Low-Dose Radiation Therapy (LDRT) for Benign Musculoskeletal Disorders

A White Paper for Medical Directors and Insurance Decision-Makers

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1. Executive Summary

Low-Dose Radiation Therapy (LDRT) is a non-invasive, evidence-based treatment for various chronic benign musculoskeletal disorders including osteoarthritis (OA), plantar fasciitis, and tendonitis. Although widely used in European healthcare systems for decades, its application in the United States has been limited due to outdated perceptions of radiation risk.

Multiple publications from countries including Germany, Spain, Iran, and most recently the United States (Koneru et al., 2025) provide robust support for low-dose radiotherapy (LDRT). These include high-quality clinical trials, long-term follow-up studies, and national guidelines, all reinforcing LDRT's effectiveness, safety, and cost-efficiency. LDRT addresses a critical gap between conservative therapies and surgical intervention, offering durable pain relief without systemic side effects.

This white paper provides a review of the clinical evidence, mechanism of action, international guidelines, economic analyses, and safety considerations to guide U.S. insurance decision-makers toward the thoughtful integration of LDRT into reimbursement frameworks.

Key Takeaways:

- Clinical Efficacy: Over 70% of patients experience significant pain reduction lasting 1–2 years.
- Safety: No serious adverse effects; theoretical cancer risk mitigated by low doses and age restrictions.
- Cost-Effectiveness: Reduces downstream costs by minimizing medication and surgical needs.
- Call to Action: Insurers should pilot LDRT coverage to align with global standards and address unmet needs.

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2. Burden of Disease and Limitations of Current Management

Osteoarthritis (OA) affects more than 32 million adults in the United States and over 650 million people globally over the age of 40 [3][4]. Plantar fasciitis and tendinopathies impact millions

more, with plantar fasciitis affecting 10% of the population over their lifetime [27]. These conditions result in $185 billion in U.S. healthcare costs annually, including direct medical expenses and lost productivity [5].

Conventional treatments include:

- **NSAIDs**, Associated with a 2–4% annual risk of gastrointestinal bleeding, kidney injury, and a 20% increased risk of cardiovascular events in elderly patients [6][7].
- **Intra-articular corticosteroids**, which offer only temporary relief (2-4 weeks) and have been associated with cartilage loss (hazard ration: 1:7) and joint degeneration when used repeatedly [8].
- **Physical therapy**, effective in 50% of mild-to-moderate disease, is often limited by pain levels, insurance coverage, and patient adherence [9][12].
- **Surgery**, particularly joint arthroplasty, costing $30K - $50K per patient. While effective in end-stage OA, carries substantial risks and is not accessible or appropriate for all patients [10].

There exists a large population of patients who are either not surgical candidates or do not respond adequately to pharmacologic or rehabilitative interventions. These individuals often suffer from chronic pain, escalating opioid prescriptions (20% of OA patients), and increasing disability. LDRT provides an opportunity to address this gap.

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3. Historical and International Use of LDRT

LDRT has a long history of use for benign diseases. As early as the 1900s, it was employed for arthritis, bursitis, and tendonitis. Its use in the U.S. declined mid-20th century due to general concerns about radiation. However, in Europe, LDRT remained in practice and was integrated into formal clinical guidelines.

- In **Germany**, the DEGRO (German Society for Radiation Oncology) published S2e guidelines recommending LDRT for OA, plantar fasciitis, and tendinopathies using low doses of 0.5–1.0 Gy per session over 6–12 sessions (total dose: 3–6 Gy) [2].
- **Poland**, **Spain**, and **Iran** have adopted similar guidelines and conducted independent clinical trials demonstrating its effectiveness and tolerability [13][14][22].
- LDRT is also used in **Russia**, where a 10-year follow-up study showed substantial reductions in disability claims and showed reduction in pain, disability, improved quality of life (physical & mental), reduction in objective MRI degenerative changes [14].

LDRT is widely reimbursed in these countries and forms part of a tiered care model that delays or avoids surgery in appropriate patients.

