

American Radium Society® (ARS) Appropriate Use Criteria (AUC) for Adjuvant Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids

Expert Panel for Adjuvant Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids:

Suzanne Russo MD¹; Corinne Wee, MD²; Sam Jean-Baptiste, MD, MS³; Austin N. Kirschner, MD, PhD⁴; Bobby Koneru, MD⁵; Christien Kluwe, MD⁶; Diane C. Ling, MD⁷; Neil Newman, MD, MS⁸; Kevin Pearlstein, MD⁹; Yasamin Sharifzadeh, MD¹⁰; Rahul Tendulkar, MD¹¹; Austin Dove, MD¹²

¹Principal Author, Department of Radiation Oncology, MetroHealth, Case Western Reserve University School of Medicine, Cleveland OH

²Division of Plastic Surgery, MetroHealth Medical Center, Case Western Reserve University School of Medicine, Cleveland OH

³Department of Radiation Oncology, University of Florida, Jacksonville FL

⁴Department of Radiation Oncology, Vanderbilt University Medical Center, Nashville TN

⁵Department of Radiation Oncology, Cardinal Bernadin Cancer Center, Loyola University Stritch School of Medicine, Maywood, IL

⁶Department of Radiation Oncology, University of Texas Health Science Center at San Antonio, San Antonio, TX

⁷Department of Radiation Oncology, Keck School of Medicine, University of Southern California, Los Angeles, CA

⁸Department of Radiation Oncology, University of Miami, Miami, FL

⁹Department of Radiation Oncology, University of North Carolina at Chapel Hill, Chapel Hill, NC

¹⁰Department of Radiation Oncology, Mayo Clinic, Rochester, MN

¹¹Department of Radiation Oncology, Cleveland Clinic Foundation, Cleveland, OH

¹²Department of Radiation Oncology, Tennessee Oncology, Chattanooga, TN

Conflict of Interest Disclosure Statement

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:

Dr. Jean-Baptiste reports honoraria, travel and meeting support from Florida Society of Clinical Oncology

Dr. Koneru reports consulting fees from Radiance RT

Dr. Sharifzadeh reports grant support from Mayo Clinic Kogod Center for Aging and travel/meeting support from Mayo Clinic

Dr. Tendulkar reports honoraria from Varian Medical Systems and Eisai IC

Acknowledgements

Ellie See, Talley Management Group for her attention to detail and diligence in this project.

The ARS Appropriate Use Criteria seek and encourage collaboration with other organizations on the development of the Criteria through representation on expert panels. Participation by representatives from collaborating organizations on the expert panel does not necessarily imply individual or society endorsement of the final document.

*The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences or the Department of Defense or the National Institutes of Health. Reprint requests to: auc@americanradiumsociety.org

INTRODUCTION

Hypertrophic scars and keloids are dermal proliferations of fibrous tissue that most often arise at sites of cutaneous injury. They affect approximately 10% of the global population, are most common between the ages of 10 and 30 and have a higher prevalence (15–20%) in individuals of African, Asian, or Hispanic descent. Individuals with higher Fitzpatrick skin types are estimated to be 15 times more likely to develop hypertrophic scars/keloids.¹ Risk factors include history of prior hypertrophic scars/keloids, local skin tension, follicular inflammation or infection and family history. Keloid scars are increasingly considered advanced hypertrophic scarring. They often form after skin trauma (piercings, acne, surgery, tattooing, insect bites, burns, lacerations, abrasions, vaccinations, and any other process resulting in cutaneous inflammation) and can result in functional and cosmetic burden or psychosocial effects from developing disfiguring scars. Hypertrophic scars/keloids result from abnormal wound healing, presenting as raised, firm lesions that extend beyond the margins of original injury. They are often pruritic or painful and can cause restrictions in movement in severe cases.² They may develop anywhere on the body, most commonly shoulder, chest, upper back and earlobe, and occur as early as 1 to 3 months or as late as one year after injury. Spontaneous lesions have been reported. Hypertrophic scars/keloids do not regress spontaneously.

