

American Radium Society® (ARS) Appropriate Use Criteria (AUC) for Low Dose Radiotherapy for the Treatment of Inflammatory Periarticular Disorders

Expert Panel Adjuvant Therapy for Low Dose Radiotherapy for Inflammatory Periarticular Disorders:

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All panelists were required to declare all conflicts of interest for the previous 36 months prior to initiating work on this document. These complete disclosure forms are retained by the American Radium Society™ in perpetuity. The ARS Appropriate Use Criteria Steering Committee reviewed the disclosures with the chair and co-chair of this document and approved participation of the panelists prior to starting development of this work. Disclosures potentially relevant to the content of this guideline are provided:

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INTRODUCTION

Inflammatory periarticular disorders are among the most common causes of chronic musculoskeletal pain and functional limitation in adults.^{1,2} These soft tissue conditions include tendinitis, enthesitis, bursitis, and related degenerative inflammatory syndromes.³⁻⁶

Common Inflammatory Periarticular Disorders by Joint Location

- ***Tendinitis:***
 - Shoulder: rotator cuff tendinitis (swimmer's shoulder) involving the supraspinatus tendon and long head of the biceps (often with calcific deposits)⁷
 - Elbow: lateral epicondylitis (tennis elbow)⁸, medial epicondylitis (golfer's elbow)⁹
 - Wrist/hand: base of thumb (De Quervain's tenosynovitis)¹⁰, extensor carpi ulnaris¹¹, and flexor tendinitis (trigger finger)¹²
 - Hip: greater trochanteric pain syndrome (GTPS) (gluteus medius/minimus)¹³, iliopsoas tendinitis¹⁴
 - Knee: patellar tendinitis (jumper's knee)¹⁵, quadriceps tendinitis^{16,17}, popliteus tendinitis¹⁸
 - Ankle/heel: Achilles tendinitis (insertional or mid-portion)^{19,20}, tibialis posterior tendinitis²¹, peroneal tendinitis²²
- ***Enthesitis*** (where tendon/ligaments meet the bone)^{23,24} and ***fasciitides***:
 - Shoulder: rotator cuff enthesitis insertional at greater/lesser tuberosity (not mid-tendon)²⁵
 - Elbow: medial epicondylitis (golfer's elbow) at medial humeral epicondyle, lateral epicondylitis (tennis elbow) at lateral humeral epicondyle
 - Hand: palmar fasciitis (paraneoplastic or inflammatory)²⁶
 - Hip: GTPS / gluteal enthesitis²⁷, hamstring enthesitis at ischial tuberosity²⁸, rectus femoris enthesitis at anterior inferior iliac spine²⁹, iliotibial band syndrome (fascia lata syndrome)³⁰
 - Knee: patellar tendon enthesitis insertional at inferior patellar pole or tibial tuberosity³¹, iliotibial band friction syndrome (lateral knee)³²
 - Heel: Achilles enthesitis at posterior calcaneal tuberosity³³
 - Foot: plantar fasciitis (heel and foot arch pain)³⁴
- ***Bursitis:***
 - Shoulder: subacromial-subdeltoid bursitis (part of the subacromial pain syndrome)³⁵, scapulothoracic bursitis (snapping scapula syndrome)³⁶
 - Elbow: olecranon bursitis (student's elbow)³⁷
 - Hip: trochanteric bursitis often involving gluteus medius/minimus tendinitis with bursal inflammation (lateral hip pain exacerbated by lying on affected side, walking, or stair climbing)³⁸, ischiogluteal bursitis (weaver's bottom, pain over ischial tuberosity aggravated by sitting)³⁹, iliopsoas bursitis (anterior hip/groin pain)⁴⁰
 - Knee: prepatellar bursitis (housemaid's knee, superficial bursa anterior to patella)⁴¹, infrapatellar bursitis (anterior knee pain below patella)⁴², anserine bursitis (medial knee pain approximately 5cm distal to joint line)⁴³
 - Ankle/Foot: retrocalcaneal bursitis (deep bursa between Achilles tendon and calcaneus, causes posterior heel pain with dorsiflexion)⁴⁴, superficial calcaneal bursitis (between Achilles tendon and skin)⁴⁵, talar bursitis (Gruber's bursitis, between extensor digitorum longus and dorsolateral talus)⁴⁶

Pathophysiology

Inflammatory periarticular disorders share a common pathobiologic mechanism involving a continuum of mechanical overload, microtrauma, and failed tissue healing within the "entheses organ" complex, which includes the tendon insertion, adjacent bursa, fat pads, and cortical bone.⁴⁷ The pathophysiology of bursitis involves irritation or direct trauma triggering synovial cells to multiply and hyper-secrete high-protein fluid, leading to painful swelling,

capsular distension, and localized inflammation. Tendinitis is characterized by inflammation in the tendon complex usually as a result of repetitive microtrauma or other injury, which when chronic can be destructive leading to scarring, micro-tearing, calcium deposits, and tendinosis.^{24,48,49} With severe cases of tendinosis, progressive breakdown of collagen in the tendon complex can lead to muscle atrophy and tendon rupture.⁵⁰ Enthesitis and fasciitis involve the bone-tendon/ligament interface affecting the tendon substance, typically 2-6 cm proximal to insertion.^{4,51} Histopathologic findings include collagen disorganization, fibroblast proliferation, neovascularization, and low-grade inflammation mediated by cytokines such as IL6/IL10/IL-17/IL-23/IL-1 β and TNF- α .^{49,52-54}

Patient Evaluation

In physical examination, joint-specific provocative maneuvers should support the diagnosis of a periarticular disorder. Examples include the Neer/Hawkins test for subacromial pain syndrome⁵⁵⁻⁵⁷, the Cozen test for lateral epicondylitis^{58,59}, the single-leg stance or FABER test for GTPS⁶⁰, and the Windlass test for plantar fasciitis.^{44,61} Enthesitis tenderness is typically maximal at the bony insertion, not along the tendon course.⁴⁷

Plain radiographs are often first-line to exclude fracture or tumor and may identify calcifications or degenerative changes. Ultrasound and/or magnetic resonance imaging (MRI) are useful when structural tears, advanced degeneration, or alternative diagnoses are suspected.⁶² By ultrasound, peripheral entheses may show thickening, altered Doppler signal, or erosions.⁶³⁻⁶⁵ MRI is most valuable in distinguishing tendinosis from full-thickness tendon rupture.⁶⁶

Treatment Options

Management of periarticular disorders is stepwise and multidisciplinary. Options for treatment of periarticular inflammatory disorders include self-care measures, physical therapy, pharmacologic agents, intraarticular injection, dry needling and barbotage, extracorporeal shockwave therapy (ESWT), surgical intervention, and low-dose radiation therapy (LDRT).^{3,67,68}

Conservative Measures (Self-Care and Bracing)

First-line therapy includes ice/heat application, activity modification, ergonomic adjustments, bracing, orthotics, and structured home exercise programs.^{69,70} Examples of orthotics include heel pads for plantar fasciitis and counterforce bracing for lateral epicondylitis.^{71,72} Limitations include compliance, especially adherence to activity modifications, particularly when occupational demands or athletic activities are central to a patient's livelihood. Prolonged rest may lead to deconditioning and joint stiffness, particularly in shoulder conditions where immobilization can cause adhesive capsulitis. While conservative measures are overall low risk, they are often insufficient for established chronic conditions.⁷³

Physical Therapy

As a cornerstone of management for tendinitis, supervised rehabilitation and eccentric loading exercise programs may be helpful.⁷⁴⁻⁷⁸ Standard components of physical therapy include manual therapy, stretching, and progressive strengthening.^{79,80} Limitations include the risk of exacerbating the symptoms, especially with too aggressive physical therapy during acute inflammatory phases.⁸¹ Patients with high physical demand occupations are recommended to engage in a phased approach to reintroduce stress. Several weeks to months of consistent therapy are typically required before meaningful improvement is observed.^{82,83} In addition, variability in therapist expertise and insurance coverage may limit access.⁸⁴

Pharmacologic Therapy

Oral nonsteroidal anti-inflammatory drugs (NSAIDs) and topical therapies are frequently used as first-line pharmacologic agents for pain control in periarticular disorders. However, long-term use may be limited by gastrointestinal, renal, and cardiovascular risks.⁸⁵ These risks include gastrointestinal ulceration and bleeding that increases with age and duration of use, risk of myocardial infarction and stroke, and risk of renal impairment

especially in patients with pre-existing kidney disease. Among the NSAIDs, celecoxib appears to have a more favorable safety profile than naproxen or ibuprofen.⁸⁶ To minimize these risks, NSAIDs should be used for a limited duration and at the lowest effective dose. NSAIDs address pain and inflammation but do not modify the underlying degenerative pathology.

Surgical and Other Procedures

- **Corticosteroid Injections:** Image-guided intra-articular or periarticular corticosteroid injections are commonly used for short-term symptom relief in periarticular disorders.⁸⁷ Pain relief typically lasts 1-12 weeks, with high recurrence rates.⁸⁸ Repeated injections into or near tendons are associated with tendon rupture, collagen disorganization, and compromised repair potential.⁸⁹ It is recommended to limit the frequency of injections. Local adverse effects include post-injection flare, facial flushing, skin hypopigmentation, and subcutaneous fat atrophy.^{90,91} Systemic adverse effects include transient hyperglycemia, adrenal suppression, and reduced bone mineral density with repeated use.⁸⁹ Caution is warranted in patients on anticoagulation or immunocompromised status.
- **Platelet-Rich Plasma (PRP) Injections:** Platelet-Rich Plasma (PRP) therapy uses the patient's own concentrated platelets and growth factors to target inflammatory periarticular disorders, such as tendinitis, bursitis, and ligament strain. It works by modulating the immune response, reducing local swelling, and accelerating tissue repair.⁹² It has demonstrated promising efficacy for various inflammatory and degenerative periarticular disorders.^{93,94} While corticosteroids provide better short-term relief, PRP delivers more sustained, long-term improvements in pain reduction and joint function—frequently lasting 6 to 12 months without major adverse side effects.⁹⁵ PRP injections may modulate inflammation and promote tissue healing, but there is variable evidence regarding its efficacy.⁹⁴ Limitations include procedural risks such as infection, pain at injection site, and rare immunologic reactions.⁹⁵ In addition, PRP is typically not covered by insurance and represents a significant out-of-pocket expense.^{92,96,97}
- **Dry Needling and Barbotage:** Dry needling involves the insertion of thin needles into hypersensitive spots within taut bands of skeletal muscle, also known as myofascial trigger points, which may elicit a local twitch response and release muscle tension. Barbotage involves moving the needle like a piston to repeatedly penetrate calcific depots in tendons to fragment and promote resorption.^{98,99} In clinical studies, both methods are associated with pain reduction lasting over weeks to months, with comparable efficacy to conservative treatments and open-release surgery.⁹⁹ However, randomized trials show no benefit compared to exercise therapy, and there is low-to-moderate quality of clinical evidence involving heterogeneity in techniques, small sample sizes, difficulty blinding, and lack of long-term follow-up.¹⁰⁰ Limitations include minor adverse events from needle insertion including bleeding, bruising, pain during insertion, and post-needling soreness. Very rare serious complications can occur if inserting needles near critical structures such as lungs, spinal cord, peripheral nerves, or major blood vessels.
- **ESWT and Ultrasound Therapy:** ESWT delivers acoustic energy noninvasively to promote neovascularization and tissue healing.¹⁰¹ However, efficacy is variable in clinical studies, with questionable benefit beyond placebo.¹⁰² Limitations include ESWT-induced pain requiring analgesia and potential adverse effects on cartilage.¹⁰³
- **Surgical Intervention:** Surgical intervention is appropriate when structural pathology (e.g., full-thickness tendon tear) is present or when all conservative and noninvasive/minimally invasive options fail.¹⁰⁴⁻¹⁰⁶ These may include procedures involving debridement, surgical repair, and tenotomy or fasciotomy including ultrasound-guided percutaneous procedure.¹⁰⁷⁻¹¹⁰ Limitations include the invasiveness of surgery that can be associated with risk of infection, nerve injury, prolonged recovery, and scar tissue formation. Pain relief may vary and postoperative physical therapy is typically