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4. Mechanism of Action

Unlike high-dose oncologic radiation therapy, LDRT works through anti-inflammatory and immunomodulatory mechanisms at sub-cytotoxic doses.

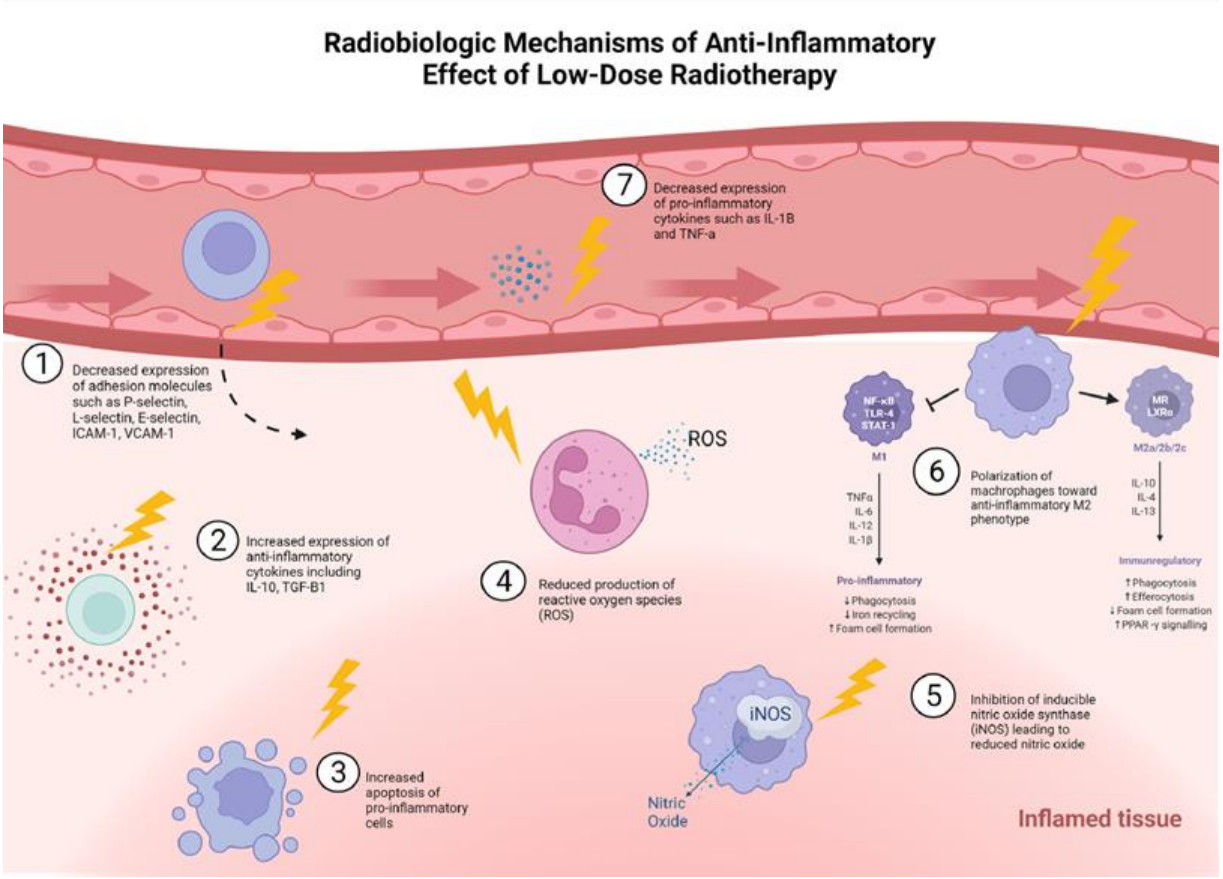
Key biological effects include:

- **Cytokine suppression**: LDRT downregulates TNF-α, IL-1β, and IL-6; central mediators of chronic inflammation in musculoskeletal tissues [1][16].
- **Macrophage polarization**: Promotes a shift from pro-inflammatory M1 to anti-inflammatory M2 macrophages [17].
- **Endothelial modulation**: Inhibits ICAM-1 and VCAM-1, reducing leukocyte migration into tissues [1].
- **Neuromodulation**: Alters neurogenic inflammation and peripheral nociception, resulting in reduced pain perception [18].