Pathophysiology

Hypertrophic scar/keloid formation is a result of aberrant wound healing and involves the dysregulation of complex inflammatory pathways.³ This process involves fibroblasts with increased proliferative activity that are associated with lower rates of apoptosis resulting in increased fibroblast activity. This results in an overproduction of collagen and cytokines. Collagen synthesis in hypertrophic scars/keloids is 20 times greater than that of healthy skin and three times greater than a hypertrophic scar. Transforming growth factor-beta (TGF-beta), which promotes chemotaxis of fibroblasts to sites of inflammation and production of collagen, is thought to be a primary driver of this process.⁴ Platelet-derived growth factor (PDGF) is a family of proteins released from platelets during clotting, stimulates connective tissue growth, and wound healing by driving cell proliferation, migration and collagen production has also been implicated in formation of hypertrophic scars/keloids. It has also been implicated in formation of hypertrophic scars/keloids. Dysregulation of these pathways leads to fibrosis and abnormal scar response.^{5,6} Additionally, increases in proinflammatory cytokines including IL-6 and -8, and decreases in anti-inflammatory IL-10 have been associated with increased scar formation.³

Patient Evaluation

The diagnosis of a hypertrophic scar or keloid is clinical. They present as erythematous, flesh-colored or hyperpigmented, firm, rubbery nodules and typically extend above the skin surface. Keloids may expand to a broad plaque beyond the area of initial trauma. Hypertrophic scars are typically smaller, do not project further than 4 millimeters above the skin, and do not extend beyond the initial area of injury. The differential diagnosis is narrow, and a biopsy is not required unless the diagnosis is in question, especially if there is concern for dermatofibroma or other malignancy. Biopsy is rarely required and increases the risk of further scarring.

Treatment Options

Although hypertrophic scars and keloids are unique entities, they are quite similar and can be approached similarly from a treatment standpoint. The goals of treatment of hypertrophic scars/keloids are symptom relief or improvement in cosmesis. First-line treatments depend on site, size and history of prior treatments. Typically smaller, single sites are treated first with non-surgical approaches and larger lesions are treated with surgical excision and adjuvant therapy.

Non-surgical treatments include:

- **Massage and manual scar therapies** are sometimes used to promote circulation, lymphatic drainage, and collagen realignment during scar formation.⁷⁻¹⁰
- **Topical therapies** including pressure dressings¹¹⁻¹⁴, silicone gel or sheets¹⁵⁻¹⁹, and corticosteroid tape²⁰ are sometimes used alone or in combination with other therapies²¹, but with limited success and often limited by patient compliance^{22,23}. Topical corticosteroid monotherapy is not recommended routinely due to lack of efficacy.²⁴

- **Intralesional corticosteroids** (triamcinolone) usually require multiple injections at 4- to 6-week intervals, with doses ranging from 10 to 40 mg/cc. Triamcinolone injections alone have response rates ranging from 50% to 100% and are associated with recurrence rates of 9% to 50% depending on lesion and treatment characteristics.^{25,26} They act through inhibition of leukocyte and monocyte migration and phagocytosis, vasoconstriction, inhibition of fibroblast proliferation, decreasing collagen synthesis and increasing collagen degradation.²⁷ Intralesional steroids are often used in combination with other modalities.^{26,28}
- **Other intralesional therapies**, including intralesional Botox²⁹, verapamil³⁰, bleomycin³¹, mitomycin³², and 5-fluorouracil^{33,34} are considered second-line treatments. They have also been reported to be successful alone or in combination with other modalities.³⁵⁻³⁷
- **Laser therapy**, delivered in successive sessions, can result in regression of keloids and is considered most effective for flatter lesions as efficacy relates to depth of laser penetration. Laser therapy is not recommended for larger scars, which are associated with high rates of recurrence.³⁸ Laser therapy can be combined with other treatments.³⁹

Two types of laser technologies can be used:

1. Vascular lasers (585 nanometer (nm) pulsed dye laser (PDL)) destroy vasculature within scar tissue, resulting in ischemia and down-regulation of TGF-beta.^{40,41}
 2. Resurfacing lasers (1065 nm neodymium-doped yttrium aluminum garnet (ndYAG) or carbon dioxide (CO₂) lasers) are used to improve texture and size of the scar tissue by stimulating skin remodeling.^{37,42}
- **Cryotherapy** using liquid nitrogen can be delivered as a spray or intralesional-needle cryoprobe and similarly requires multiple treatments utilizing freeze-thaw cycles of 10- to 20 seconds. It is considered highly effective for destroying scar tissue, often reducing size by 50%.^{43,44} It is optimally used for small-to-medium keloids and frequently combined with intralesional corticosteroid injections.^{43,44} This treatment often results in pigment changes and is considered less desirable in patients with darker skin.