prolonged and intensive.^{104,111} Contraindications to surgery include advanced age, medical comorbidities, and patient preference.

Low Dose Radiotherapy (LDRT)

LDRT is a non-invasive anti-inflammatory treatment for chronic, refractory, non-ruptured, inflammatory periarticular disorders, particularly for patients with persistent symptoms despite conservative treatments.^{3,112-116} Although it has been used for decades internationally, LDRT has only recently re-emerged as a modern management strategy in the US.^{117,118} Although the evidence discussed in this manuscript regarding LDRT in the treatment of inflammatory periarticular disorders focuses on common presentations, including plantar fasciitis, lateral epicondylitis, GTPS, and painful shoulder syndromes, it can be considered for inflammatory periarticular disorders of other locations.

LDRT Mechanism of Action

The therapeutic effect of LDRT is primarily attributed to its anti-inflammatory and immunomodulatory effects, including modulation of cytokine activity (e.g., IL-1 β , IL-6, and TNF- α) and alterations in immune cell profiles, which contribute to symptom reduction and improved quality of life.^{53,119} LDRT at doses of 1.0 Gy or below per fraction exerts immunomodulatory and anti-inflammatory effects.^{120,121} Preclinical and translational studies demonstrate LDRT promotes macrophage polarization toward an anti-inflammatory M2-like phenotype, modulates endothelial adhesion molecules, and reduces leukocyte recruitment including by increased TGF- β 1.¹²²⁻¹²⁴ Additional mechanistic data for LDRT indicates there is downregulation of pro-inflammatory mediators, such as matrix metalloproteases and modulation of mitochondrial signaling pathways associated with tissue degeneration. Emerging clinical data indicates LDRT is associated with changes in peripheral blood immune cell populations.¹¹⁹ Importantly, the anti-inflammatory effects of LDRT appear dose-dependent and are most pronounced when ≤ 1 Gy per fraction, as higher doses per fraction used in typical oncologic regimens may not confer the same biological modulation and instead can promote fibrosis or tissue injury.¹²⁵

This systematic review and guidelines summarize the current evidence to guide treatment decision making when considering LDRT for inflammatory periarticular disorders. The Population, Intervention, Comparator, and Outcome (PICO) questions included (1) What is the role of LDRT in the treatment of inflammatory periarticular disorders?, (2) Which patients are considered appropriate candidates for LDRT?, (3) What are the risks associated with LDRT?, and (4) What is the optimal LDRT technique?

METHODS

Using the Population, Intervention, Comparator, Outcome, Timing and Study Design (PICOTS) framework, the evidence regarding treatment outcomes was assessed using Cochrane and PRISMA 2020 methodology.^{126,127} Eligible studies included prospective studies, phase II-III trials, and retrospective analyses including ≥ 15 patients published between 1/1/1996 and 1/1/2026 in the Embase, Medline and PubMed databases. Appendix A contains the database search strategy designed by a librarian specializing in systematic reviews. The lead authors independently screened the comprehensive list of articles, and one assessed the full text articles to determine the final studies included in the Summary of the Literature Review which advised our recommendations (Appendix B). Discrepancies between the reviewers were resolved by consensus. Of the 662 articles identified using the search strategy, 51 were selected for inclusion that met all inclusion criteria. 9 additional studies were included through backward citation searching that significantly contributed to the literature were identified from the reference list of articles found from the search strategy. An additional 123 studies referenced outside the “Summary of Literature Review” are included to provide context, but unless they are also cited within the “Summary of Literature Review” they were not used by the committee to guide recommendations. In total, 183 references were selected for inclusion. Study type and quality for these references were assessed via American Radium Society™ (ARS) Appropriate Use Criteria (AUC) methodology

(Appendix C). The systematic review PRISMA 2020 checklist confirms the completion of essential elements (Appendix D). Well-established RAND-UCLA consensus methodology (modified Delphi) was used by the expert panel to rate the appropriateness of the treatment options¹²⁸, with a total of 2 rounds of voting employed by the group. Categories included (1) usually not appropriate (U, score 1-3); (2) may be appropriate (M, score 4-6); and (3) usually appropriate (A, score 7-9). The project proposal as well as this executive summary were reviewed and approved by the ARS AUC steering committee, which includes a librarian with expertise in systematic reviews. For further details on ARS AUC methodology guidelines. See <https://www.americanradiumsociety.org/page/aucmethodology>.

RESULTS/SUMMARY OF LITERATURE REVIEW

Topic 1/ What is the role of LDRT in the treatment of inflammatory periarticular disorders?

Subtopic 1/ Efficacy

Clinical evidence from randomized trials, prospective trials, and retrospective studies showed that LDRT provides clinically meaningful pain relief and functional improvement in patients with chronic, refractory inflammatory periarticular disorders who have not achieved adequate relief with first-line therapies such as NSAIDs, physical therapy, or injections, which is commonly assessed using validated pain scales, such as the visual analog scale (VAS).^{129,130} The available evidence supports LDRT as an effective adjunctive or second-line treatment modality for selected patients with periarticular disorders, offering durable pain relief through biologically mediated anti-inflammatory mechanisms while maintaining a favorable safety profile.¹³¹ Prospective and retrospective series demonstrate benefits from LDRT typically using doses of 3.0 to 6.0 Gy delivered in 0.5 to 1.0 Gy fractions.^{114,132} For insufficient responders, there is consideration for repeating the course after 6-12 weeks, with re-irradiation generally well-tolerated.¹³²⁻¹³⁵

Large retrospective cohorts demonstrate consistent real-world effectiveness of LDRT including multiple inflammatory periarticular conditions.¹¹⁷ A German national patterns-of-care analysis from 76 institutions including 7,947 patients with plantar fasciitis showed that 70% of patients experienced pain reduction at ≥ 3 months, with persistent pain relief occurring in 65%, with no acute or chronic side effects.¹³⁶ In a retrospective analysis of 91 patients treated for benign musculoskeletal disorders (including epicondylitis, plantar fasciitis, and osteoarthritis), LDRT of 6 Gy in 0.5 Gy fractions 2-3 times weekly produced clinically meaningful analgesic effects and symptom improvement across treated sites with 65% complete response at 4-6 months, supporting its generalizability.¹³⁷ A retrospective study of 141 patients with chronic shoulder periarthritis failing conservative therapies treated with LDRT (mostly 6 Gy in 1 Gy fractions twice weekly) reported immediate pain relief in 56% that increased to 73% at 3.9 years, with virtually no side effects.¹³⁸ A retrospective analysis of 138 elbows treated with LDRT by linear accelerator for epicondylitis found the median pain scores decreased from 7 to 0 and 64.6% of patients achieved complete or near-complete pain relief.¹³⁹ Similarly, retrospective data in 60 patients (74 hips) with refractory GTPS demonstrated meaningful rates of remission following LDRT (3-4 Gy in 0.5-1.0 Gy fractions), with patient-reported improvements in pain (partial or complete) in 70% at 3 months with corresponding functional improvement. Clinical predictors associated with better outcomes, included presence of night pain (OR 3.48, $p = 0.038$) and inclusion of the entire femoral neck circumference in the target volume. Conversely, pain flare during LDRT correlating with treatment failure (OR 0.21, $p = 0.007$).¹⁴⁰

A prospective study of 166 elderly patients with benign painful skeletal disorders showed significant reductions in pain scores following LDRT (6 Gy in 0.5-1.0 Gy fractions), with mean VAS pain scores improving from 6.38 to 4.49 shortly after treatment ($p < 0.001$) in 37%.¹⁴¹ At a median of 29 months, sustained responses were observed, with nearly 50% having complete pain relief or marked improvement in the long-term.¹⁴¹ In another prospective cohort of 703 patients with painful degenerative joint disorders (including trochanteric bursitis, calcaneodynia, achillodynia, and painful shoulder syndrome), LDRT of 6 Gy in 0.5-1.0 Gy fractions produced significant immediate pain reduction with mean VAS decreasing from 6.63 to 4.51 ($p < 0.001$).¹²⁹ Initial response rate was 37.6% immediately after LDRT, which increased to 58.4% at a median of 33 months ($p < 0.001$), except for painful gonarthrosis (knee site) which continued to have a 30% response rate.¹²⁹ A prospective study of 45

elbows (41 patients) treated with LDRT (6 Gy in 1 Gy fractions over 3 weeks) found satisfactory analgesia at 7.5 weeks in 68.9%, alleviating the pain at rest and on exercise from lateral epicondylitis.^{142,143} In a prospective study of 104 patients with refractory humeral epicondylitis treated with LDRT (two courses separated by 6 weeks each comprised of 6 Gy in 1 Gy fractions over 3 weeks), 74% of elbows achieved complete or major pain relief at a mean of 4 years follow-up, with Morrey elbow scores improving substantially from 78 to 96 points.¹⁴⁴

