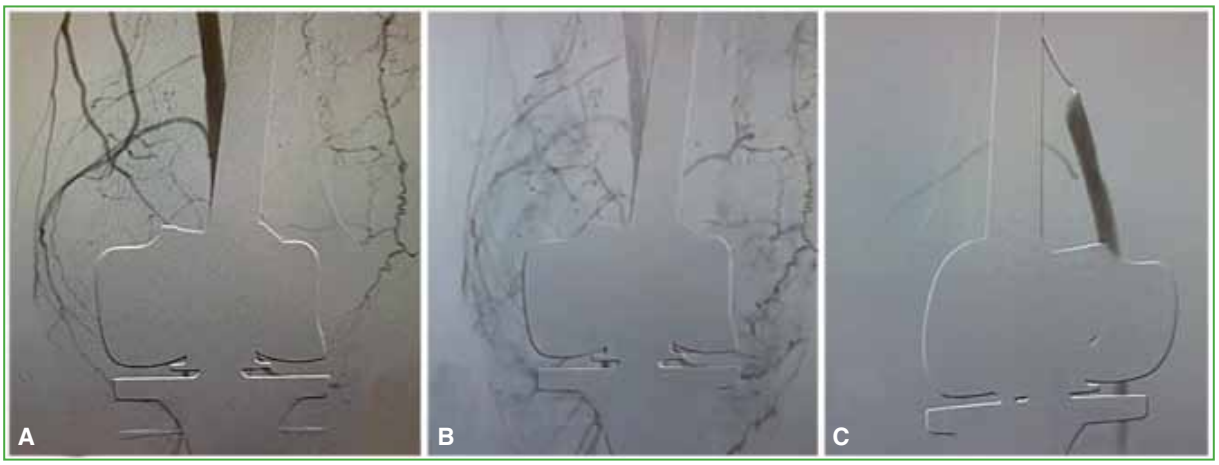

Figure 5. A and B. Synovial vascular proliferation with a "cotton-like," cumulonimbus-type appearance. **C.** Selective arterial embolization showing disappearance of the cloudy image. The recurrent hemarthrosis resolved clinically.

In terms of safety, most adverse events reported have been mild and self-limited. The most common is mild, transient post-procedural pain, which usually resolves with symptomatic management. In rare cases, superficial skin ulcerations have been observed, related to non-target embolization of cutaneous branches; these typically heal favorably with conservative local measures. Such events have been associated with the use of permanent embolic agents. These findings support the favorable safety profile of genicular artery embolization when performed using a superselective technique and with appropriate embolic material selection. Furthermore, operator experience plays a crucial role in minimizing risks and optimizing clinical outcomes.[18]

While most of the accumulated experience pertains to knee osteoarthritis, the technique is now being explored for other musculoskeletal conditions associated with pathological neovascularization and chronic pain, such as rotator cuff tendinopathy, lateral epicondylitis, Achilles tendinopathy, and plantar fasciitis. In these entities, peritendinous neovascularization is often accompanied by sensory neoinnervation, perpetuating pain and functional limitation.

Preliminary pilot studies and case series have shown that selective embolization of these abnormal vessels may lead to pain relief and functional improvement in patients unresponsive to conservative therapies, with a safety profile comparable to that observed in the knee.[24-34]

Despite these encouraging results, the current evidence presents limitations: small numbers of randomized controlled trials, heterogeneous patient selection criteria, variability in embolization technique and embolic materials used, and relatively short follow-up periods in most studies. These constraints preclude definitive conclusions regarding durability of the effect and need for repeat interventions. Therefore, larger-scale prospective studies with longer follow-up are required to more precisely define the efficacy, safety, and role of genicular artery embolization in the therapeutic algorithm for knee osteoarthritis and other musculoskeletal disorders.

Initial experience suggests that selective embolization, whether genicular or targeting other musculoskeletal sites, represents a minimally invasive, safe, and effective procedure within the multidisciplinary management of chronic pain conditions characterized by neovascularization and inflammatory foci that impact pain sensitivity.

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