Surgery, either debulking or complete resection, is used as initial treatment for hypertrophic scars/keloids. . However, surgical excision alone is associated with high recurrence rates between 45% and 100%⁴⁵ and is often followed by adjuvant therapy such as radiation therapy (RT), intralesional corticosteroids, or topical therapies. Surgical technique requires careful consideration to decrease the risk of hypertrophic scar/keloid formation, including methods to minimize wound tension.^{4,23,46} Post-surgical compression therapy utilizing pressures of 15 to 45 mmHg for more than 23 hours per day for at least 6 months following surgery has also demonstrated efficacy in reducing keloid development.⁴⁷

Adjuvant RT has been associated with reduced recurrence rates when delivered within 1-3 days following surgery.^{48,49} RT techniques include external-beam RT (including electron and low-energy photon beam) and high-dose rate (HDR) or low-dose rate (LDR) brachytherapy (BT), typically delivered with a surface applicator.^{49,50}

Mechanism of Action/ Biologic Rationale for Radiotherapy

Adjuvant RT is known to display both anti-proliferative and anti-inflammatory effects. The direct anti-proliferative effects of RT act through DNA damage and result in inhibition of new cell formation, delayed mitosis, and induction of apoptosis.⁵¹ Adjuvant RT for prevention of recurrent hypertrophic scars/keloids specifically slows proliferation of fibroblasts and myofibroblasts, which are responsible for collagen deposition.⁵² RT delivered within 24 hours of surgery optimizes these effects and corresponds to the proliferation phase after injury, with decreasing benefit observed up to 72 hours.^{53,54} Indirect anti-inflammatory effects of RT include lymphocyte apoptosis, leukocyte adhesion, and effects on cell membranes and endothelial cells. Adjuvant RT inhibits angiogenesis by damaging microvasculature that is important during the early phases of wound healing. These developing endothelial vascular beds are extremely radiosensitive and may also play a role in inhibition of scar formation.⁵⁵

This systematic review and guideline summarizes the current evidence for the appropriate use of adjuvant RT for the prevention of recurrent hypertrophic scars/keloids. The Population, Intervention, Comparator, and Outcome (PICO) questions included (1) what is the role of RT in the treatment of hypertrophic scars/keloids?, (2) which patients are considered appropriate candidates for adjuvant RT?, (3) what is the optimal RT technique?, and (4) what are the risks associated with adjuvant RT?

METHODS

This ARS AUC multi-specialty-led committee is comprised of all key specialties (radiation oncology, plastic surgery, and dermatology). 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.^{56,57} Eligible studies included prospective studies, phase II-III trials, and retrospective analyses including ≥ 15 patients published between 1/1/1980 – 5/5/2026 in the Ovid Medline database. 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 as evidence in the Summary of the Literature Review which advised our recommendations (Appendix B). Discrepancies between the reviewers were resolved by consensus. Of the 165 articles identified using the search strategy, 87 were selected for inclusion (Appendix C). An additional 50 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, 137 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 options⁵⁸, with a total of 1 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 was 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 RT in the treatment of hypertrophic scars/keloids?

Subtopic 1/ Efficacy of Adjuvant RT in the Prevention of Recurrent Hypertrophic Scars/Keloids

The addition of adjuvant RT following surgical excision of recurrent hypertrophic scars/keloids is associated with a reduced recurrence rate of approximately 20% versus 45% or greater with surgery alone.⁵⁹ Adjuvant RT can be delivered via several modalities. The most commonly used techniques include electron beam RT, low-energy photon beam RT, and surface “mold” HDR BT. Direct comparisons of efficacy for these different modalities are limited. Other RT-related factors influencing efficacy include RT fractionation schedules, total RT dose, and timing of RT following surgery. In addition, the RT dose distribution can vary with type of RT source and energy, which must be taken into account to ensure optimal dose delivery.

External Beam Radiotherapy

- **Electron Beam RT:** Reported recurrence rates associated with adjuvant electron beam RT following surgery varies widely from 0% to 57%.^{46,48,53,60-77} Treatment site is the most prognostic of recurrence.⁷⁸ Earlobe scars are associated with the lowest recurrence rates compared to other locations on the ear, chest, shoulder, abdomen and extremities.^{64,79} Large tumor size is also predictive of recurrence.⁸⁰ Other prognostic factors for recurrence include male gender, young age, infection, incomplete excision, and local tension.^{79,80}

- **Photon Beam RT:**

Low Energy Photons (usually superficial kilovoltage (50 to 150 kV)): Historically, most keloids were treated with superficial quality (approximately 120 kV) photon beams. An advantage of using low-energy photons to treat resected hypertrophic scars/keloids is the ability to provide a therapeutic dose to the surface without requiring bolus while sufficiently penetrating to the bottom of the resection bed. Thicker lesions can be treated by orthovoltage (150 to 500 kV). Recurrence rates using low-energy photons range from 0% to 59%.^{77,81-87} However, such treatment has become less common because of the availability of electron beam producing linear accelerators and the consequent economic disincentive to have a low-energy photon (only) treatment machine in many Radiation Oncology Departments.