A prospective study of 157 patients (204 sites) over age 40 years with chronic epicondylitis, plantar fasciitis, or finger osteoarthritis having pain more than 6 months despite conservative therapy had significant improvements following LDRT (0.5 Gy twice weekly for 4 weeks, with one repeat course if needed).¹⁴⁵ At 12 months, those with lateral epicondylitis had significant reduction in pain at rest ($p < 0.001$), during activity ($p < 0.001$), and increased hand grip strength (extension $p < 0.001$, flexion $p = 0.002$).¹⁴⁵ Those with medial epicondylitis reported pain relief at rest ($p = 0.041$) and during activity ($p = 0.041$) and significant increase in hand grip strength ($p = 0.022$).¹⁴⁵ Patients with plantar fasciitis reported pain reduction at rest ($p < 0.001$), during activity ($p < 0.001$), and faster walking times ($p < 0.001$).¹⁴⁵

A prospective study of 155 elderly patients with GTPS using LDRT (either 6 or 10 Gy) showed mean VAS pain scores decreased from 8 to 4 over 4 months, with 83% achieving at least 1-point reduction, 29% achieving a VAS pain score of < 3 , and 53% maintaining analgesic response at 5 years, supporting LDRT as durable treatment option for refractory GTPS in older adults.^{146,147} In another prospective study of 60 patients with recurrent trochanteritis who had failed conservative therapy receiving LDRT, 62% achieved significant improvement with mean VAS pain scores decreasing from 8 ± 2 to 4 ± 2 ($p < 0.0001$) at 4 months, with 70% of responders maintaining improvement beyond 24 months.¹⁴⁸ In a prospective study of 71 sites (65 patients) with GTPS, LDRT (3-4 Gy in 0.5-1.0 Gy fractions) achieved a 59% good response at 2 months, with re-irradiation in 2 courses significantly outperforming 1 course (72.5% vs 42%, $p = 0.015$).¹⁴⁹ Interestingly, prior temporary response to steroid injection (> 7 days pain relief) strongly predicted radiotherapy success (73% vs 28%, $p = 0.001$), while regional structural abnormalities had reduced response rates (44% vs 73%, $p = 0.017$), suggesting key patient selection factors.¹⁴⁹

A randomized trial of 66 patients with plantar fasciitis showed that LDRT of 6 Gy in 6 fractions (standard dose arm) produced superior pain relief compared to 0.6 Gy in 6 fractions (low dose arm) at 3 months, with statistically significant ($p = 0.001$) improvements in VAS, calcaneodynia score, and SF-12. Patients with a favorable response at 3 months continued to have sustained or further improved outcomes at 12 months, and the standard dose arm had fewer courses of re-irradiation ($p < 0.001$).¹⁵⁰

Dose optimization studies further support efficacy while suggesting flexibility in fractionation. A prospective nonrandomized trial of 199 patients with painful elbow syndrome demonstrated substantial pain reduction following LDRT of 6 fractions of 0.5-1.0 Gy per fraction with optional reirradiation, with pre-treatment VAS scores 56-59 decreased to 32-34 at 6 weeks and 10-21 at 3 years, and no significant difference in outcomes between 0.5 Gy and 1.0 Gy fractionation regimens ($p = 0.28$), indicating comparable efficacy across commonly used dose schedules.¹⁵¹ A 2025 systematic review of 33 studies involving 12,143 patients comparing kilovoltage and megavoltage radiotherapy techniques reported high overall response rates (62-85%) in the short and long-term, further reinforcing the effectiveness of LDRT across technical approaches.¹⁵²

Additional prospective and retrospective studies across various periarticular conditions, including calcaneodynia and achillodynia, consistently demonstrate reductions in pain measured by validated scales such as VAS, supporting the reproducibility of treatment effect across disease sites.¹⁴¹

Overall, the literature demonstrates that LDRT produces clinically significant and durable pain reduction as well as functional improvement across multiple periarticular disorders, particularly in conditions such as plantar fasciitis and other enthesitis. The efficacy is supported by randomized trials, prospective studies, and large retrospective analyses, with consistent benefit observed among different disease sites, dosing regimens, and technical approaches.

Subtopic 2/ Comparison of LDRT to other treatments

Plantar Fasciitis: For plantar fasciitis, there is direct comparison between LDRT and other modalities. A prospective randomized trial of 128 patients with plantar fasciitis demonstrated that radiotherapy was significantly superior to palpation-guided local corticosteroid injection in terms of pain relief (pre-treatment mean VAS 7.6-6.9 decreased to 2.8 for LDRT and 4.6 for corticosteroid, $p < 0.001$) and functional outcomes at 3 and 6 months, with sustained benefit through a median follow-up of 13 months. There was also a longer response duration for LDRT before the need for repeat treatment ($p = 0.045$).¹⁵³ A prospective randomized trial of 40 patients with plantar fasciitis demonstrated both LDRT or platelet-rich plasma (PRP) treatment provided similar significant improvements in pain (pre-treatment mean VAS 6.5 decreased to 2.3 at 6 months, $p < 0.0001$), functional status (pre-treatment American Orthopaedic Foot and Ankle Score 52 improved to 89 at 6 months, $p < 0.0001$), and plantar fascia thickness (pre-treatment 6.7 mm decreased to 5.6 mm at 6 months, $p < 0.0001$).¹⁵⁴ Other common treatment options include rest, plantar fascia stretching, physical therapy, orthotics, night splints, anti-inflammatory agents, corticosteroid injections, and surgery.^{155,156} In a retrospective cohort of 40 patients with plantar fasciitis comparing ESWT (mean of 20.6 kV combined with mean of 2506 pulses) to plantar fasciotomy, similar results (82% vs 83% improved symptoms) were found. Pre-treatment mean VAS pain score 7.9 improved to 2.95 within 7 days postoperatively and 4.2 at a mean of 8.4 months.¹⁵⁷ Similarly, a prospective randomized study of 47 patients (49 feet) with refractory chronic plantar fasciitis treated with 3 sessions of ESWT (3000 shockwaves/session at 0.2 mJ/mm² weekly) led to substantial improvement, with VAS pain decreasing by 64-84% and increased walking tolerance, while 3 months of conservative management had no meaningful improvement until crossover to ESWT.¹⁵⁸

Lateral epicondylitis (Tennis Elbow): There are no studies directly comparing the effectiveness of LDRT to other treatment modalities in patients with lateral epicondylitis. Prospective single arm studies evaluating LDRT in patients with refractory epicondylitis report satisfactory analgesia in 70% to 75% of patients.¹⁴²⁻¹⁴⁴

Other types of treatments to be considered include oral or topical analgesics, EWST, corticosteroid injections, and surgical intervention. In a randomized, double-blind crossover study of 14 patients with chronic lateral epicondylitis, topical diclofenac (2% pluronic lecithin liposomal organo-gel [PLO]) substantially reduced pain compared to pretreatment, washout, and placebo periods (mean VAS 2.1 vs 3.4-3.6) and improved wrist extension strength from 5.9 kg to 8.4 kg, with one case of localized rash reported.¹⁵⁹ In a multicenter, double-blind randomized trial of 129 patients with lateral epicondylitis, oral diclofenac (150 mg daily for 28 days) combined with immobilization produced a statistically and clinically significant reduction in pain compared to placebo, but did not improve grip strength or functional outcomes.¹⁶⁰ Gastrointestinal side effects, such as diarrhea and abdominal pain, were more common in the oral diclofenac group. A systematic review and meta-analysis of 76 randomized controlled trials (28 meeting criteria for meta-analysis) found that ESWT was not beneficial for lateral epicondylitis, and there was a lack of evidence for long-term benefit of physical interventions in general, though further research with long-term follow-up into manipulation and exercise was indicated.¹⁶¹ A literature review of tennis elbow reported that local corticosteroid injections were superior to physiotherapy (Cyriax method), and surgical release of the common forearm extensor origin produced 70% excellent or good results at 1 year and 89% at 5 years, demonstrating effectiveness of both injection and surgical approaches.^{162,163} However, although short-term benefits were observed in a randomized, placebo-controlled trial of 165 patients with chronic lateral epicondylalgia, corticosteroid injection resulted in worse long-term outcomes than placebo, with lower rates of recovery at 1 year (83% vs 96%) and substantially higher recurrence in pain (54% vs 12%), while physiotherapy did not significantly improve long-term outcomes compared to no physiotherapy.¹⁶⁴ For treatment of refractory lateral epicondylitis, a retrospective cohort of 62 patients treated with arthroscopic debridement of the common extensor tendon without or with arthroscopic suture anchor repair showed that repair produced better improvements in function and performance scores, with similar outcomes in pain improvement and an overall 98.4% surgical satisfaction rate.¹⁶⁵

Greater trochanteric pain syndrome (GTPS): There are no studies directly comparing the effectiveness of LDRT to other treatment modalities in patients with GTPS. Prospective studies evaluating LDRT in patients with refractory GTPS report durable analgesic effects in 50% to 75% of patients.¹⁴⁶⁻¹⁴⁸ By comparison, a randomized trial of 204 patients with gluteal tendinitis reported that both education plus exercise and corticosteroid injection improved pain and global outcomes compared to a wait-and-see approach at 8 weeks (VAS pain scores mean decrease of 2.2 points versus 1.2 points), but education plus exercise produced greater improvement.¹⁶⁶ At 52 weeks, education plus exercise remained superior for global improvement, while pain outcomes were similar between exercise and injection, supporting exercise-based therapy as the most durable of these options.¹⁶⁶ The 2022 International Society of Hip Preservation (ISHA) provided guideline-based recommendations for GTPS that emphasize multimodal non-operative management, such as physiotherapy, before procedural interventions.¹⁶⁷

Knee: There are no studies directly comparing the effectiveness of LDRT to other treatment modalities in patients with refractory inflammatory periarticular diseases of the knee. A prospective cohort study of patients treated with LDRT for painful joint disorders reported inferior long-term analgesic response rates for patients with knee pain compared to other joint sites (30% for knees compared to 58 for other joints).¹²⁹ Surgical intervention is also considered in these patients. In a systematic review and meta-analysis of 9 trials in patients with degenerative knee disease with or without radiographic signs of osteoarthritis, arthroscopic surgery (including partial meniscectomy and debridement) provided only a small short-term pain benefit (effect size 0.14, corresponding to a benefit of 2.4 mm on 0-100 mm VAS) that was not sustained beyond 6 months and showed no significant improvement in physical function.¹⁶⁸ Importantly, the procedure was associated with harms, including deep vein thrombosis (4.1 per 1000 procedures), pulmonary embolism, infection, and death, and overall findings did not support routine use in middle-aged or older patients.¹⁶⁸

Shoulder: There are no studies directly comparing the effectiveness of LDRT to other treatment modalities in patients with refractory inflammatory periarticular diseases of the shoulder. A prospective cohort of patients treated with LDRT for painful joint disorders including shoulder reported initial improvement in pain in 37% of patients, which increased to 58% at 3 years following treatment.¹²⁹ Other types of treatments to be considered include oral or topical analgesics, rehabilitation exercises, corticosteroid injections, and surgical intervention. A systematic review of 26 clinical practice guidelines on shoulder disorders found that only 12 (46%) were of high quality, with acetaminophen, oral NSAIDs, and rehabilitation exercises recommended for all shoulder pain, while surgical recommendations varied widely.¹⁶⁹ For example, acromioplasty for chronic rotator cuff tendinitis was recommended in 6 guidelines but not recommended in 4 others.¹⁶⁹ This aligns with a literature review of shoulder impingement syndrome that found conservative management, such as NSAIDs, injections, and exercise, achieved satisfactory outcomes in approximately 60% of patients within 2 years.¹⁷⁰ However, for persistent symptoms, decompressive surgery may be considered when structural abnormalities are present, but overall evidence remains low quality and no clear superiority of surgical versus conservative treatment has been established.¹⁷⁰

In summary, there are little data comparing LDRT in the treatment of inflammatory periarticular disorders compared to other treatment modalities. Consideration of efficacy and potential side effects of all treatments should be evaluated when considering LDRT as a non-invasive option for refractory cases. Although some treatment methods, such as corticosteroid injections, give prompt symptom relief, their long-term effectiveness is poor. Others treatment options, such as exercise, are effective for prolonged periods. There are notable limitations to most other methods of treatment, such as surgery and ESWT, either due to risk factors involved in the procedures or limited success.