These changes collectively reduce swelling, improve joint mobility, and restore tissue homeostasis. Pain relief typically begins within 4–6 weeks and can last over a year in many patients.

To further mitigate even theoretical risks of carcinogenesis, most modern protocols limit LDRT to patients aged 45 or older, and to peripheral sites, giving low long-term radiation risk due to non-hematological tumor latency thresholds [11].

Figure 1: Mechanism of LDRT in Musculoskeletal Tissue



Radiobiological mechanisms of anti-inflammatory effect of low-dose radiation therapy (LDRT). LDRT modulation of endothelial cells by reduced expression of adhesion molecules (1), resulting in a cascade of decreased cell migration and increased anti-inflammatory cytokines (2). Irradiated leukocytes result in a decrease of proinflammatory cytokines (7) and subsequent increased apoptosis (3); Reactive oxygen species (ROS) production is also reduced with irradiated leukocytes (4). Macrophage modulation by radiation (6) promotes regulatory immune cytokines while inhibiting proinflammatory cytokines and inducible nitric oxide synthase, downregulating nitric oxide production (5).
Dove et al, (2022).

5. Clinical Evidence

A growing body of evidence supports the use of LDRT in benign musculoskeletal disease:

- **United States – Koneru et al. (2025):**
  In the first large U.S.-based analysis of LDRT for OA, 69 patients and 168 joints were treated at a single center using 3 Gy over 6 fractions (0.5 Gy per session) [26].
  Findings:
  - Statistically significant pain reduction using the Numerical Rating Scale (NRS) and von Pannewitz score (VPS)
  - No adverse effects or late toxicity
    This study adds crucial domestic validation of LDRT, aligning with decades of European experience.
- **Iran – Fazilat-Panah et al. (2025):**
  A double-blind, sham-controlled randomized trial on 60 patients with knee OA showed significant improvements in VAS pain scores and WOMAC function scores after treatment with 3Gy in 6 fractions [13].
- **Russia – Russian Open Medical Journal (2023):**
  A 10-year longitudinal study in Russia found that patients treated with LDRT experienced sustained reductions in pain and disability, significant improvements in both physical and mental quality of life, and a slower progression of degenerative changes on MRI compared to controls [14].
- **Germany – Ott et al. (2014):**
  This comprehensive review of over 15,000 cases affirmed that low-dose radiotherapy provides effective pain relief in plantar fasciitis and other degenerative conditions with minimal toxicity. [19].
- **Turkey – Canyilmaz et al (2015):**
  This prospective randomized trial directly compared LDRT (6 × 0.5 Gy = 3 Gy total) to steroid injection in patients with plantar fasciitis, and found both modalities reduced pain, but radiotherapy offered more sustained relief at 12 months. [31]
- **Spain – Montero et al. (2022):**
  CT-guided LDRT achieved >80% success in treating plantar fasciitis and Achilles tendinopathy in a prospective study [20].
- **Germany – Ruhle et al. (2021):**
  A multicenter study of 970 elderly patients found that LDRT significantly reduced osteoarthritis-related pain across 1,185 treated joints, with consistent effectiveness regardless of patient age [29].
- **Germany – Ott et al. (2019):**
  A randomized trial comparing 3 Gy and 6 Gy LDRT found both regimens equally effective in relieving pain, supporting 3 Gy as a viable lower-dose alternative [30].
- **Switzerland – Rogers et al (2020):**
  A prospective study showing that low-dose radiotherapy significantly improved pain, quality of life, and function in patients with non-malignant musculoskeletal conditions including plantar fasciitis, epicondylitis, and hand osteoarthritis [21].

