



# Genicular Artery Embolization and other Non-Operative Procedures in Management of Knee Pain

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Indiana University home of the CFP National Champions/IU Health



# Financial Disclosures

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- None



# Learning Objectives

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Identify the relevant neuroanatomy of the genicular nerves and the vascular supply

Differentiate between the physiological mechanisms and procedural techniques of genicular nerve radiofrequency ablation (RFA), cryoneurolysis, and genicular artery embolization (GAE).

Evaluate clinical indications and patient selection criteria for non-operative interventions in patients with chronic knee osteoarthritis or persistent post-arthroplasty pain.

Recognize absolute and relative contraindications, as well as potential procedural complications



# Background



Osteoarthritis frequently impacts the knee, significantly contributing to pain, disability, and reduced daily function.

In the United States, 58.5 million adults are affected by arthritis, with 25.7 million experiencing activity limitations attributable to the condition.

Chronic pain affects 51.6 million adults in the U.S.; many individuals with knee osteoarthritis remain in a treatment gap between conservative management and surgical intervention.

This is a high-frequency clinical problem across primary care, sports medicine, PM&R, pain, and musculoskeletal radiology.

Opioid-sparing and surgery-sparing options are needed to improve participation in rehab and exercise.

Newer procedures require better understanding of patient selection and risk counseling.



# Traditional Treatments

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- Physical therapy
- Bracing
- OTC/Rx
  - NSAIDs
    - Topical (ie Voltaren gel)
    - Oral
      - Tylenol
  - Rx Pain meds
    - Tramadol
    - Opioids
- Injections
  - CSI
  - HA
    - Less traditional
      - PRP/BMAC (and other regenerative medicine techniques)
      - Prolotherapy
- Weight management (ie GLP-1)
- OMT
- Education



# Traditional treatment of chronic knee osteoarthritis

## Core nonpharmacologic treatment

- Education and self-management programs
- Exercise therapy: strengthening, aerobic, neuromuscular, and aquatic options
- Weight loss when overweight or obese
- Assistive devices, unloading brace, activity modification
- Can be paired with OMT and home exercise to improve function

## When traditional care is not enough

- Persistent moderate to severe pain despite PT, weight loss, bracing, and medications
- Functional limitation or inability to progress rehabilitation
- Medication intolerance or repeated but short-lived injection benefit
- Not ready for or not a candidate for arthroplasty

## Common medication / injection options

- Topical NSAIDs; oral NSAIDs if risk profile allows
- Acetaminophen
- Intra-articular corticosteroid injection can provide short-term relief
- Hyaluronic acid is not routinely recommended by major guidelines
- PRP/prolotherapy etc not covered by insurance and typically cash pay

## How this sets up interventional care

- RFA and cryoneurolysis target nociceptive input from periarticular sensory nerves
- GAE targets synovial hypervascularity and inflammatory pain generators
- Goal is to reduce pain enough to restore participation in exercise and conservative care
- These are generally adjuncts, not replacements, for comprehensive OA management



# Treatment Gaps

- The most recently published American Academy of Orthopaedic Surgeons (AAOS) clinical practice guidelines in 2021 recommended the following conservative treatments for symptomatic knee osteoarthritis:
- **Strong Recommendations:** Use of oral NSAIDs/acetaminophen and topical NSAIDs to improve pain and function.
  - **Recommended Modalities:** Self-management, patient education and exercise (including land-based or water-based) are highly recommended (Strong), braces. (Moderate).
- **Weight Management:** Sustained weight loss is strongly advised for overweight or obese patients. (Moderate)
- **Injections:**
  - Corticosteroid injections are considered for short-term relief (Moderate)
  - Platelet-rich plasma (PRP) was recognized as potentially reducing pain (Limited)
- **Strongly Avoid:** Oral narcotics and tramadol are strongly recommended against due to lack of efficacy and high risk of adverse events.
- Denervation therapy may reduce pain and improve function in patients with symptomatic osteoarthritis of the knee. (Limited)
- **Not Recommended:** Lateral wedge insoles, ***Hyaluronic acid (HA) injections***, arthroscopic lavage/debridement.

\*\*\*Embolization not addressed\*\*\*



# Treatment Gaps

## 1 Conservative care

- Education and activity modification
- Weight management when applicable
- Bracing, PT, rehabilitative exercise
- OMT/OMM as adjunctive care

## 2 Interventional bridge

- RFA: sensory denervation
- iovera: temporary cold block
- GAE: synovial devascularization
- Goal: reduce pain enough to restore function and participation in rehab

## 3 Surgery / post-TKA pain

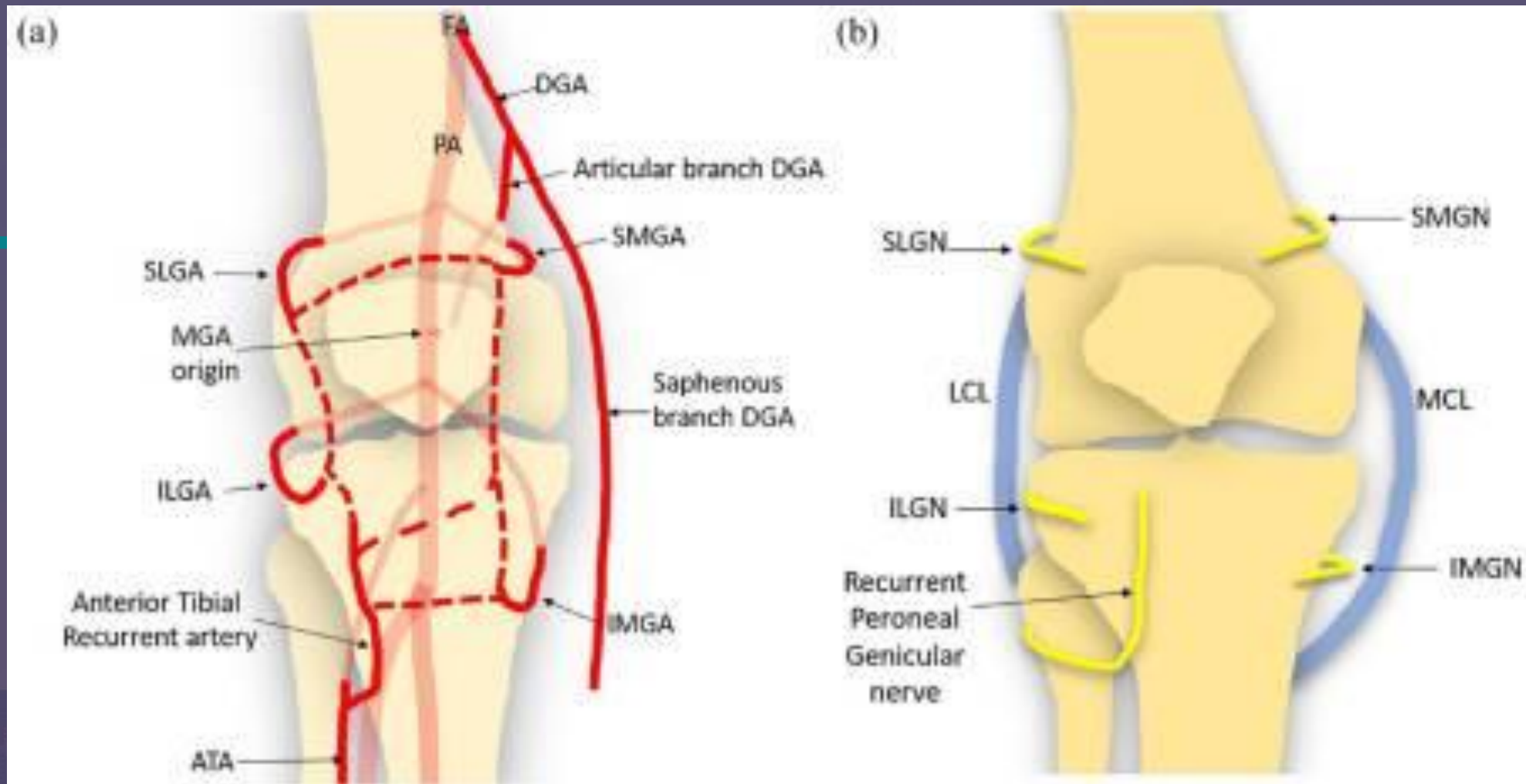
- Some patients are not yet surgical candidates
- Some wish to delay arthroplasty
- Some remain painful after TKA with workup excluding major mechanical/infectious causes



# Essential Neuroanatomy & Vascular Supply

- Sensory Innervation
- Primarily from the genicular nerves.
  - Superior Lateral (SLGN)
  - Superior Medial (SMGN)
  - Inferior Medial (IMGN)
- Note: The Inferolateral (ILGN) is often spared to avoid Common Peroneal Nerve injury.