Subtopic 3/ Combined modality approaches

LDRT may be integrated within a multimodal treatment framework alongside conservative, pharmacologic, interventional, and surgical therapies, rather than used in isolation. Many clinical studies supporting LDRT include

patients who have previously received or continue to receive concurrent nonpharmacologic approaches (such as weight loss, exercise, bracing, and physical therapy), pharmacologic therapies (such as NSAIDs), intra-articular injections, or are being considered for surgery. This reflects a sequential or combined treatment paradigm, rather than a mutually exclusive management strategy.

Importantly, available clinical evidence indicates that LDRT can be safely combined with other treatment modalities without compromising future interventions, with minimal to no acute and late effects.¹³¹ LDRT has no known interactions with anticoagulation and systemic medications. LDRT has no limitation or impact on other management modalities that may be used for recurrent symptoms, including surgery. Specifically, published data report no evidence that LDRT increases surgical risks or precludes subsequent surgical procedures.

Subtopic 4/ Reirradiation for recurrent/refractory disease

Reirradiation is a part of the longitudinal management strategy for patients with periarticular disorders, in which multiple courses of LDRT may be used over several months to years. Evidence demonstrates that patients with incomplete response or recurrent symptoms after initial LDRT may benefit from additional courses of LDRT, with overall response rates in the range of 50-80% after repeat treatment.^{133,150} For example, in a retrospective cohort of 99 re-irradiated elbows with humeral epicondylitis, median pain scores decreased from 6 to 3 at 6 weeks, 2 at 12 months, and 1 at 24 months, with 50.9% pain-free or nearly pain-free at 24 months.¹³³ Remarkably, all subgroups including those with no initial response, partial response, or recurrent pain after initial response achieved significant pain reduction following re-irradiation, supporting this strategy for improved outcomes.¹³³

Variant cases were developed as examples for these guidelines to illustrate practical applications of consensus recommendations. (***Tables 1–8***).

Topic 2/ Which patients are considered appropriate candidates for LDRT?

A structured clinical evaluation is essential before considering LDRT. The goals of evaluation are to confirm a benign periarticular diagnosis, assess chronicity and severity, document prior therapies, and exclude alternative pathology (e.g., infection, malignancy, fracture, or complete structural tendon rupture).

While data formally evaluating appropriate patient selection when considering LDRT for treatment of periarticular inflammatory disorders are lacking, LDRT is most effective in relieving pain in patients with refractory inflammatory periarticular disorders without complete structural disruption, especially when high level of discomfort and negatively affecting a patient's overall health.¹⁷¹ LDRT is not recommended as first-line treatment for early-stage inflammatory periarticular disorders or in cases with full-thickness tendon tears, but LDRT may be considered as second-line treatment of chronic plantar fasciitis refractory to other therapies or in patients with other types of chronic, refractory inflammatory periarticular disorders not associated with complete tendon tears. Candidates eligible for LDRT are adults with refractory symptoms and functional limitations that do not respond to conservative measures.¹³⁰

LDRT may be considered in patients age 40 and older, in whom the benefit of pain relief and improved function outweighs the minimal carcinogenic risk. LDRT should only be considered carefully selected, severely symptomatic younger individuals (< 40 years) who have exhausted other reasonable options. LDRT should be avoided in children and adolescents, who are actively developing, and have a longer remaining lifetime for long-term effects to manifest.

The use of adjuvant RT therapy must balance the benefit of recurrence prevention with the potential risk of harm. Caution should be used when considering LDRT in patient who may be at higher risk for complications from RT. At-risk populations include individuals with certain autoimmune diseases, especially certain connective tissue disorders such as Scleroderma, Systemic Lupus Erythematosus (SLE), Rheumatoid Arthritis (RA) and Sjögren's Syndrome, which are associated with enhanced sensitivity to RT. These individuals are more likely to experience severe acute and late-stage tissue toxicity, such as extreme skin inflammation,

tissue scarring (fibrosis), and disease flares in the irradiated area.

Shared decision-making is essential.

Topic 3/ What are the risks associated with LDRT?

Subtopic 1/ Radiation-Induced Malignancy Risks

The risk of radiation-induced malignancy following LDRT remains an area of ongoing debate, with uncertainty driven largely by extrapolation from higher-dose and whole-body radiation exposure data that is difficult to apply to LDRT to an extremity. Risk is influenced by several factors including patient age, sex, treated volume, anatomic site, and total dose. The estimated rates of radiotherapy-induced malignancy believed to be extremely low for LDRT to extremities, especially in patients over the age of 40 years.¹⁷²⁻¹⁸⁰ Despite widespread historical use of LDRT in Europe for decades, there have been no definitive associations reported between LDRT and malignancy in large clinical series. Nevertheless, the absence of long-term prospective data and incomplete follow-up remain important limitations.

Subtopic 2/ Non-Malignant Risks

Non-malignant risks associated with LDRT for periarticular disorders are generally minimal, particularly when compared to alternative therapies. Nevertheless, these risks should be considered in clinical decision-making. LDRT is associated with minimal acute or late side effects, including rare grade 1 skin erythema that is transient.^{114,135} Commonly used agents such as NSAIDs, injections, and surgery carry well-established risks, such as gastrointestinal bleeding, cardiovascular events, renal dysfunction, infection, bleeding, thromboembolic events, nerve injury, and postoperative stiffness. In contrast, LDRT is associated with a very low incidence of acute and late toxicities at the doses used for inflammatory periarticular disorders in selected patients. Across published series, the most frequently reported acute side effect from LDRT is low-grade (grade 1-2) skin erythema within the treatment field, which is rare and transient, and does not progress. In a review of over 1000 patients treated with LDRT, minimal side effects were observed.¹³¹

Importantly, LDRT has never been reported to be associated with complications seen with higher-dose radiation, such as impaired wound healing, non-union, fibrosis, or chronic soft tissue injury. There is no clinical evidence that LDRT increases perioperative risk or precludes subsequent surgical intervention. Overall, clinical evidence supports that LDRT carries a very low risk of non-malignant side effects, particularly when compared to other available treatment modalities for periarticular disorders.

Topic 4/ What is the optimal LDRT technique?

Subtopic 1/ Timing and sequencing

LDRT is typically considered after the failure of conservative treatments, such as non-pharmacologic, pharmacologic, and injection therapies. The course of LDRT is usually given over a 2- to 3-week period with treatments on nonconsecutive days. Evaluation of response is performed at 6-12 weeks after finishing radiotherapy, with the option for reirradiation for inadequate initial response.^{133,150}

Subtopic 2/ Dose fractionation

Dose and fractionation for LDRT for periarticular disorders is fairly uniform in the clinical literature. The most frequently used fractionation protocols include total dose of 3.0 to 6.0 Gy in fractions of 0.5 to 1.0 Gy, with individual treatments given 2 to 3 times per week on nonconsecutive days.¹⁴¹ Clinical trials demonstrate that similar results can be obtained by using either a dose of 0.5 Gy or 1.0 Gy per fraction.^{151,181,182} For example, in a prospective randomized trial of 130 patients with painful heel spurs, LDRT of 3 Gy in 6 fractions compared to 6 Gy in 6 fractions both resulted in highly significant symptom reduction at 6 months, with no substantial difference in

response between the dose levels.¹⁸² However, mechanistic laboratory studies suggest more favorable anti-inflammatory effects are achieved by a dose closer to 0.5 Gy compared to 1.0 Gy.^{123,124}

Subtopic 3/ Modality

Orthovoltage and megavoltage photon radiotherapy are often used for LDRT treatment periarticular disorders.^{136,181} The modality selection depends on the target depth and anatomic location, as well as availability of equipment. For superficial targets, such as lateral epicondyle and plantar fascia, orthovoltage or electron radiotherapy is preferred. Deeper targets, such as hip and shoulder joints, may be best treated by megavoltage photon radiotherapy (4-10 MV).

Subtopic 4/ RT field design

Limited literature exists to define the optimal radiation treatment fields in the treatment of periarticular disorders. Field design may include the entire joint space, while keeping to a minimum the radiation dose to adjacent normal tissues.¹⁸³ Treatment fields may extend outside the joint cavity to incorporate surrounding tissues, such as tendon insertions, bursae, and joint capsules as part of the multidimensional nature of the pain generation within an affected region as identified using 3D-based treatment planning from CT simulation. In most cases, margins beyond the affected region are kept reasonably small (approximately 1 cm) to allow for setup uncertainty. The LDRT beams are typically direct fields that encompass the target by parallel opposed arrangement. Fields should be designed to fit the anatomy with appropriate use of shielding/blocking, while ensuring that both structural and inflammatory components of the periarticular disorder are encompassed. For example, field design for GTPS involves inclusion of the greater trochanter and the gluteal tendon insertions. Field design for plantar fasciitis includes the origin of the plantar fascia from the calcaneus.

Subtopic 5/ Shielding

Shielding should be individualized based on joint location, proximity to radiosensitive structures, and treatment geometry. Shielding is aimed at reducing radiation doses to nearby healthy tissues while still targeting diseased tissues effectively. Examples include shielding of medial/central pelvic structures in the case of hip joint irradiation and shielding of the breast/chest wall in cases of shoulder irradiation. Nailbed shielding should be considered to preserve nail growth function. Gonadal shielding should be considered in patients who are concerned about fertility impact from scattered dose.

Supplemental material illustrates commonly used RT field designs for treatment of the elbow, shoulder, hip, and foot (plantar fasciitis).