6. Conflicting Evidence and Critical Appraisal

The primary counterargument comes from a study in the Netherlands by Mahler et al. (2019): A double-blind RCT involving 117 OA patients that found no statistically significant difference in pain reduction between LDRT and sham treatment at 4 and 12 weeks [15].

However, this study has major limitations:

- **Refractory patient population:** The study enrolled patients with long-standing, treatment-resistant osteoarthritis, a group that tends to respond poorly to radiotherapy, which may have limited observable benefits.
- **Single-phase treatment only:** Most patients received just one 6 Gy course. A second treatment phase is often recommended in cases of persistent symptoms.
- **Trial powered for large effects only:** The study design assumed that only a large treatment effect would be meaningful, potentially overlooking moderate but clinically relevant improvements.
- **Limited outcome context:** The study relied only on patient-reported outcomes, without imaging, functional scores, or long-term evaluation.
- **Not representative of broader evidence:** This trial should be interpreted in the context of a larger international body of evidence, which consistently supports the efficacy of LDRT in similar populations.

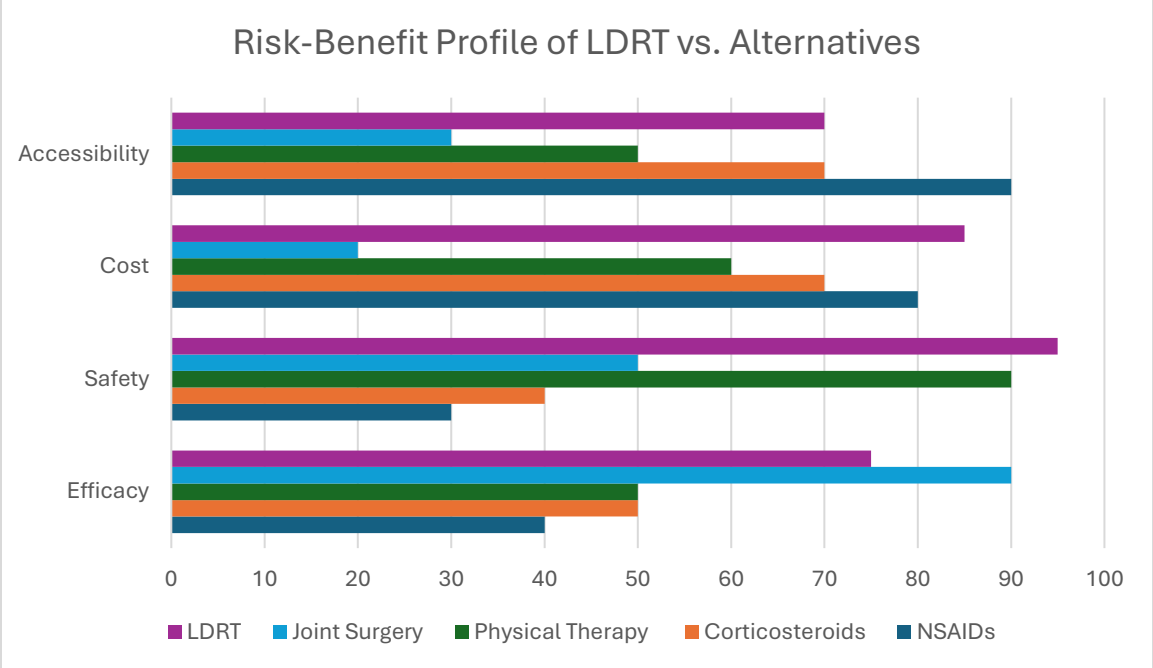
A second Dutch RCT by Minten et al. (2016) found similar results in a smaller group of 55 patients. [25]

Unfortunately, some in the medical community have **overstated** the implications of these very small, flawed study, despite being an outlier among a very large body of evidence including > 65 trials. While valuable as part of the conversation, the Dutch trials' conclusions should be interpreted with **skepticism** and **contextualized** within the broader evidence base.