- Vascular Supply: The genicular arterial network, which becomes "hypervascular" in the setting of chronic inflammation (synovitis).
- The Mechanism:
  - Nerve Blocks: Disrupting the "pain wires."
  - "Embolization: Reducing the "fuel" for inflammation.



# Genicular Nerve Radiofrequency Ablation (RFA)



Mechanism: "Hot" nerve block. Uses a radiofrequency current to create a precise heat lesion on the sensory nerves.



Process:

1. Diagnostic Block: Local anesthetic to confirm the nerve is the pain source.
2. Ablation: Heat interrupts the nerve's ability to send pain signals.



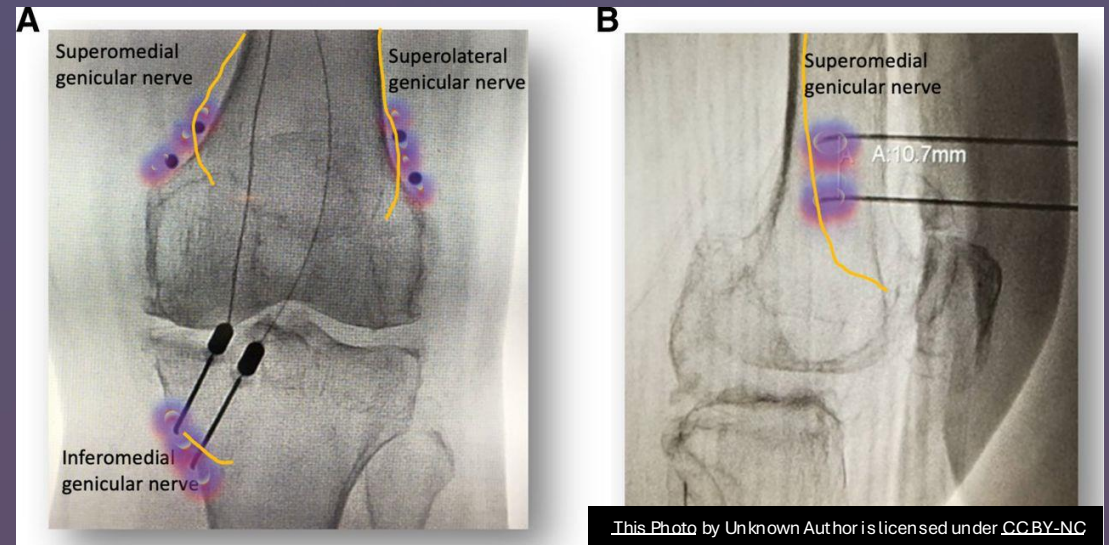
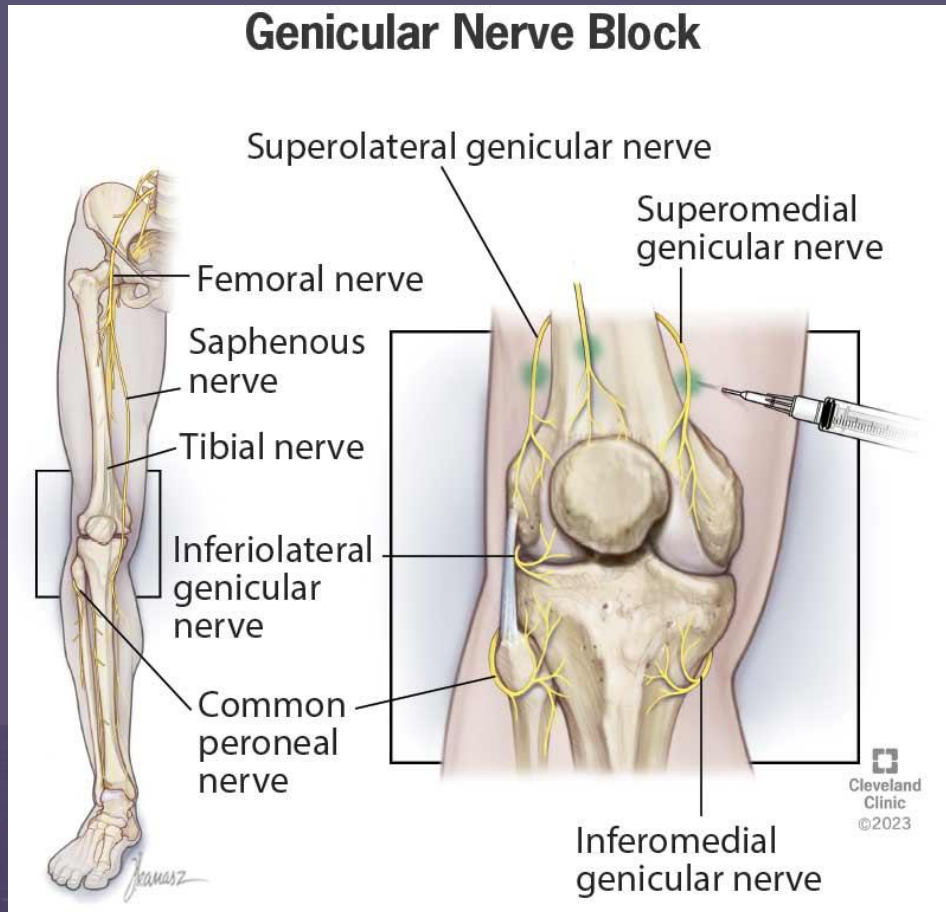
Efficacy: Typically provides relief for 6–18 months; relief is temporary as nerves can regenerate.



Pros/Cons: Effective symptom masker, but does not address underlying inflammation.