CONCLUSIONS/SUMMARY OF RECOMENDATIONS

1. The panel recommends that LDRT is usually not an appropriate treatment as first-line management for the typical case of early-stage periarticular disease (including subacromial pain syndrome as in Variant Case 1). The clinical literature supports initial use of conservative and minimally invasive approaches such as physical therapy, NSAIDs, and injections, as these modalities address the inflammatory and mechanical contributors to early disease and are effective in many patients. It is most appropriate to offer LDRT as a later-line option after failure of multimodal conservative management for at least 3–6 months. [**Table 1; Variant 1**].
2. The panel recommends that LDRT is usually not an appropriate treatment for the typical case of periarticular disease with full-thickness tendon tears. Complete tendon tears typically require surgical repair to restore anatomy and function. [**Table 2; Variant 2**].
3. The panel recommends that LDRT may be an appropriate treatment for the typical case of chronic, refractory periarticular disorders that are not associated with full-thickness tendon tears with pain refractory to comprehensive

conservative management (including subacromial pain syndrome associated with tendinosis and subacromial bursitis, but without full-thickness tear or severe joint degeneration as in Variant Case 3). [Table 3; Variant 3].

4. The panel that LDRT is usually not an appropriate treatment for the typical case of acute lateral epicondylitis due to the self-limited and treatment-responsive nature of early disease, with minimal prior therapy and short symptom duration. Conservative measures are effective in the majority of cases, such as activity modification, physical therapy, NSAIDs, and injections. [Table 4; Variant 4].

5. The panel recommends that LDRT may be an appropriate treatment for the typical case of lateral epicondylitis refractory to conservative measures. LDRT may be considered after failure of multimodal therapy and prior to surgical intervention. Given its noninvasive nature, minimal toxicity, and lack of interference with future surgical options, LDRT serves as an intermediate step that may obviate or delay the need for surgery in a subset of patients. [Table 5; Variant 5].

6. The panel recommends that LDRT is usually not an appropriate treatment for the typical case of greater trochanteric pain syndrome associated with complete tendon tear as the presence of structural tendon disruption necessitates surgical evaluation and potential repair. [Table 6; Variant 6].

7. The panel recommends that LDRT may be an appropriate treatment for the typical case of refractory greater trochanteric pain syndrome without structural tendon tear, especially when considering a minimally invasive treatment for chronic joint pain and tendon injuries. [Table 7; Variant 7].

8. The panel recommends that LDRT is usually appropriate for the typical case of chronic plantar fasciitis in patients with persistent symptoms despite conservative management as an adjunct to conservative measures or second-line therapy. [Table 8; Variant 8].

DISCUSSION

The level of evidence to support the use of LDRT for treatment of inflammatory periarticular disorders is emerging. The literature does not support its use as first-line treatment for early-stage inflammatory periarticular disorders or in cases with full-thickness tendon tears, but LDRT may be considered as second-line treatment of chronic plantar fasciitis refractory to other therapies or in patients with other types of chronic, refractory inflammatory periarticular disorders not associated with full-thickness tendon tears. Further high-level evidence including prospective, randomized, sham-controlled trials adequately powered to detect statistical significance for clearly defined and optimally evaluated endpoints is certainly warranted. It is important to note the methodological shortcomings associated with this body of evidence. While there are a few randomized controlled trials, we acknowledge limitations of the supporting evidence which is heterogeneous with the majority of these studies being retrospective and non-randomized. With regard to the randomized controlled trials, some suffer from small study samples, inadequate duration of follow-up, heterogeneous study subjects, and varied outcome measures, making cross study comparisons difficult. Future trials are needed that control for various factors including patient enrollment criteria including history of disease course and prior treatments, co-administration of pain medications, and consistent endpoints using objective evaluation methods. Furthermore, adequate follow-up is needed to determine long-term outcomes for both efficacy and potential late effects of LDRT treatment. International collaboration and patient registries are likely to be more successful designs that will generate an adequate evidence level through rigorous research. Although available data provide insufficient high-level data to **strongly** inform our decisions, current literature suggests that LDRT may be considered as second-line treatment of chronic plantar fasciitis refractory to other therapies or in patients with other types of chronic, refractory inflammatory periarticular disorders not associated with complete tendon tears. Future investigations and improvements in technique will likely lead to more consistent results and strengthened recommendations.

Summary of Evidence

Of the 183 references cited in the American Radium Society® Appropriate Use Criteria for LDRT for Periarticular Disorders, 51 were identified through the search strategy, with 9 additional studies included through backward citation searching, identified by examining the reference lists of articles directly found through the search strategy. 123 additional studies referenced outside the “Summary of Literature Review” are included to provide context, but

unless they are also cited within the “Summary of Literature Review” they were not used by the committee to guide recommendations. In sum, the authors added 132 citations from bibliographies, websites, or books not found in the literature search. Of the 60 references used as evidence, 60 are categorized as therapeutic references including 8 well-designed studies (Phase II randomized and Phase III), 15 moderately well-designed studies that account for most common biases (matched cohort and Phase II studies), 15 studies with design limitations (retrospective reviews), 19 supplemental studies (not useful as primary evidence), and 3 meta-analyses.

Supporting Documents

For additional information on the ARS Appropriate Use Criteria methodology and other supporting documents go to <http://www.americanradiumsociety.org/page/aucmethodology>.

The American Radium Society™ Appropriate Use Criteria and its expert panels have developed criteria for determining appropriate procedures for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide treating and referring physicians in making decisions regarding diagnosis and treatment of cancers and related or associated conditions. Generally, the complexity and severity of a patient’s clinical condition should dictate the selection of appropriate diagnostic procedures or treatments. Only those examinations or treatments generally used for evaluation of the patient’s condition are ranked. Other procedures necessary to evaluate or treat other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate procedures or treatments. Procedures, techniques, or other interventions classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment, applications, and treatment protocols should be encouraged. The ultimate decision regarding the appropriate use of any specific examination or treatment must be made by the referring physician and oncologist in light of all the circumstances presented in an individual examination.

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Table 1; Variant 1: Early Subacromial Pain Syndrome

A 52-year-old female (BMI = 26) presents with 3 months of right shoulder pain following increased overhead activity. Pain is exacerbated by abduction and reaching overhead, and is associated with increased pain at night, especially when lying on right side. Physical examination demonstrates tenderness to palpation at the rotator cuff, and positive Neer and Hawkins tests. She has preserved strength and range of motion. Ultrasound imaging shows mild supraspinatus tendinitis with subacromial bursal distension with mild anechoic fluid accumulation. There is no significant rotator cuff tearing. She has used intermittent NSAIDs but has not yet participated in structured physical therapy or received injection therapy. She remains fully functional at work. She presents requesting radiotherapy after reading about alternative treatment options.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	U	2	7	1	0	0	0	0	0	0	2		L	S
Surgical Management	U	3	7	0	0	0	0	0	0	0	2		L	S

Variant Discussion:

The clinical literature supports initial use of conservative and minimally invasive approaches that are effective in many patients to address the inflammatory and mechanical contributors to early disease.

Physical therapy is the cornerstone of first-line treatment for subacromial pain syndrome, and is associated with high quality studies and the strongest support in clinical practice guidelines.

NSAIDs and injections provide modest short-term pain relief and may be helpful to support physical therapy, but by themselves have limited impact on function. Extracorporeal shockwave therapy has limited pain relief effect and uncertain evidence for noncalcific rotator cuff tendinitis, although may be considered as an adjunctive modality if conservative measures are insufficient.

With limited prior therapy, LDRT is not appropriate as first-line management for early-stage periarticular disease, including subacromial pain syndrome. It is most appropriate to offer LDRT as a later-line option after failure of multimodal conservative management for at least 3–6 months. Given the absence of refractory symptoms in this scenario, escalation to LDRT would expose the patient to unnecessary intervention without sufficient justification based on current evidence.

Surgical management is not indicated in this clinical scenario as this patient does not have a full rotator cuff tear or has not improved after at least 6 months of nonoperative treatment.

Table 2; Variant 2: Full-Thickness Rotator Cuff Tear with Mechanical Dysfunction

A 67-year-old male (BMI = 28) presents with progressive left shoulder pain and weakness over 9 months, now unable to lift his arm above shoulder height. Examination demonstrates weakness with abduction and external rotation and a positive drop-arm test. MRI reveals an isolated full-thickness supraspinatus tear with tendon retraction and early fatty atrophy, with remainder of the rotator cuff intact. The pain and limitations are refractory to NSAIDs, physical therapy, and steroid injections. Orthopedic evaluation recommends surgical repair. He inquires whether radiotherapy could be used instead of surgery.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	U	6	3	1	0	0	0	0	0	0	1		L	S
Surgical Management	A	0	0	0	0	0	0	2	5	3	8		S	S

Variant Discussion:

In the setting of a full-thickness rotator cuff tear, LDRT is not appropriate because the underlying pathology is structural rather than primarily inflammatory. The clinical literature emphasizes that LDRT exerts benefit through anti-inflammatory and immunomodulatory mechanisms and is most effective in conditions such as tendinitis or bursitis without major structural disruption.

High quality clinical literature supports the effectiveness of surgical repair for complete tendon tears to restore anatomy and function. Therefore, management should prioritize surgical intervention, as LDRT would not address the mechanical deficit driving symptoms.

Table 3; Variant 3: Chronic Refractory Subacromial Pain Syndrome

A 71-year-old female (BMI = 30) presents with 18 months of persistent shoulder pain limiting sleep and activities of daily living. She has completed multiple courses of physical therapy, discontinued NSAIDs due to renal insufficiency, and has had three corticosteroid injections with diminishing benefit. Subsequent MRI shows rotator cuff tendinitis and subacromial bursitis without full-thickness tear or severe joint degeneration. Orthopedic consultation does not recommend surgery due to absence of structural repairable pathology and medical comorbidities. She seeks non-operative options for durable pain control.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	M	0	0	0	0	5	5	0	0	0	6		M	S

Variant Discussion:

For patients with chronic, refractory subacromial pain syndrome who have failed comprehensive conservative management for more than 6 months, LDRT may be considered. The literature demonstrates that LDRT provides clinically meaningful pain relief and functional improvement through modulation of inflammatory cytokines and immune cell activity. Evidence from prospective and retrospective studies shows sustained reductions in pain scores and improvement in function, particularly in chronic conditions unresponsive to first-line therapies.