7. Comparative Therapeutic Analysis

Therapy	Typical Duration	Common Risks	Cost (Est.)	Comments
NSAIDs	Weeks–Months	GI bleeding, renal failure, cardiovascular	$100-$500/year	Contraindicated in elderly, polypharmacy issues
Corticosteroids	Months (short-term)	Cartilage damage, tendon rupture	$500-$1,000/year	Cumulative joint damage risk
Physical Therapy	Ongoing	Low	$1,000-$3,000/year	Infeasible with severe pain
Joint Surgery	Decades	Infection, implant failure, high morbidity	$30,000–$50,000	Access, comorbidity, long recovery
LDRT	1–2 years	Rare skin erythema, negligible long-term	$2,500–$4,000	Durable, non-invasive, repeatable

Figure 2: Ris-Benefit Profile of LDRT vs. Alternatives



LDRT offers a uniquely favorable risk-benefit and cost-benefit profile for patients not suitable for other options. However, there may be reimbursement challenges, particularly for commercially insured patients.

8. Cost-Effectiveness and Insurance Value Proposition

- **Low cost per course:** $2,500–$4,000 vs. $50,000+ for surgery [10]
- **Reduced downstream costs:** Fewer injections, medications, hospital visits
- **No rehab necessary**
- **Improved function:** Delays or eliminates need for joint replacement

Supporting studies:

- **Alvarez et al. (2020):** Found high QALY yield in Spanish OA patients with failed conservative care [22]
- **Seegenschmiedt et al. (2000):** A multicenter German study demonstrated consistent and sustainable use of LDRT for benign diseases across institutions, supporting its clinical feasibility. [24]

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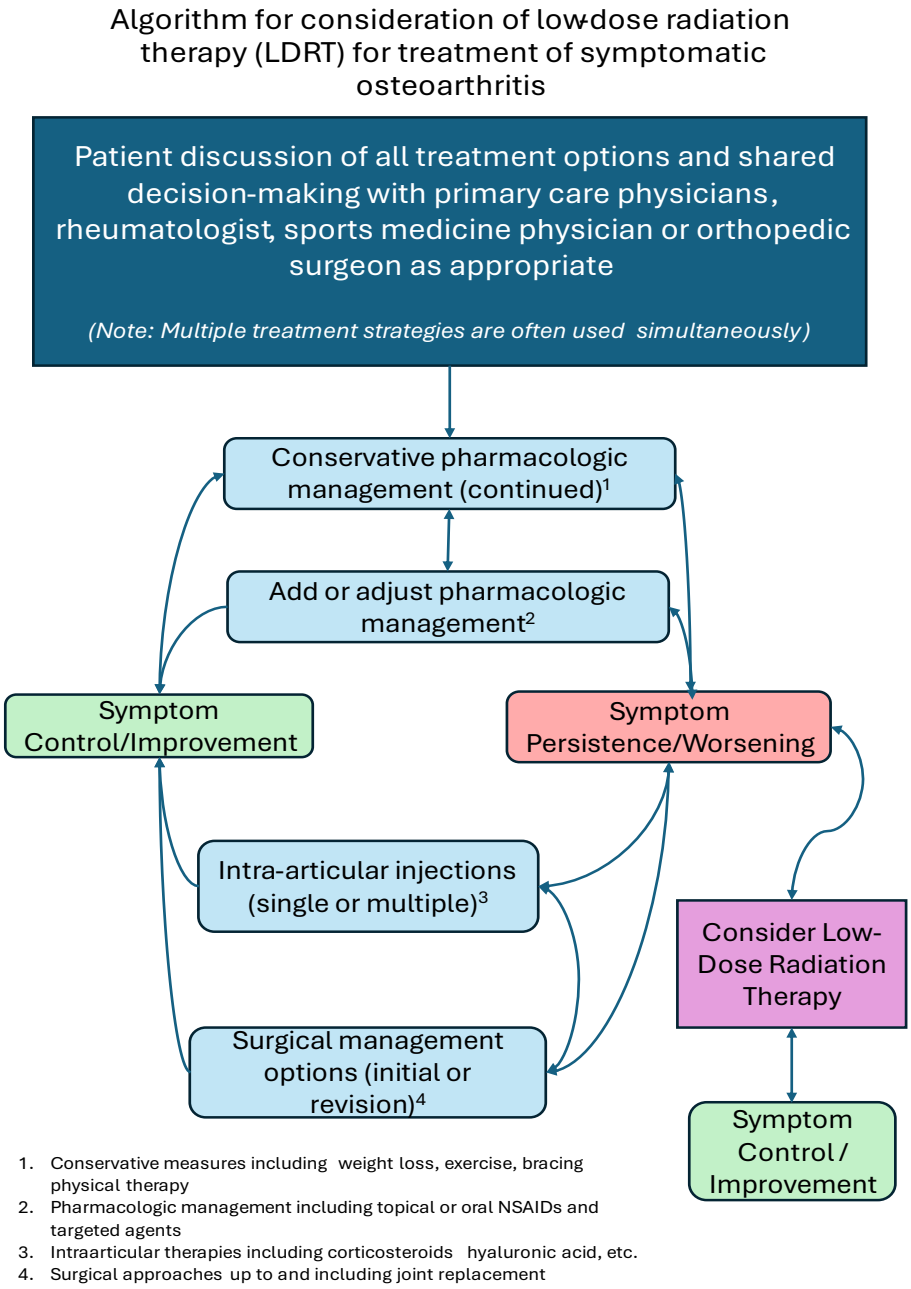
9. Guidelines and Global Consensus