# Genicular Nerve Radiofrequency Ablation (RFA)



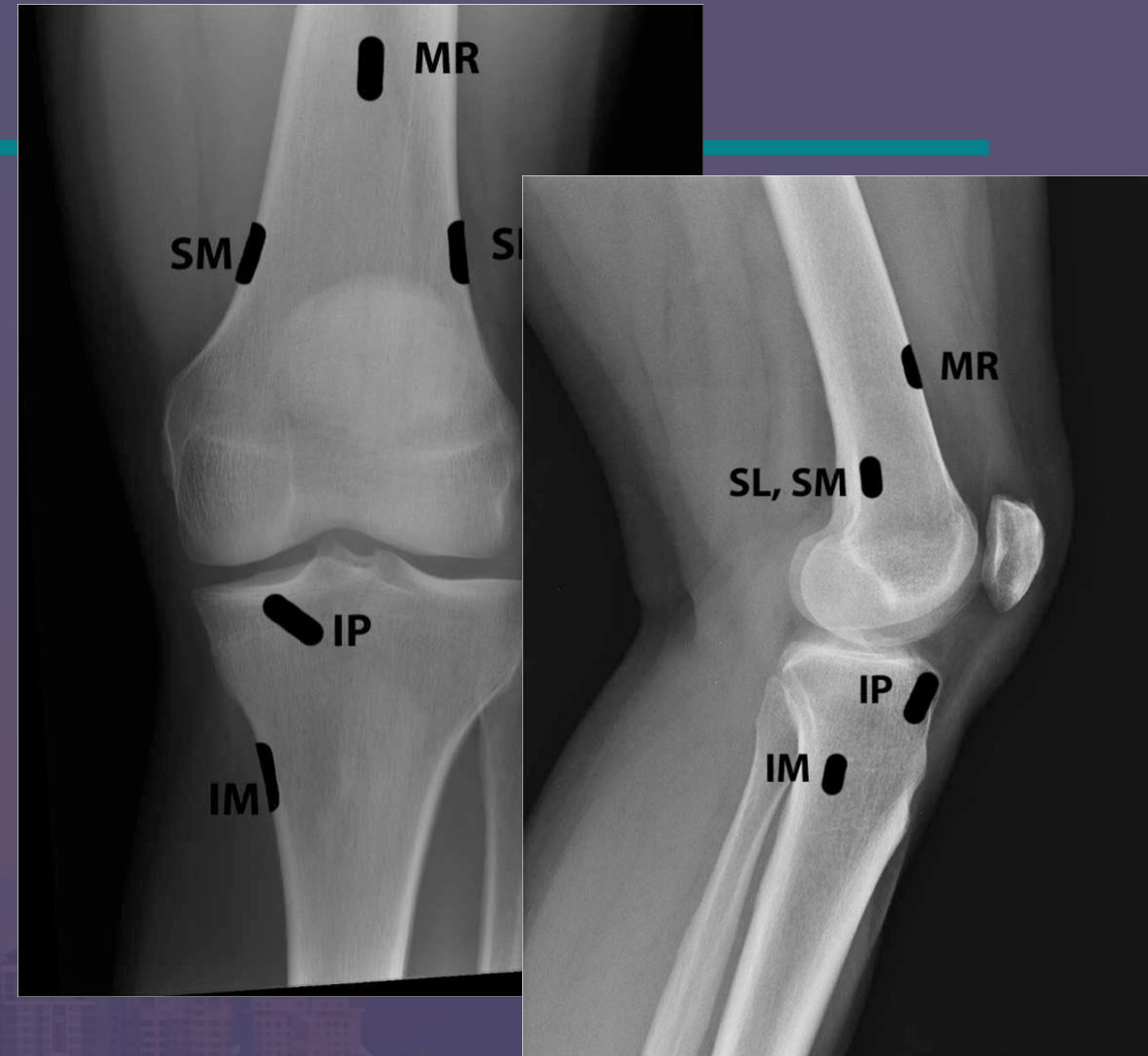
## RFA

The knee is innervated by several genicular nerves. These nerves are articular branches formed from the femoral, saphenous, common peroneal, tibial and obturator nerves. There are several branches, but the following 3 are the ones targeted for treatment. They run along the bones, which give us fluoro targets:

Superior lateral (SL) (along femur)

Superior medial (SM) (along femur)

Inferior medial (IM) (along tibia)



# Block (dexamethasone, .025% Bupivacaine, 1% lidocaine) with 50% improvement of pain

IR Genicular Nerve Iniection  
F

IR Genicular Nerve



: 1 of 1

Page: 1 of 1

\* cm

Page: 1 of 1

IM: 300

Page: 1 of 2

\* cm

Nerves blocked are: **medial and lateral geniculate, suprapatellar branches of the vastus intermedius, and medial inferior geniculate nerves**

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# RFA



# RFA



**Diagnostic Block:** 0.5–1.0 mL of local anesthetic at SMGN, SLGN, and IMGN. Success is defined as > 50% pain reduction for the duration of the anesthetic.



**Ablation:** Standard RFA ( 80 degrees Celsius or Cooled RFA 60 degrees Celsius). Cooled RFA Cooled RFA creates a larger, spherical lesion, increasing the likelihood of capturing the nerve.



**Clinical Evidence:** Davis et al. (2018) showed RFA is superior to corticosteroids for up to 6 months in pain reduction and physical function.



# Genicular nerve radiofrequency ablation (RFA)

## Mechanism / technique

- Thermal or cooled lesioning after a positive diagnostic genicular block.
- Usually fluoroscopic or ultrasound-guided and outpatient.
- Sensory denervation only - does not correct malalignment or instability.

## Contraindications / cautions

- Local infection or uncontrolled bleeding risk.
- Diagnostic uncertainty or untreated major mechanical pathology.
- Caution with distorted anatomy, severe neuropathy, or inability to cooperate.

## Typical indications

- Chronic knee OA pain refractory to conservative therapy.
- Selected persistent pain after TKA once infection or major mechanical causes are excluded.
- Patients seeking to delay surgery or who are poor surgical candidates.

## Most common adverse effects

- Transient soreness or pain flare
- Bruising, numbness, paresthesia, or knee swelling
- Rare but important: burn, infection, vascular or nerve injury

*Bridge to exercise, OMT, and functional recovery.*



# Cryoneurolysis (iovera)



**Mechanism:** "Cold" nerve block. Applies extreme cold to temporarily stop peripheral nerves from sending pain signals.



**Efficacy:** Provides immediate, drug-free relief for up to **90 days**.



**Clinical Benefits:**

Improved range of motion.

Reduced stiffness and need for opioids post-surgery.



**Ideal Candidate:** Patients seeking immediate relief or those preparing for surgery (TKA).



# Cryoneurolysis (iovera)



**Mechanism:** Uses the **Joule-Thomson effect** to deliver extreme cold -20 to -100 degrees Celsius, causing Wallerian degeneration of the axon while leaving the endoneurium intact.



**Key Advantage:** "Drug-free" pain relief that does not damage the nerve structure permanently, allowing for eventual regeneration (usually ~90 days)



**Best Use Cases:** \* Acute relief for patients with moderate OA.



Pre-operative "blocking" 1–2 weeks before TKA to reduce post-surgical opioid consumption.



Radnovic et al 2017 specifically evaluated the efficacy of cryoneurolysis in comparison to placebo control in patients with knee OA. It was found that the group receiving cryoneurolysis had improved total WOMAC, WOMAC stiffness, WOMAC pain, WOMAC physical function and in VAS pain compared to placebo control group