Table 4; Variant 4: Acute Lateral Epicondylitis

A 45-year-old right-hand-dominant male (BMI = 25) presents with 2 months of lateral right elbow pain related to new occupational repetitive activities. Examination demonstrates tenderness over the right lateral epicondyle and pain with resisted wrist extension. Ultrasound shows mild common extensor tendinitis without tendon tearing. He has not yet attempted physical therapy, bracing, or activity modification and has only used occasional NSAIDs. Symptoms are bothersome but do not significantly impair daily function.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	U	1	6	3	0	0	0	0	0	0	2		L	S
Surgical Management	U	2	7	1	0	0	0	0	0	0	2		L	S

Variant Discussion:

In acute lateral epicondylitis with minimal prior therapy and short symptom duration, conservative measures are effective in the majority of cases. NSAIDs typically provide modest short-term pain relief, but are not disease-modifying and are best combined with other conservative strategies such as activity modification, bracing, or structured physical therapy.

Physical therapy is the most appropriate first-line intervention for lateral epicondylitis with minimal risks, although clinical evidence is moderate. Corticosteroid injection therapy provides short-term pain relief but is associated with worse long-term outcomes and high recurrence rates.

Extracorporeal shockwave therapy has limited and clinically uncertain benefit for lateral epicondylitis and is generally not recommended.

Given the acute presentation and lack of exhausted conservative treatments, neither surgery nor LDRT is appropriate at this time. In cases that are chronic or refractory to conservative management, consideration of LDRT would be reasonable.

Table 5; Variant 5: Lateral Epicondylitis Refractory to Other Treatments

A 63-year-old right-handed male (BMI = 32) presents with 10 months of right lateral elbow pain refractory to extensive conservative management including activity modification, bracing, NSAIDs, physical therapy, and corticosteroid injections. MRI shows partial tearing of the right common extensor tendon without rupture. Pain interferes with occupational duties and quality of life. Surgical intervention has been discussed, but the patient prefers to avoid operative management if possible.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	M	0	0	0	0	2	8	0	0	0	6		M	S

Variant Discussion:

In a patient who has lateral epicondylitis refractory to corticosteroid injections, continuing injection therapy is not recommended. Although injections may provide short-term pain relief, they are associated with worse long-term outcomes and high recurrence rates.

LDRT may be considered after failure of conservative therapies and prior to surgical intervention. The literature indicates that LDRT can provide substantial and durable pain relief in tendinitis through anti-inflammatory effects, with reasonably high response rates reported across multiple studies. If insufficient response to an initial LDRT course, re-irradiation can further increase response rates. Given its noninvasive nature, minimal toxicity, and lack of interference with future surgical options, LDRT serves as an intermediate step that may obviate or delay the need for surgery in a subset of patients.

Surgical management is the definitive option if non-operative measures fail, with consistent evidence of significant pain reduction and functional improvement in refractory cases. Surgical intervention includes repair, debridement, or ultrasound-guided percutaneous tenotomy. Percutaneous tenotomy is typically considered for patients with recalcitrant pain lasting 6–12+ months that has failed comprehensive conservative treatment (physical therapy, orthotics, injections, NSAIDs). It is best suited for those with persistent functional impairment. In this case, the patient prefers to avoid surgery.

Table 6; Variant 6: Greater Trochanteric Pain Syndrome with Complete Tendon Tear

A 69-year-old female (BMI = 27) presents with lateral left hip pain and progressive gait instability. She is refractory to NSAIDs, physical therapy, and steroid injections. Subsequent MRI demonstrates complete tear of the gluteus medius tendon with associated bursitis and tendon retraction. Orthopedic evaluation recommends surgical repair. She requests evaluation for radiotherapy as a less invasive alternative.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	U	3	5	1	1	0	0	0	0	0	2		L	S
Surgical Management	A	0	0	0	0	1	0	2	5	1	8		S	S

Variant Discussion:

For greater trochanteric pain syndrome associated with a complete tendon tear, corticosteroid injection therapy has limited evidence of benefit and is not recommended for continued use, especially when refractory to initial attempts.

Extracorporeal shockwave therapy has emerging evidence for benefit in greater trochanteric pain syndrome with tendinitis and bursitis, but studies typically exclude patients with complete tendon tears as the mechanical deficit would not be addressed.

LDRT is not appropriate because the presence of structural tendon disruption necessitates surgical evaluation and potential repair. As with other conditions involving mechanical instability or complete tears, the anti-inflammatory mechanism of LDRT does not address the underlying pathology.

Surgical management is the preferred approach for a complete tendon tear causing progressive gait instability.

Table 7; Variant 7: Refractory Greater Trochanteric Pain Syndrome without Structural Tear

A 76-year-old female (BMI = 25) presents with over 1 year of lateral right hip pain interfering with ambulation and sleep. She has failed physical therapy, NSAIDs, and corticosteroid injections. Subsequent MRI shows gluteus medius and minimus tendinitis with trochanteric bursitis but no evidence of tendon rupture. She is not considered a surgical candidate due to age and medical comorbidities.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	M	0	0	0	0	3	5	2	0	0	6		M	-

Variant Discussion:

In refractory greater trochanteric pain syndrome without structural tendon tear with more than 1 year of symptoms despite conservative therapies including corticosteroid injections, continuing corticosteroid injection therapy is not recommended.

Extracorporeal shockwave therapy has moderate evidence for short-term benefit for greater trochanteric pain syndrome, but long-term durability remains uncertain. With minimal risks, shockwave therapy may be an appropriate management option.

The use of LDRT may be considered based on a moderate level of clinical evidence, which demonstrates meaningful rates of pain relief and functional improvement in this population, particularly when symptoms persist despite conservative therapies. A repeat course of LDRT may provide further improvement in patients who have insufficient response to a first course of LDRT. The anti-inflammatory effects of LDRT target the underlying enthesopathy and bursitis commonly seen in this condition. Given the low toxicity profile and compatibility with other treatments, LDRT provides a valuable noninvasive option for symptom control in appropriately selected patients.

Table 8; Variant 8: Chronic Plantar Fasciitis

A 59-year-old male (BMI = 33) presents with 14 months of severe heel pain refractory to rest, foot orthosis, stretching, night splints, NSAIDs, shockwave therapy, and corticosteroid injections. The patient is now unable to complete work activities due to impairment of ambulation. MRI demonstrates severe plantar fascia thickening with perifascial edema and without evidence of fascial tearing. Orthopedic consultation recommends surgical intervention. The patient requests evaluation for radiotherapy instead of surgery.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
LDRT	A	0	0	0	0	1	3	4	2	0	7		M	
Surgical Management		0	0	0	0	0	4	5	1	0	7	X	S	

Variant Discussion:

In chronic plantar fasciitis refractory to multimodal conservative and interventional therapies, both LDRT and surgical management may be appropriate management options. LDRT for chronic plantar fasciitis has been studied in randomized clinical trials as well as numerous prospective and large retrospective cohorts supporting its efficacy. LDRT demonstrated significantly superior outcomes across all endpoints, including pain reduction and functional improvement in two randomized trials. LDRT at a radiation dose of 6 Gy in 6 fractions was superior to 0.6 Gy in 6 fractions in one randomized trial, demonstrating a dose response. In a second randomized trial, LDRT was twice as effective as corticosteroid injections, and resulted in a more durable benefit.

Surgical intervention is an appropriate treatment option in cases of chronic refractory plantar fasciitis lasting more than 6 months that has failed conservative treatment options (such as physical therapy, orthotics, injections, NSAIDs) and is best suited for those with persistent functional impairment. Surgical intervention may be considered as an alternative or subsequent option if LDRT is pursued and proves insufficient. Surgical approaches include open plantar fasciotomy/release, endoscopic plantar fasciotomy, or ultrasound-guided percutaneous fasciotomy/debridement, all of which have high success rates and durable pain relief.

While surgical and procedural options can be considered, LDRT offers a noninvasive alternative with durable symptom relief in selected patients. Its role is therefore as an adjunct to conservative measures or second-line therapy in patients with persistent symptoms following conservative management.

Please refer to the supporting documentation for a more complete discussion of the concepts and definitions below.

Rating Categories: U Usually not appropriate; M May be appropriate; A Usually appropriate

Disagree: The variation of the individual ratings from the median rating indicates panel disagreement on the final recommendation.

SOE: S Strong; M Moderate; L Limited; EC Expert Consensus; EO Expert Opinion

SOR: ↑ Strong Recommendation; ↓ Weak Recommendation; - Not strong, not weak

Key:

BMI: body mass index

NSAIDs: non-steroidal anti-inflammatory drugs

LDRT: low-dose radiation therapy

MRI: magnetic resonance imaging

Appendix A: ARS AUC for LDRT for Periarticular Disorders

Search Dates 01 Jan 1996 through 01 Jan 2026

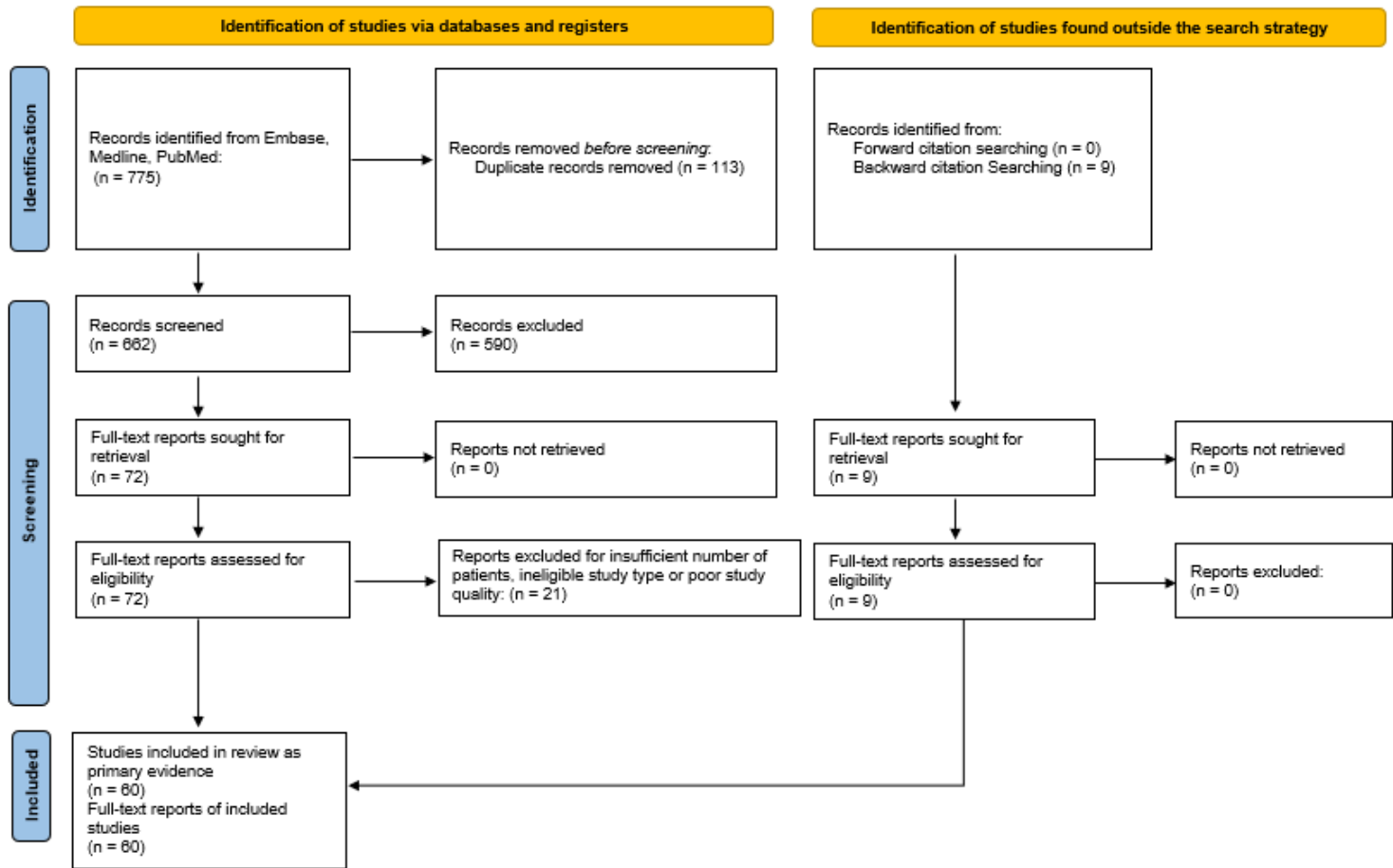
EMBASE AND MEDLINE

No.	Query	Results
#2	#1 and (radiotherap* OR radiat* OR irradiat*)	775
#1	(Tendonopathies OR Tendonopathy OR Tendonosis OR Tendonoses OR Tendonitis OR Tendonitides OR Enthesopathies OR Enthesopathy OR Fasciitis OR Bursitis)	73,697

PUBMED

(Tendonopathies OR Tendonopathy OR Tendonosis OR Tendonoses OR Tendonitis OR Tendonitides OR Enthesopathies OR Enthesopathy OR Fasciitis OR Bursitis) and (radiotherap* OR radiat* OR irradiat*)	662
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Appendix B: PRISMA 2020 Study Selection Flow Diagram for LDRT for Periarticular Disorders



Appendix D: PRISMA 2020 Checklist for LDRT for Periaricular Disorders

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract
INTRODUCTION			INTRODUCTION/BACKGROUND
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	¶2
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	¶2
METHODS			METHODOLOGY
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	¶1
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	¶1
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Appendix A: Search Strategy
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	¶1
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	¶1
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	¶1
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	¶1
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Appendix C: Evidence Table
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	N/A
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	N/A

Appendix D: PRISMA 2020 Checklist for LDRT for Periaricular Disorders

Section and Topic	Item #	Checklist item	Location where item is reported
Reporting bias assessment	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	N/A
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A
	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Variants 1-8 via Strength of Evidence (SOE)
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Appendix B: Flow Diagram
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Appendix B: Flow Diagram
Study characteristics	17	Cite each included study and present its characteristics.	Appendix C: Evidence Table
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Appendix C: Evidence Table
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	N/A
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	N/A
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	N/A
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Variants 1-8 via Strength of Evidence (SOE) and Strength of Recommendation (SOR), & section "SUMMARY OF RECOMMENDATIONS"
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	SUMMARY OF LITERATURE REVIEW Topics 1 - 4
	23b	Discuss any limitations of the evidence included in the review.	N/A
	23c	Discuss any limitations of the review processes used.	N/A

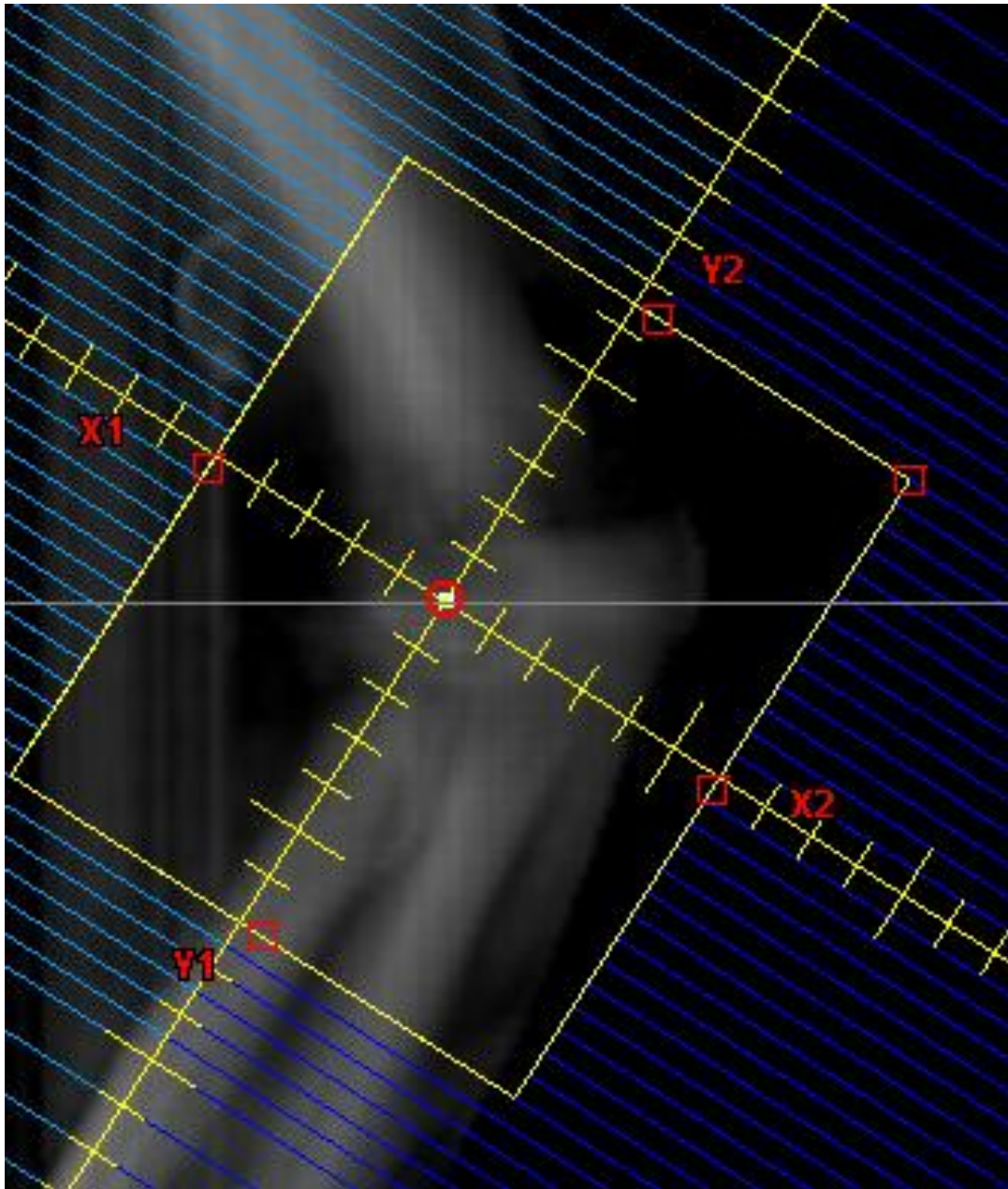


Appendix D: PRISMA 2020 Checklist for LDRT for Periarthritic Disorders

Section and Topic	Item #	Checklist item	Location where item is reported
	23d	Discuss implications of the results for practice, policy, and future research.	N/A
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	N/A
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	N/A
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Title Page
Competing interests	26	Declare any competing interests of review authors.	Title Page
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	https://www.americanradiology.org/page/aucmethodology

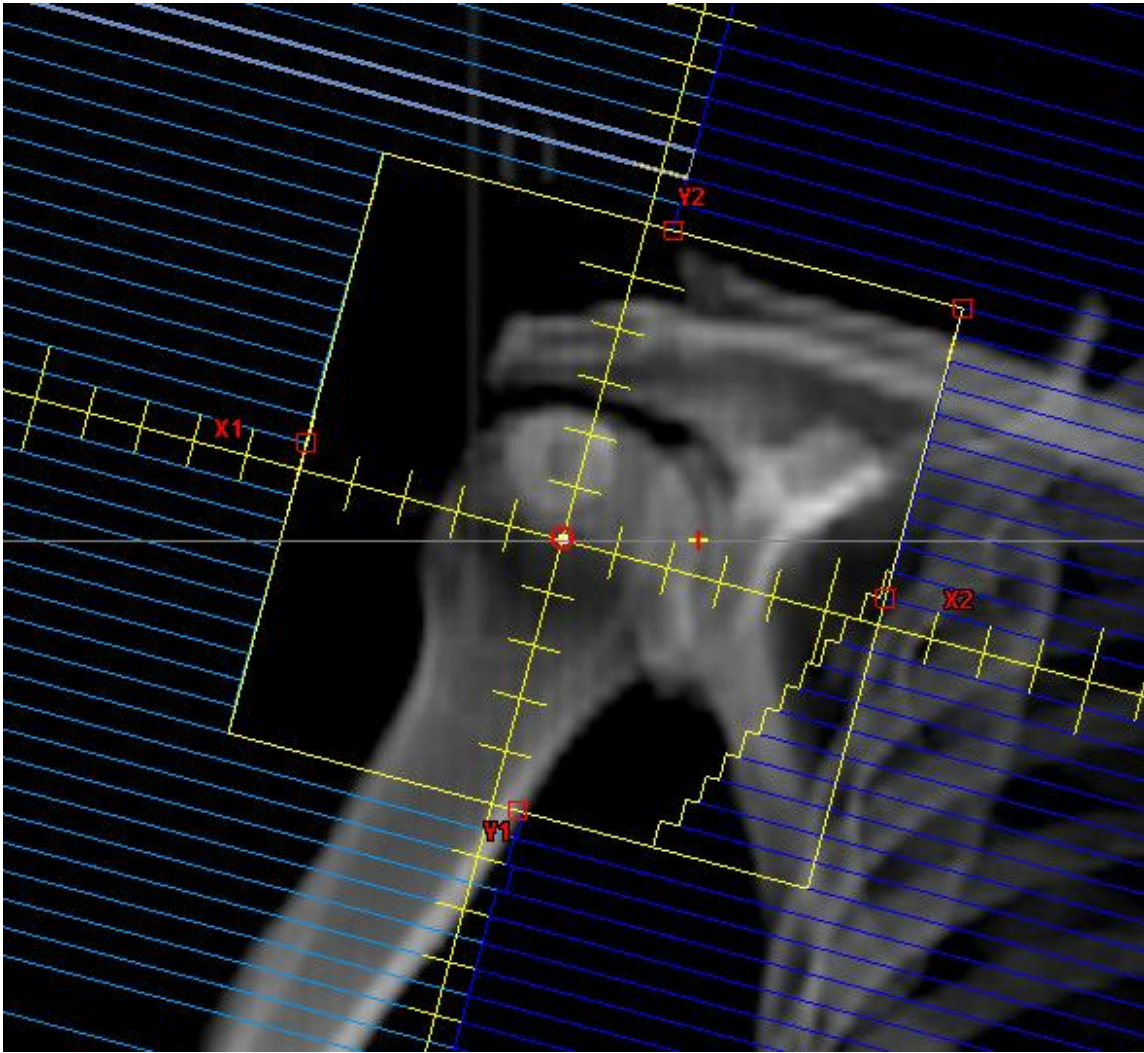
From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71
For more information, visit: {HYPERLINK "http://www.prisma-statement.org/"}