LDRT is already part of standard care in several international systems:

- **Germany – DEGRO Guidelines (2022):**
  Officially endorse LDRT for OA, plantar fasciitis, and enthesopathies with structured dose protocols [2]
- **Austria & Spain:**
  Regional protocols align with DEGRO; image-guided delivery promoted for optimal targeting
- **Iran & Russia:**
  Government-funded research and registry data support broad use in musculoskeletal clinics [13][14]
- **United States – Koneru et al. (2025):**
  The first major U.S. study provides **domestic evidence** for effectiveness and safety. Though not yet part of formal guidelines, it lays the groundwork for coverage and inclusion in evidence-based pathways [26].

Figure 3: LDRT Treatment Decision Flowchart



10. Risk and Safety Considerations

LDRT has a **favorable safety profile**, especially compared to pharmacologic or surgical alternatives.

10.1 Long-Term Cancer Risk

- Therapeutic LDRT doses (3–6 Gy) are **<10%** of oncology radiation doses.
- Delivered locally to joints, sparing major organs.
- **No significant increase in malignancy** reported in decades of follow-up [1][11].

Proactive Safeguards:

- **Age threshold:** Most protocols limit use to patients **over 45–50 years** to reduce theoretical latency risk.
- **No repeat exposure required**: Unlike medications or injections, most patients benefit from one or two treatment courses.

10.2 Short-Term Toxicity

- Mild, self-limiting erythema (<2% incidence)
- No tissue fibrosis, necrosis, or systemic effects
- No interaction with medications

10.3 Comparative Risk Summary

Treatment	Major Risks
NSAIDs	GI bleeding, renal failure, cardiovascular risk [6][7]
Steroids	Joint degeneration, osteoporosis, infection [8]
Surgery	Infection, anesthesia risk, prosthesis failure [10]
LDRT	No known serious risks; theoretical cancer risk mitigated by dose and age selection [1][11]

LDRT emerges as **among the safest interventional options** for musculoskeletal pain in older adults.