High Energy Photons: Less data have been reported on the efficacy of adjuvant RT using high energy photons in the megavoltage (MV) range for prevention of recurrent hypertrophic scars/keloids. However, for very large resection beds, particularly on curved surfaces that can most effectively be encompassed in tangential fields, with tissue compensation/bolus, MV photons can occasionally provide elegant therapy. Recurrence rates using high-energy photons ranges from 9% to 12%.^{88,89}

Brachytherapy (BT)

The majority of efficacy data for adjuvant BT for prevention of recurrent hypertrophic scars/keloids is reported for HDR BT rather than LDR BT. Various treatment planning parameters have been reported. The best outcomes are associated with computed tomography (CT) planning, which offer more precise estimation of the target volume and adequate dose coverage.^{90,91} A variety of dose fractionation schedules have been reported for HDR BT, making comparisons difficult. Reported recurrence rates using HDR BT range from 0% to 43% depending on the dose fractionation regimen. Lower recurrence rates have been associated with higher total doses and larger doses per fraction.^{61,90,92-104} Reported recurrence rates for adjuvant LDR BT range from 21% to 30% using doses from 16 to 18 Gray (Gy) over 3 to 4 days.^{96,105}

Subtopic 2/ Combined Modality Approaches

Adjuvant RT is sometimes used in combination with other therapies for the prevention of recurrent hypertrophic scars/keloids. An observational study compared outcomes for patients treated with adjuvant electron beam RT combined with intralesional corticosteroids and 5-fluorouracil to surgery with adjuvant RT or surgery alone. This study reported an 8% recurrence rate for surgery plus adjuvant RT compared to 13% for adjuvant RT plus injections and 45% for surgery alone.¹⁰⁶ Another study investigated the addition of botulinum toxin to adjuvant RT following excision of large chest keloids and reported a lower recurrence rate with combination therapy. At 6 months follow-up, the total effective rate and satisfaction of combined therapy group were higher compared to those that received adjuvant RT alone, and the Vancouver scar scale (VSS) score for the combined therapy group was lower than the adjuvant RT alone group ($P < 0.05$).¹⁰⁷

Subtopic 3/ Primary RT for Extensive or Unresectable Hypertrophic Scars/Keloids with Limited Treatment Options

While there is an abundance of data describing outcomes for RT used in the adjuvant setting for prevention of recurrent hypertrophic scars/keloids, efficacy and safety data associated with primary RT for unresectable keloids is sparse. The largest study was published by Malakar et al.¹⁰⁸ in which 86 keloids in 64 patients received kV photons or electrons to treat bulky unresectable keloids. A hypofractionated approach using 5 fractions delivered once weekly to a total dose of 37.5 Gy was used. Ninety-seven percent experienced significant regression, and 3% had partial regression 18 months after completing RT.¹⁰⁸ Smaller series have confirmed these results.¹⁰⁹ Alternative fractionation using 24 Gy delivered in 3 fractions has also been used with 79% of patients showing complete and 14% with partial flattening.¹¹⁰ A recent retrospective series reported by Tsai et al. reviewed

outcomes for 64 keloids in 35 patients who were treated with 5 Gy x 6 fractions for a total of 30 Gy using electrons or photon-based intensity modulated RT (IMRT). Scar regression, symptomatic relief and cosmetic improvement were experienced in most patients with no cases of recurrence or serious adverse events.¹¹¹ Guix et al. reported outcomes for a cohort of 22 patients who were treated with interstitial HDR BT using 18 Gy delivered over 6 fractions over 1 ½ days as primary therapy for unresected keloids. Persistent disease was reported in 13.6% at 7 years follow up.¹¹²