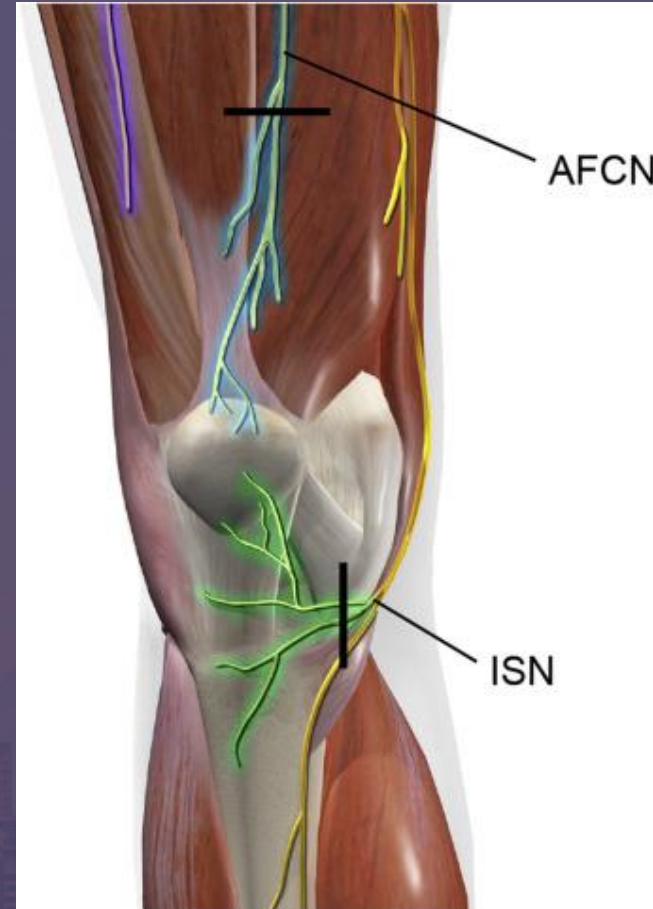


iovera<sup>o</sup>



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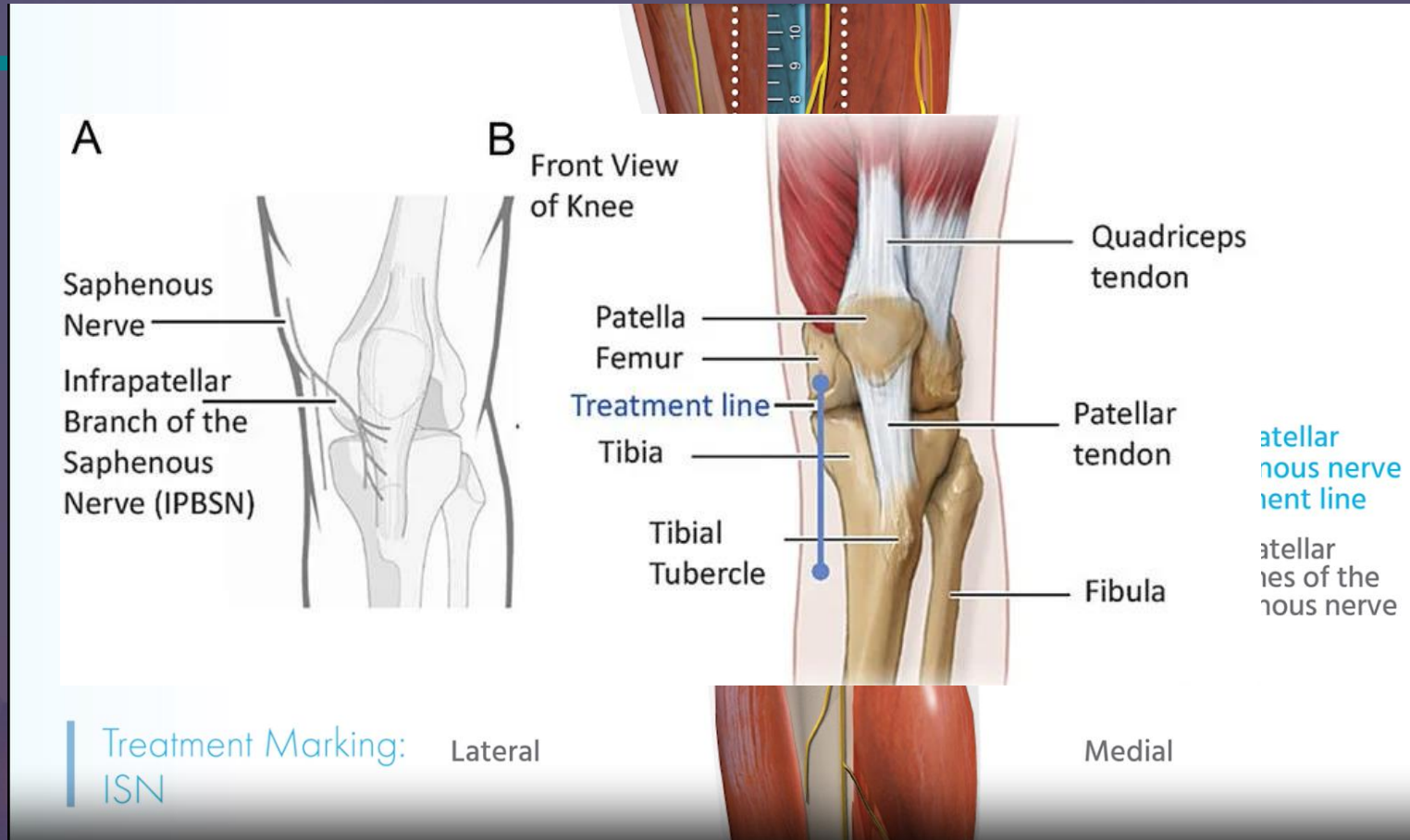
- Cutaneous nerves treated
  - Infra-patellar branch of the saphenous nerve (ISN)
  - Anterior femoral cutaneous nerve (AFCN)
  - Lateral femoral cutaneous nerve (LFCN)
- Deep genicular nerves as in RFA
  - superior medial genicular nerve (SMGN)
  - superior lateral genicular nerve (SLGN)
  - inferomedial genicular nerve (IMGN)



# Technique

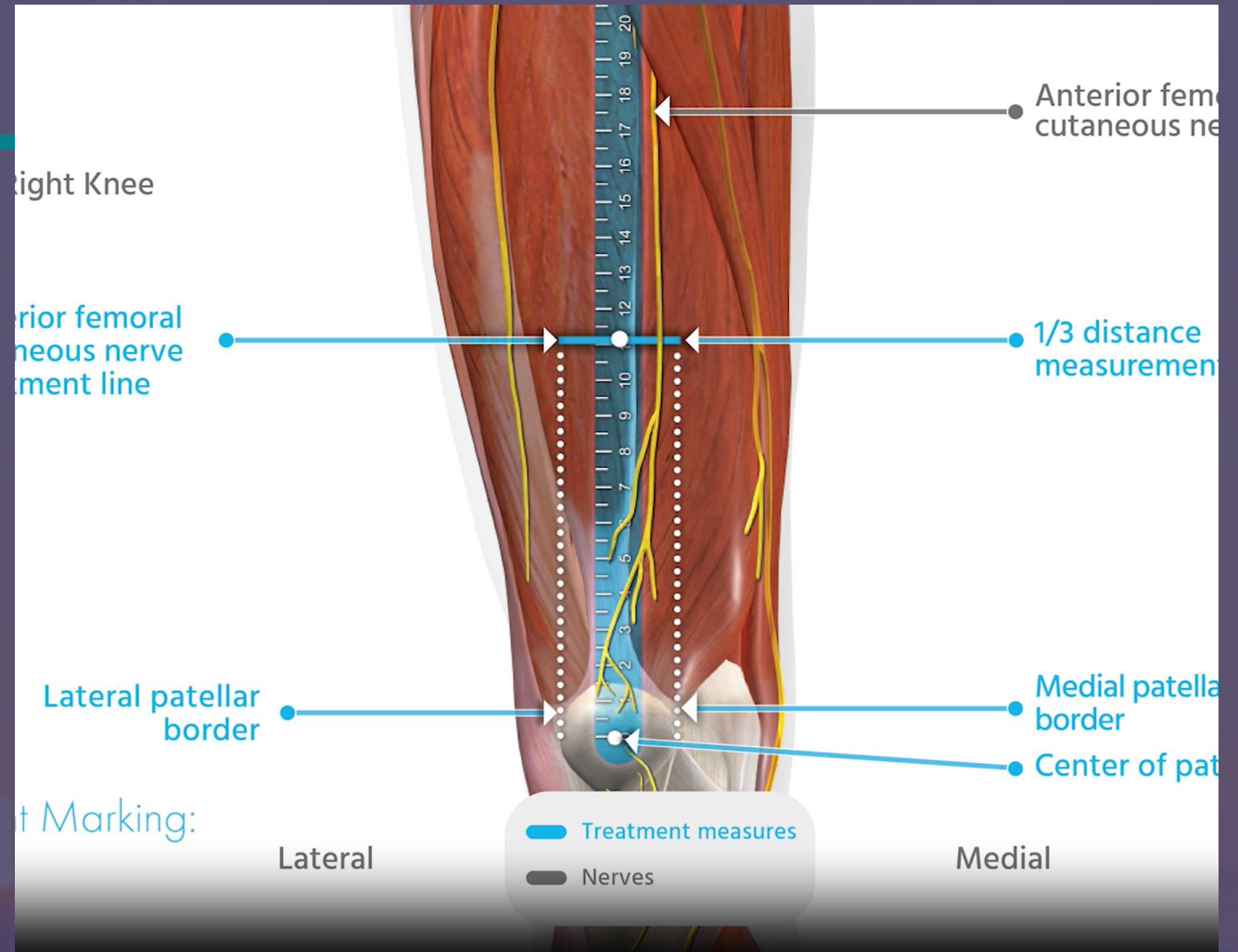
Treatment is performed unilaterally along a treatment line, the location of which was guided by visualization and palpation of anatomic landmarks

The ISN treatment line is located along the line that connects a point located 5 cm medial to the lower pole of the patella and a point located 5 cm medial to the tibial tubercle.