Supplemental Material: RT Field Design for Treatment of Elbow, Shoulder, and Hip Periarticular Disorders



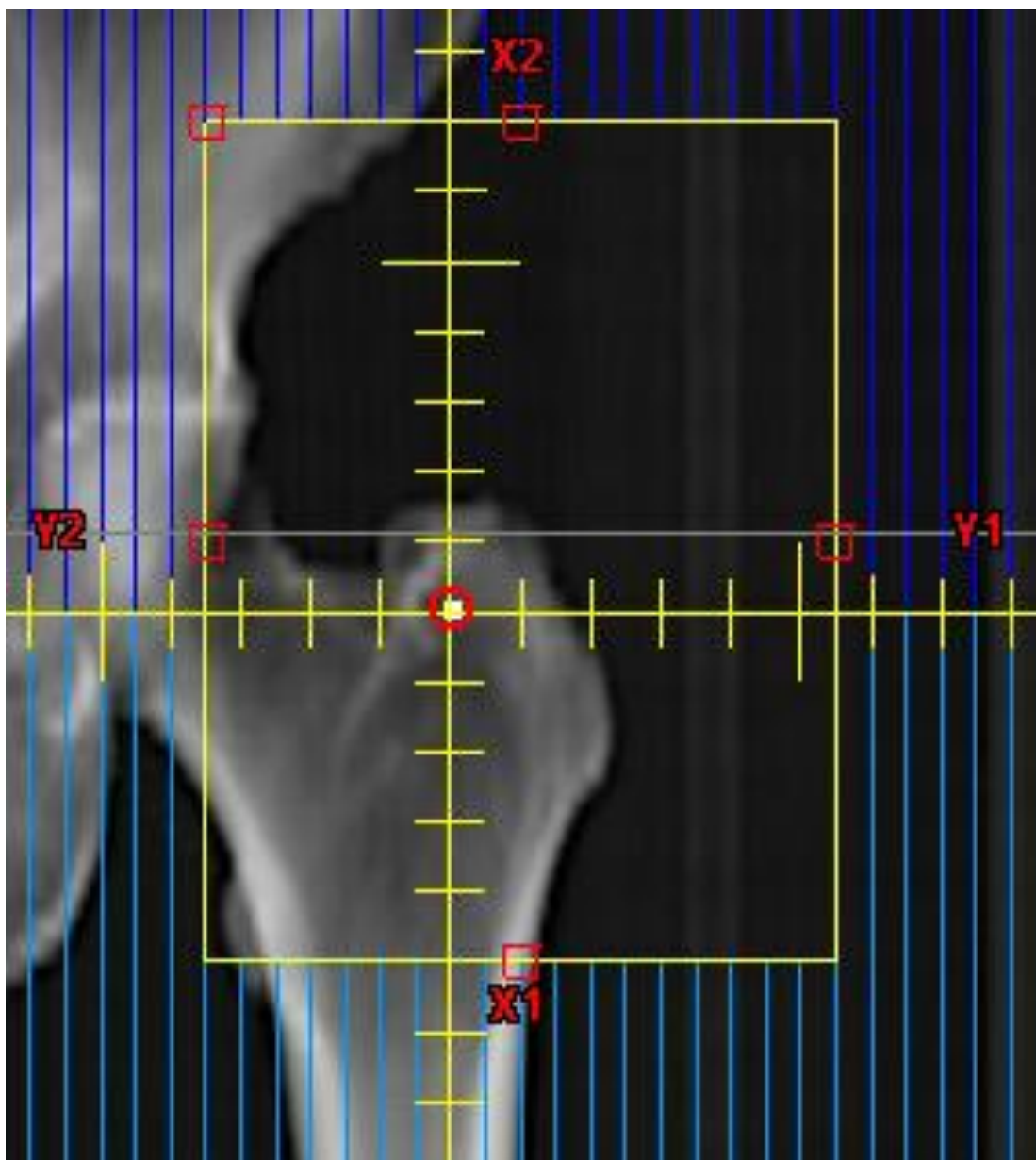
1. Example of RT Field Design for Treatment of Periarticular Disorders of the Elbow

Field design should be an individualized approach based on clinical history, examination, and prior treatments. Volumes should encompass the medial or lateral and tendon origins/insertions and any surrounding inflamed bursal tissue as identified using 3D-based treatment planning from CT simulation. In general, the field includes attached bone 2/3 below and 1/3 above the joint space to adequately cover the tendon insertion and portion of the tendon as it merges with muscle. Orthovoltage is the preferred modality (depending on availability). If 6 MV photons are used, a bolus may be needed to ensure adequate dose delivery to the epicondyle.



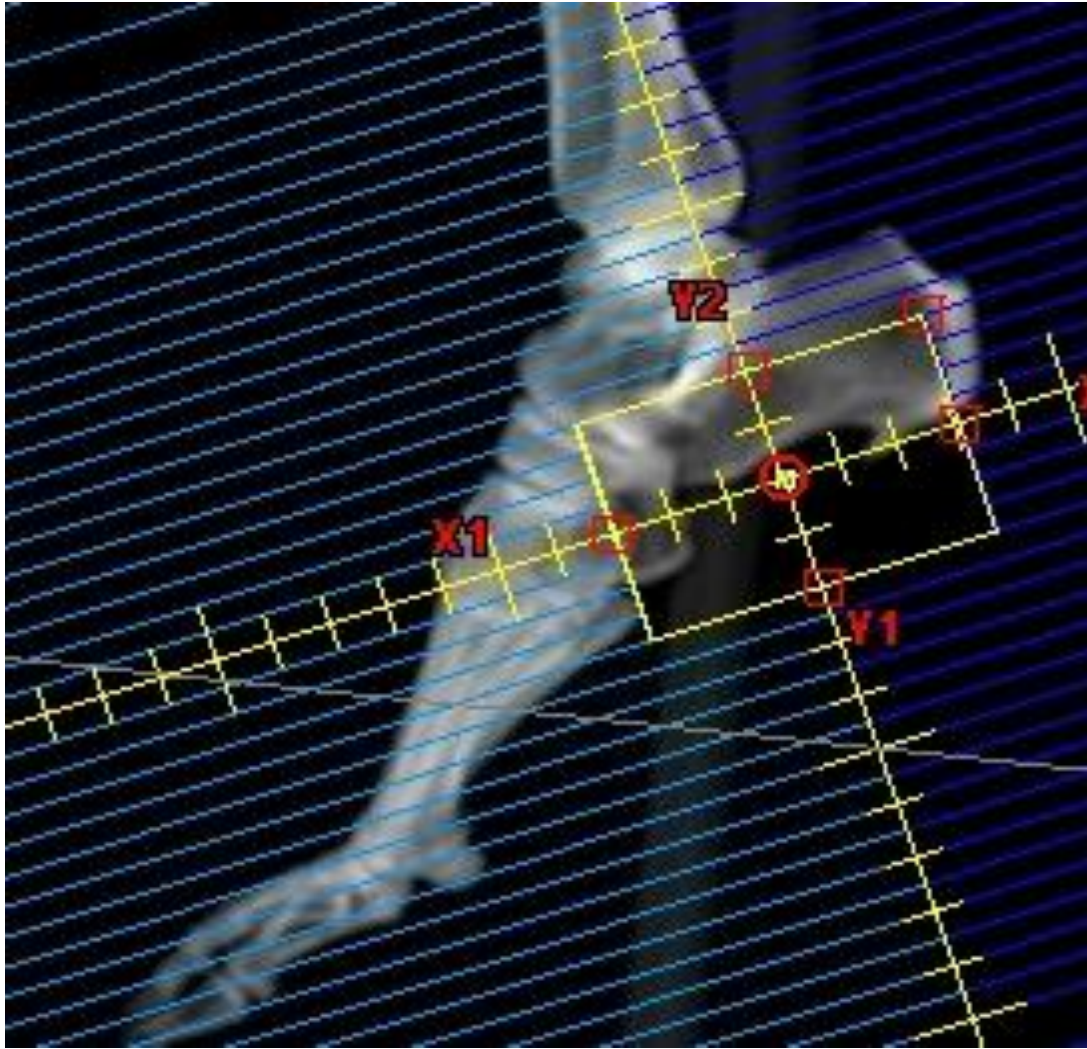
2. Example of RT Field Design for Treatment of Periarticular Disorders of the Shoulder

Field design should be an individualized approach based on clinical history, examination, and prior treatments. Volumes should encompass tendon origins/insertions and any surrounding inflamed bursal tissue as identified using 3D-based treatment planning from CT simulation.



3. Example of RT Field Design for Treatment of Periarticular Disorders of the Hip

Field design should be an individualized approach based on clinical history, examination, and prior treatments. Volumes should encompass tendon origins/insertions and any surrounding inflamed bursal tissue as identified using 3D-based treatment planning from CT simulation. In general, the field should encompass greater trochanter, gluteus medius/minimus tendon insertions and adjacent inflamed bursal tissue. Typical field sizes range from 8 x 10 to 12 x 15 depending on patient size. For superficial tendons or bursae, 6MV photons with 1 cm bolus may be appropriate for adequate superficial dose coverage. The femoral head is excluded from the treatment field.



4. Example of RT Field Design for Treatment of Plantar Fasciitis

Field design should be an individualized approach based on clinical history, examination, and prior treatments. Volumes generally include the insertion of plantar aponeurosis at the calcaneus and plantar aponeurosis anteriorly to the tarsal-metatarsal joints as identified using 3D-based treatment planning from CT simulation. The extent of plantar fascia coverage is dependent on location of pain with recommendation of 2 cm margin around pain point. The treatment field is positioned directly over the origin of the plantar fascia and any associated calcaneal spur. Smaller fields have also been effectively used and reduce radiation exposure to adjacent healthy tissue.