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11. Policy Recommendations for Insurance Coverage

Based on strong international guidelines, robust clinical evidence, and economic modeling, we propose:

11.1 Indications for Coverage

Coverage for LDRT should apply to:

- **Osteoarthritis** (knee, hip, hand and wrist, foot and ankle, shoulder, elbow)
- **Plantar fasciitis**
- **Tendinopathies/enthesopathies**
- Failed > 3 months of conservative treatment

- Or, not candidates for surgery or systemic medications

11.2 Protocol

- 0.5-1.0 Gy per session
- 6 sessions over 2–3 weeks with up to 2 courses as necessary
- Total dose per course: 3-6 Gy
- Delivered via linear accelerator or orthovoltage unit

11.3 Billing and Authorization

- **CPT Codes**: 77401 (superficial), 77402 (external beam)
- **Documentation**: Clinical diagnosis, treatment history, imaging if available
- **Optional outcomes tracking**: WOMAC, VAS, EQ-5D or SF-36

11.4 Implementation Model

- Authorized under "specialty interventional therapy" pathway
- Comparable to existing coverage for spinal injections, biologic injections, or nerve blocks

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12. Conclusion and Call to Action

LDRT is a proven, cost-effective, and safe therapy for chronic benign musculoskeletal pain, especially in populations underserved by current approaches. It has been successfully implemented in healthcare systems across Europe, Asia, and now demonstrated effective in a U.S. study (Koneru et al., 2025).

In the era of value-based care, insurers must revisit outdated assumptions and align with modern data. Adoption of LDRT coverage policies can:

- Improve patient outcomes
- Avoid surgery in high-risk patients
- Deliver long-term cost savings

LDRT should no longer be considered experimental or investigational. It is a mainstream, evidence-based treatment whose time has come.

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13. About Radiance RT

Radiance RT provides a comprehensive, in-office solution for delivering low-dose radiation therapy (LDRT) to patients with benign musculoskeletal conditions. The company focuses on increasing access to LDRT by enabling physicians to offer treatment directly within their clinical

practices. This model supports continuity of care and reduces the need for referrals to cancer centers.

Radiance RT's approach includes equipment provision, clinical protocols, staffing, and billing support. The service is structured to integrate with existing workflows and is aligned with current reimbursement pathways, including both Medicare and commercial insurers.

The Radiance RT team includes board-certified radiation therapy professionals and experienced medical physicists who collaborate closely with provider groups to ensure safe, effective, and compliant implementation of LDRT in non-oncologic settings.

For more information, visit www.RadianceRT.com.

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Appendix A: Policy Summary Sheet

Coverage Recommendation

Cover LDRT for chronic osteoarthritis, plantar fasciitis, or tendinopathies in patients who have failed ≥2 conservative therapies.

Top 5 Evidence Points

1. Over 70% clinical success rate across European studies with durable symptom relief.
2. First U.S. validation (Koneru et al., 2025) confirms safety and efficacy in 69 patients.
3. No long-term cancer risk at doses used; protocols restrict to patients >45.
4. Cost-effective: $2,500-$4,000 vs. $50,000+ for surgery.
5. Endorsed by DEGRO, Russian, Spanish, and Iranian national guidelines.

Comparative Cost Table

Treatment	Typical Duration	Risks	Estimated Cost
NSAIDs	Weeks–Months	GI bleed, renal failure	$100–$400/year
Steroid Injections	3–6 months	Cartilage damage, rupture, OA progression	$400–$1,200
Physical Therapy	Ongoing	Low risk	$1,000–$3,000/year
Surgery (TKA)	Decades	Infection, failure	$30,000–$50,000
LDRT	1–2 years	Minimal	$2,500–$4,000

Safety Summary

- No increase in malignancy observed in >20-year cohort studies
- Only mild, transient skin reactions in <2% of cases
- Limited to adults over 45 to mitigate theoretical risks

Reimbursement Pathway

- CPT: 77401 (Superficial) or 77402 (External Beam)
- ICD: M15 – 19 (Osteoarthritis) M72.2 (Plantar fasciitis), M75.1, M77.1 etc. (Tendinitis)
- Prior auth: Clinical history, failed therapies, imaging (if available)