# Technique

The AFCN treatment line is located at one-third the length of the distance from the center of the patella to the top of the femur, with a width equal to the width of the patella



# Educational Video Library

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- [Deep Genicular Nerve](#)
- [Superficial Genicular Nerve](#)
- [Training video - Superficial nerve](#)
- [Training video - Deep nerve](#)



# Cryoneurolysis (iovera)

## Mechanism / technique

- Percutaneous freezing of peripheral sensory nerves using nitrous oxide-based probes.
- Temporary conduction block / axonal disruption with later regeneration.
- Often used for OA pain and peri-TKA pain management.

## Contraindications / cautions

- Cold hypersensitivity, cryoglobulinemia/cold urticaria, Raynaud-type phenomena, or open/infected wounds near the site.
- Caution with severe sensory deficits, fragile skin, inability to report cold-related discomfort, and remember it is not for CNS tissue.

## Typical indications

- Symptomatic knee OA when a temporary minimally invasive option is desired.
- Patients preparing for or recovering from knee replacement surgery.
- Patients who are not surgical candidates or want rapid recovery.

## Most common adverse effects

- Bruising, swelling, redness, or local tenderness
- Altered sensation at the application site
- Skin dimpling/pigment change; temporary weakness outside the treatment area can occur

*Short-term option that can support rehab or peri-TKA care.*



# Genicular Artery Embolization (GAE)

OA has traditionally been thought of as a degenerative disease related to chronic repetitive injury “wear and tear”

- in most patients, there is associated chronic inflammation

The inflammatory process leads to synovial angiogenesis through the release of cytokines such as vascular endothelial growth factor .

- Angiogenesis has been linked to the formation of osteophytes, cartilage breakdown, and an increase in knee pain



# Genicular Artery Embolization (GAE)



**Mechanism:** "Synovial Devascularization." Targets the "fire" (inflammation) rather than just the "alarm" (pain signals).



**Procedure:** A minimally invasive vascular procedure where micro-beads are released into the genicular arteries to reduce abnormal blood flow (synovitis).



**Evidence:** Studies show durable relief (12–24+ months) by treating the underlying disease process. Bagla et al. (2020) demonstrated significant improvement in WOMAC scores (pain and function) that remained durable at 12 months. Research Ongoing.



**Practice Gap:** Many primary care sports medicine clinicians are unaware of GAE as a viable alternative to traditional steroid injections. Research Ongoing.



# GAE Technique

Outpatient procedure

About 2 hours

Conscious sedation

Anesthetic transfemoral approach

Catheter advance from femoral artery to common femoral artery at target limb

Angiogram performed

- synovial blush? (hyperemia)



# GAE Technique



Small particles injected (embolization)



Artery is maintained



Post procedure discharge (~4 hours)



Resume normal activities next day



# Okuno et al (Japan)

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- Original study in Japan Okuno and colleagues
  - 72 patients with OA resistant to conservative therapy
- Inclusion criteria:
  - Knee pain
  - Tenderness localized to knee joint
  - Age 40-80
  - 3 months or more of conservative therapy (oral medication, physical therapy, intra-articular injections)
  - Persistent moderate to severe pain



# Results

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- They described an 80% clinical success rate at 3-year follow-up
  - 85% for mild to moderate
  - 70% severe
  - Improvement at baseline, 1, 4, 6, 12 and 24 months in WOMAC and VAS
    - Sustained improvement at 2 and 3 year mark
    - Most no longer needed oral medication or injections at 1 and 2 years and beyond



# Limitations

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While the results from that initial trial showed a great deal of promise, most patients underwent embolization with imipenem-cilastatin, which is not readily available in the United States.

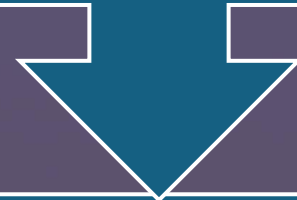


Furthermore, the treatment population was relatively homogeneous with regard to ethnicity, the median BMI was lower than that typically seen in Western populations, and patients with Kellgren-Lawrence grade-4 OA were excluded from the study



# Bagla et al (USA)

Bagla S et al. J Vasc Interv Radiol. 2020;31(7):1096-1102



Twenty patients with radiographic knee OA and moderate-to-severe pain refractory to conservative therapy were enrolled in a prospective, 2-site pilot study.

Genicular artery embolization (GAE) was performed with 75- or 100- $\mu$ m spherical particles.

Patients were assessed with magnetic resonance imaging at baseline and at 1 month and with the Visual Analogue Scale (VAS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) at baseline and at 1, 3, and 6 months.

Adverse events were recorded at all timepoints.



# Results

- Mean VAS improved from 76 mm  $\pm$  14 at baseline to 29 mm  $\pm$  27 at 6-month follow-up ( $P < .01$ ).
- Mean WOMAC score improved from 61  $\pm$  12 at baseline to 29  $\pm$  27 at 6-month follow-up ( $P < .01$ ).
- Self-limiting skin discoloration occurred in 13/20 (65%) patients.
- Two of 20 (10%) patients developed plantar sensory paresthesia that resolved within 14 days.

**Table 2. Patients Taking Various Classes of Pain Medication at Baseline versus 6-Month Follow-Up**

	Baseline	Six-Month Follow-up
Opiates	6	1
Acetaminophen	4	2
NSAIDs	13	6

NSAID = nonsteroidal anti-inflammatory drug.



# Results

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GAE to treat knee pain secondary to OA can be performed safely and demonstrates potential efficacy.



Further randomize comparative studies are needed to determine true treatment effect versus placebo effect



# Results

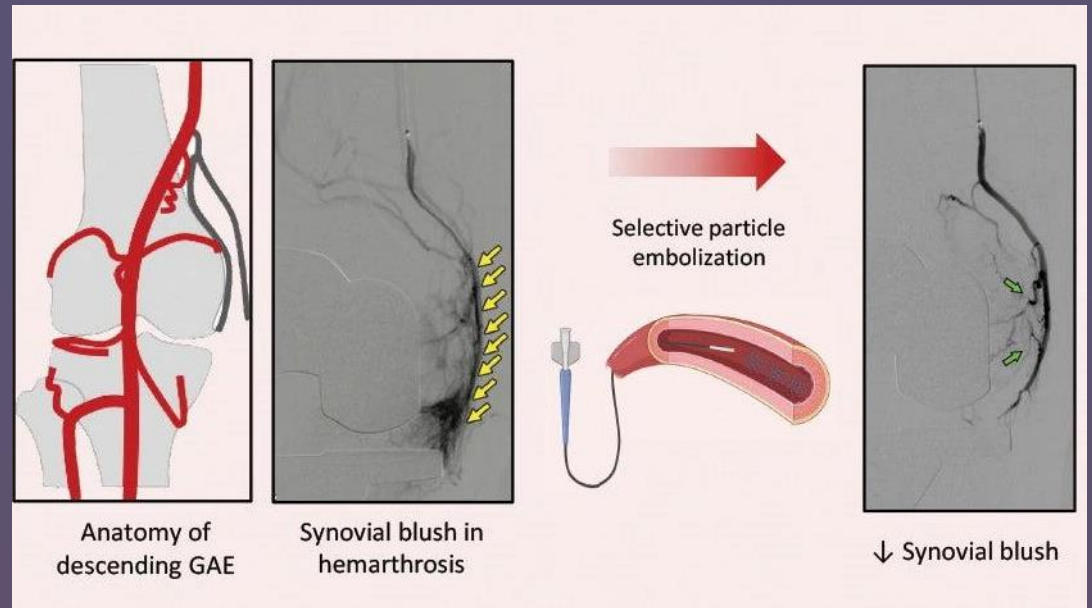
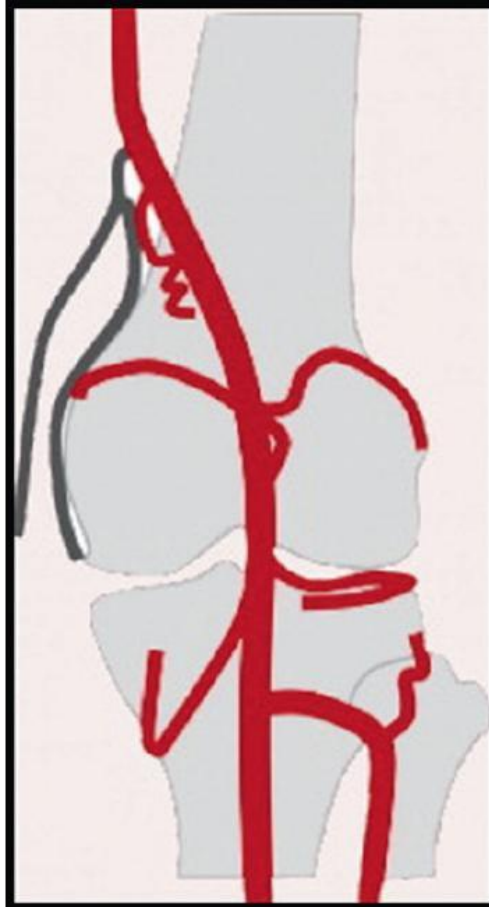
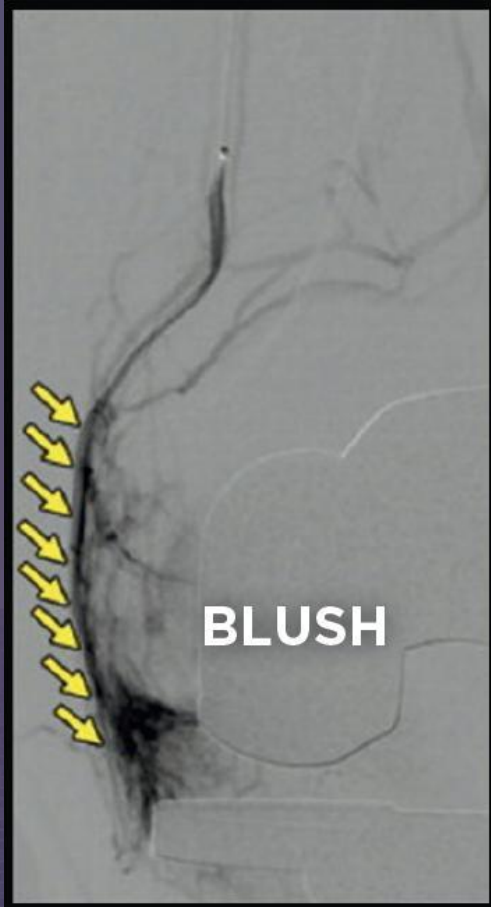
## BEFORE

Angiography of the branches of the superior medial genicular artery shows hypervascular “blush” (arrow) over the medial inferior aspect of the knee.

## AFTER

Angiography after embolization depicts the end point of “pruning” of the hypervascular synovium. The parent genicular artery remains patent.



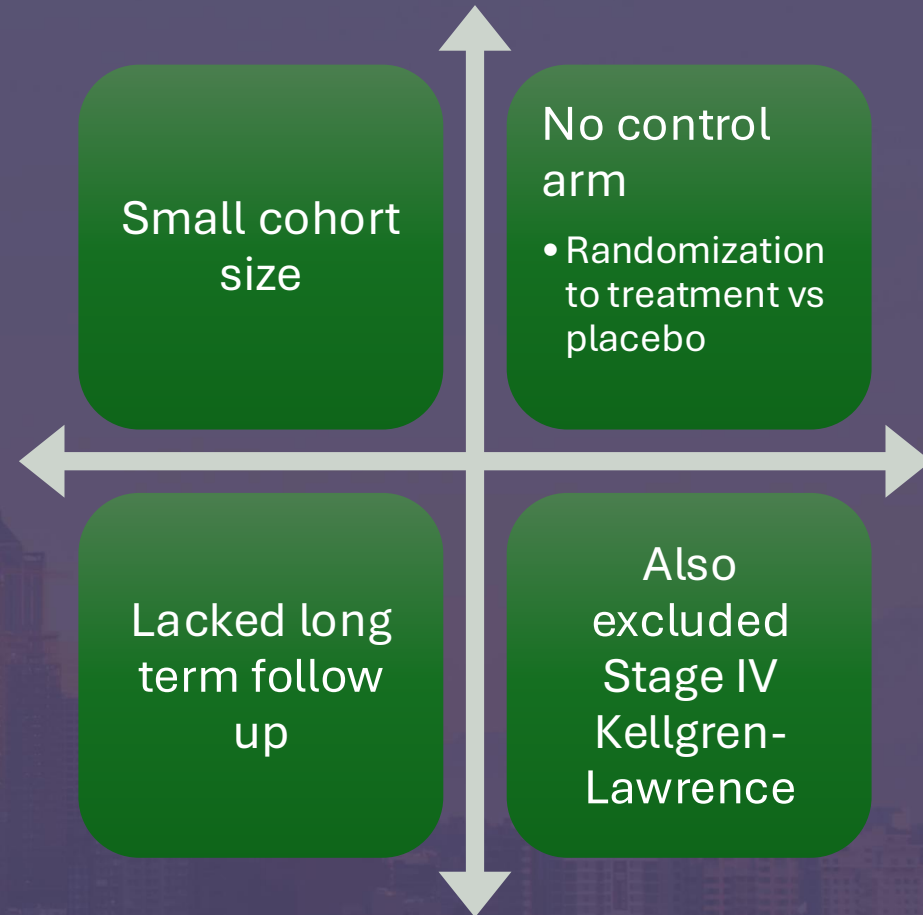


## Adverse Events

Photograph of leg 24 hours after embolization depict the patchy areas of purpura that correspond to areas of transient cutaneous ischemia that were seen in 14 of 20 patients



# Limitations



# Padia et al 2021 (JB&JS)



A prospective, single-center, open-label U.S. Food and Drug Administration-approved investigational device exemption study was conducted.



Patients enrolled in the study were 40 to 80 years old, with moderate or severe knee OA (Kellgren-Lawrence grade 2, 3, or 4), who previously had failure of conservative therapy.



Baseline pain (visual analog scale [VAS]) and symptom scores (Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC]) were assessed.



After femoral arterial access was achieved, GAE of 1, 2, or 3 genicular arteries supplying the location of the subject's pain, as determined by digital subtraction angiography and cone-beam computed tomography, was performed using 100- $\mu$ m particles.



Adverse events and symptoms scores were assessed at 1 week, 1 month, 3 months, 6 months, and 1 year after GAE.



# Results

Over a 10-month period, 40 subjects were enrolled.

The median age was 69 years (range, 49 to 80 years).

The median body mass index was 29 kg/m<sup>2</sup> (range, 19 to 44 kg/m<sup>2</sup>).

Knee OA severity was grade 2 in 18% of the patients, grade 3 in 43%, and grade 4 in 40%.

Technical success was achieved in 100% of the subjects.

The WOMAC total and VAS pain scores decreased by 61% and 67% at 12 months from a median baseline of 52 (of 96) and 8 (of 10), respectively.

- Twenty-seven patients (68%) had a reduction of  $\geq 50\%$  in both WOMAC total and VAS pain scores.



# Adverse Events

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Transient skin discoloration and transient mild knee pain after the procedure were common and expected.

Treatment-related adverse events included a groin hematoma requiring overnight observation in 1 subject, self-resolving focal skin ulceration in 7 subjects, and an asymptomatic small bone infarct on magnetic resonance imaging at 3 months in 2 subjects



# Limitations

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**Small sample size (n=40)**

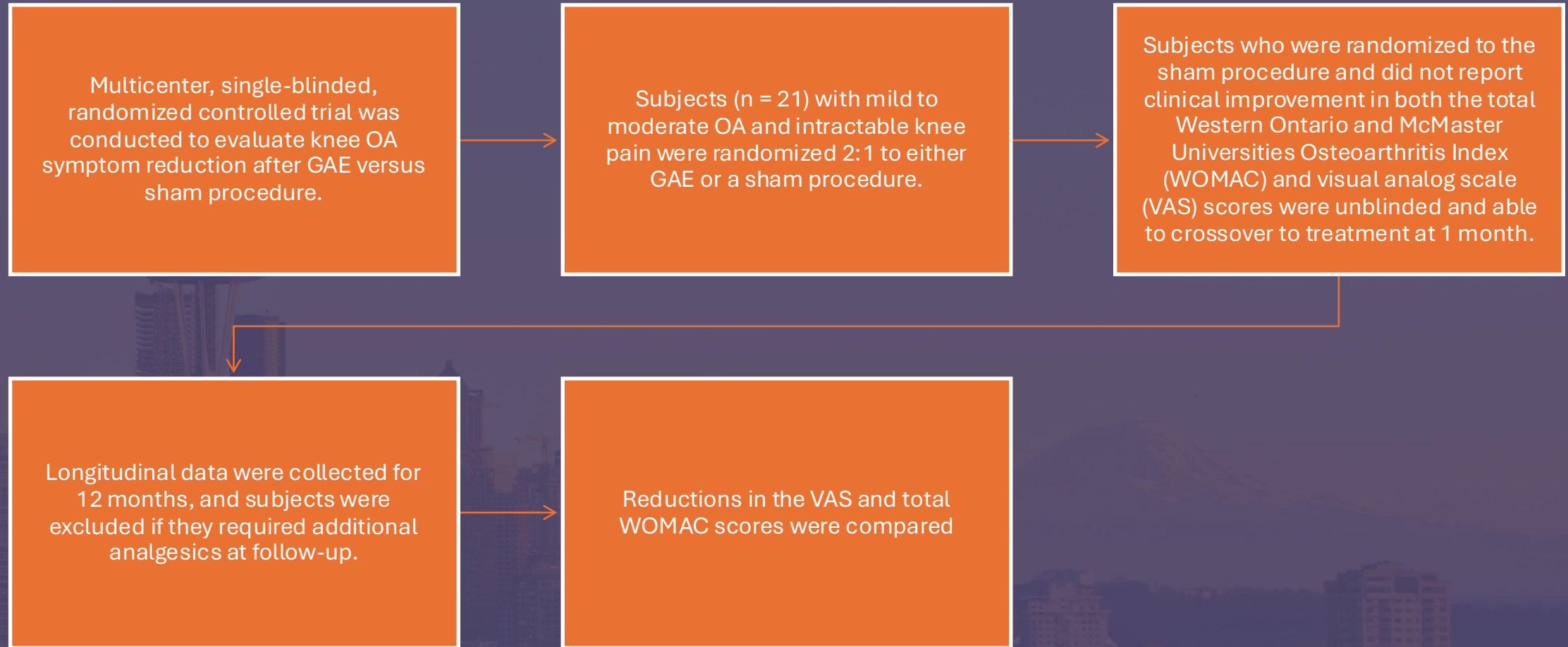


**Single – arm trial**

No placebo or control arm



# Bagla GAE vs Sham



# Results

All subjects in the sham group failed to show significant improvements at 1 month and crossed over to the treatment arm.

There was a statistically significantly greater pain reduction in the treatment group than in the sham group at 1 month (VAS, 50.1 mm; standard error [SE], 10.6; 95% confidence interval [CI], 29.0, 72.3;  $P < .01$ ).

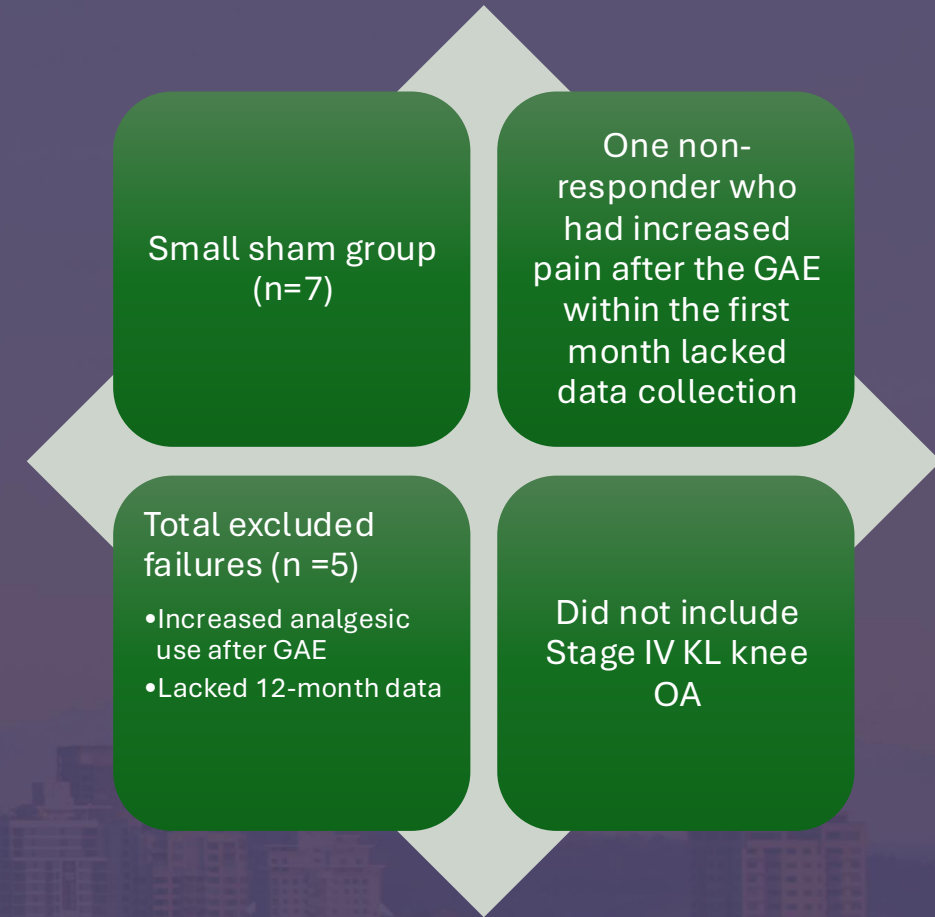
Disability improvement was also significantly greater in the treatment group (WOMAC, 24.7 points; SE, 10.4; 95% CI, 3.5, 45.9;  $P = .02$ ).

- Only minor adverse events were reported.
- Five subjects were excluded after increased analgesic use.
- Sensitivity analysis with all excluded patients confirmed significant improvements at 1 and 12 months.
  - No improvement from baseline was assumed



# Limitations

- Improvement in VAS and WOMAC should be interpreted only for what is expected from responders and not the entire populations undergoing GAE
- 12 month follow up and not beyond



# Genicular artery embolization (GAE)

## Mechanism / technique

- Catheter-based embolization of abnormal genicular neovessels supplying inflamed synovium.
- Aims to reduce synovitis, neoangiogenesis, and inflammatory pain.
- Performed by interventional radiology under fluoroscopic guidance.

## Contraindications / cautions

- Severe PAD, active infection, severe renal dysfunction, severe contrast allergy, pregnancy, or uncorrectable coagulopathy.
- Caution when end-stage structural collapse rather than synovitis is the main pain driver; vascular assessment remains essential.

## Typical indications

- Mild to moderate symptomatic knee OA after failed conservative care.
- Patients with synovitis/inflammatory phenotype who want to avoid or delay arthroplasty.
- Selected refractory cases when a non-neurolytic option is preferred.

## Most common adverse effects

- Access-site hematoma or bruising
- Transient skin discoloration/erythema or mild local pain
- Less common: non-target embolization, transient sensory change, vascular spasm/thrombosis

*Best when synovitis seems to be a major pain driver.*

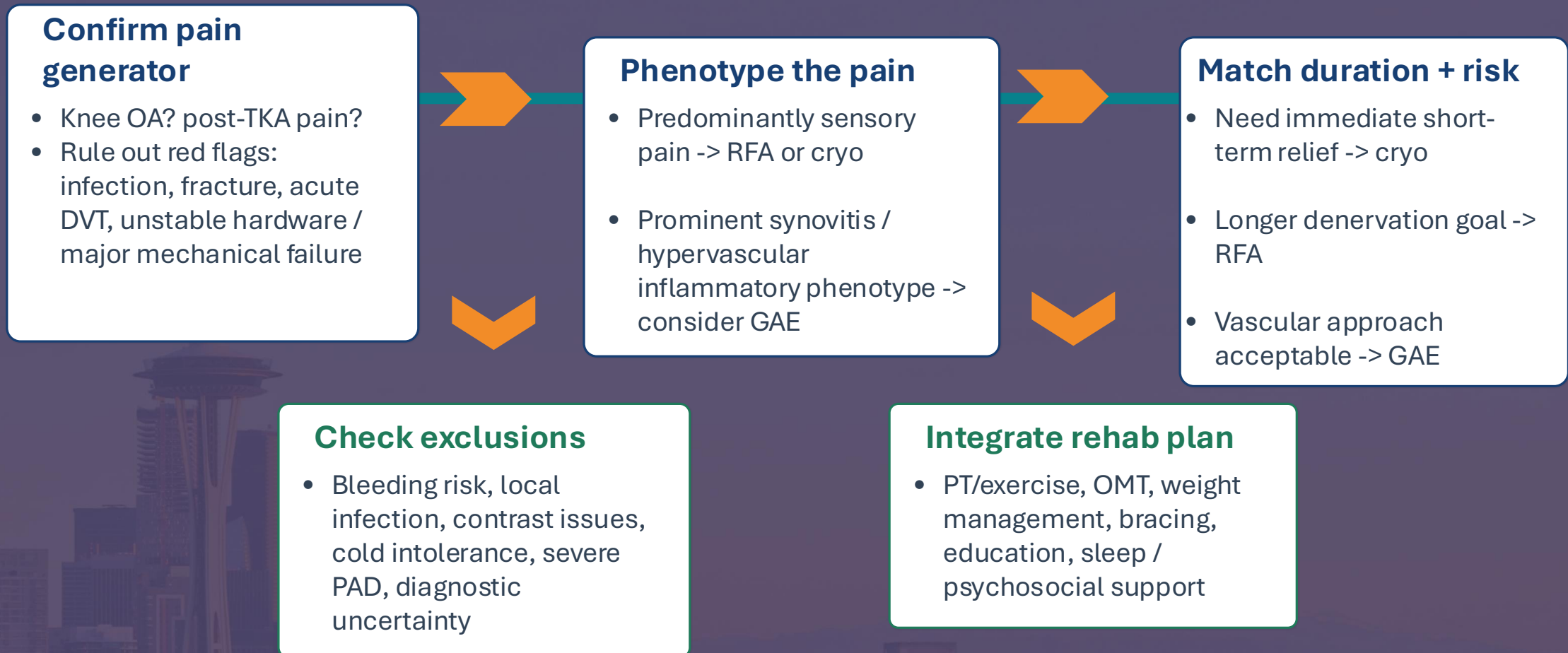


# Clinical Triage

Category	Cooled RFA	Cryoneurolysis (iovera°)	Genicular Artery Embolization (GAE)
Primary Driver	Chronic Neural Signaling	Focal or Acute Pain	Synovial Inflammation
The "Clinical Face"	"The Grinder" – Constant, daily mechanical pain that has "worn them down."	"The Bridger" – Needs a 3-month window for TKA prep or a PT breakthrough.	"The Sweller" – Recurrent effusions and "hot," inflammatory flares.
Ideal KL Grade	Grade 2–4	Grade 2–4 or Post-Arthroplasty	Grade 2–3 (Early/Moderate OA)
Onset of Action	1–2 weeks (post-procedure soreness)	Immediate (office-based)	2–4 weeks (as inflammation subsides)
Durable Relief	6–12 months	3–5 months	12+ months



# Practical patient selection



**Message for clinicians: procedure choice should follow mechanism, phenotype, comorbidity profile, and the patient's rehab goals - not just procedure availability.**



# Comparisons

Feature	Radiofrequency Ablation (RFA)	Cryoneurolysis (iovera <sup>o</sup> )	Genicular Artery Embolization (GAE)
<b>Primary Goal</b>	Denervation (Sensory)	Denervation (Sensory)	Devascularization (Synovial)
<b>Mechanism</b>	Heat	Cold	Embolic Microspheres
<b>Duration of Relief</b>	6–18 Months	~90 Days	12–24+ Months
<b>Invasiveness</b>	Percutaneous / Needle	Percutaneous / Needle	Intra-arterial Catheter
<b>Recovery Time</b>	24–48 Hours	Immediate	1–3 Days
<b>Best For</b>	Chronic OA, Post-TKA pain	Immediate relief, Pre-op	Inflammatory OA, Synovitis

- **Clinical Recommendation:** GAE addresses the *inflammatory* source, whereas RFA/iovera addresses the *pain signals*



# Take-home messages

## RFA

- Best established of the three for durable sensory denervation in refractory knee OA.
- Consider after positive diagnostic block and when conservative care has failed.
- Expect transient soreness/numbness more often than major complications.

## iovera

- Fast, temporary, office-based option with immediate effect for many patients.
- Contraindications are strongly tied to cold sensitivity and local skin/wound issues.
- Good fit when short-term pain control is needed to support rehab or peri-TKA care.

## GAE

- Targets synovitis/neovascularity rather than nerves.
- Promising for selected refractory OA, especially inflammatory phenotypes.
- Requires careful vascular screening and awareness that evidence is still evolving.

**All three are adjuncts to comprehensive longitudinal care: exercise, OMT, patient education, weight optimization, bracing, and lifestyle change remain foundational.**



# Contraindications/Complications

Procedure	Contraindications	Potential Complications
RFA	Local infection, Pacemaker (relative)	Neuritis, skin burn, "charring"
iovera <sup>o</sup>	Cold hypersensitivity (Raynaud's)	Temporary numbness, bruising
GAE	Smoking, Advanced Bone Loss, Renal failure	Skin ulceration, transient ischemia



# Side-by-side comparison

Domain	RFA	iovera	GAE	Best fit
<b>Primary target</b>	Genicular sensory nerves	Peripheral sensory nerves via cold	Abnormal synovial neovessels	Match mechanism to phenotype
<b>Onset</b>	Days to weeks	Usually immediate	Variable; often gradual	Need for quick relief favors cryo
<b>Typical duration</b>	Months; often 6-12	~90-150 days	Months; evolving evidence	Repeatability differs by modality
<b>Common AEs</b>	Soreness, numbness, paresthesia	Bruising, tenderness, altered sensation	Hematoma, skin erythema/discoloration	Counsel about expectations and recurrence
<b>Key limitation</b>	Not for untreated mechanical pathology	Relief is temporary	Evidence and reimbursement still evolving	Shared decision-making is essential

*Pearl: severe structural OA with marked malalignment or instability may still progress to arthroplasty even if an interventional procedure provides temporary relief.*



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