Investigators have also used intralesional corticosteroid and 5-fluorouracil injections to reduce thickness and firmness of smaller keloids prior to BT (15 to 20 Gy) as primary therapy and compared response to intralesional injections alone. The addition of BT reduced the 1-year recurrence rate from 85.7% to 44.4%.¹¹³ Others have combined RT with fractional CO2 laser therapy as primary treatment of keloids. The authors reported a substantial decrease in total Patient and Observer Scar Scale score with 12% recurrences (11% partial and 1% complete) at 18 months following therapy.¹¹⁴ Nonsurgical management with electron beam or BT combined with intralesional triamcinolone and 5-fluorouracil has been reported to improve symptoms such as pain and pruritis.¹¹⁵

Ongoing trials continue to evaluate RT as primary treatment for unresected keloids. NCT04722263 (Radiotherapy for Keloids) is a pilot study evaluating the safety and efficacy of RT in the treatment of unresected keloids using 15 Gy in 3 fractions delivered daily over 3 consecutive days delivered via either electrons, photons, or BT. A trial amendment in March 2023 increased the treatment dose to 25 Gy in 5 fractions prescribed to the 90% isodose line.

Subtopic 4/ Re-irradiation for Recurrent Disease

Recurrence of hypertrophic scars/keloids following surgical excision and adjuvant RT can occur, especially in patients who have large scars or those that received RT with suboptimal target coverage or dose fractionation. Our search did not return results specific for re-irradiation for recurrent hypertrophic scars/keloids in patients who have received prior adjuvant RT for prevention of recurrence. It is thought that adjuvant re-irradiation should be considered as a component of salvage treatment following surgery for refractory cases, although higher recurrence rates may be anticipated in a patient with recurrent disease following initial RT.

Table 1 summarizes key studies supporting the use of adjuvant RT for prevention of recurrent hypertrophic scars/keloids.

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

- The use of adjuvant RT therapy must balance the benefit of recurrence prevention with the potential risk of harm.
- In general, by keeping the irradiated volume confined (as much as possible) to the surgical bed, the small but not zero, risk of RT induced harm is justified.
- Adjuvant RT therefore is typically considered appropriate to reduce the risk of recurrence following optimal resection of a hypertrophic scar/keloid in patients at high-risk for recurrence.

Examples of high-risk for recurrence are:

- A history of multiple recurrences at other sites in the same patient.
- A family history of recurrences.
- Close proximity of the surgical bed to an anatomic structure that would be endangered if a keloid recurred and had to be resected again.

- Adjuvant RT as prophylaxis for keloids in patients at higher-risk of toxicity is not routinely recommended, but can be considered on a case-by-case basis though case-by-case basis though data are limited.¹¹⁶
- RT alone *without surgery) is generally not used as primary treatment of hypertrophic scars/keloids but may be considered in patients with extensive or unresectable keloids who have failed prior standard therapies, such as intralesional injections, cryotherapy, or laser treatment, although supporting data is limited. (**Topic 1; Subtopic 3**)

Caution should be used when considering RT for prevention of hypertrophic scars/keloids in patient who may be at higher risk for complications from RT. Those at risk include children and adolescents, who are actively developing, and have a longer remaining lifetime for long-term effects to manifest. Other 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.

Topic 3/ What is the optimal RT technique?

Subtopic 1/ RT Modality

The choice of RT modality used should be individualized and take into consideration specific characteristics of the hypertrophic scar/keloid including size and location. Electron beam or high-dose-rate (HDR) BT are preferred for optimization of surface dose and sparing of deeper structures. One comparison between modalities revealed that postoperative BT resulted in the lowest recurrence rates (15%) compared with photons and electrons (23% and 23%, respectively; $P = 0.04$, $P = 0.1$), although comparisons may have been limited due to variable fractionation schedules included in this analysis.⁴⁹

- **Photon beam RT.** For superficial treatments, superficial voltage is the preferred modality. Lower x-ray energies (e.g., 120 kV) can spare deeper structures as compared to higher energies, as they are associated with faster dose fall-off. By placing custom-cut shields of the appropriate thickness directly on the patient's skin, the field size can more tightly conform to the keloid bed (than if treated by electrons). They also can be absorbed by appropriate thickness malleable custom-cut lead sheets placed under the target when possible, for example in the treatment of a keloid bed on an earlobe. High energy MV treatment is rarely required except in rare cases of deep scarring and large lesions spanning curved surfaces requiring more advanced dosimetric techniques such tangential fields, tissue compensators and bolus to compensate for curved surfaces. Although high energy photons (MV) are better for clinical scenarios requiring deeper penetration, they deliver higher doses to underlying healthy tissues and are associated with the potential for damage to underlying cartilage/bone. There is less literature on the efficacy of photons for hypertrophic scar/keloid management compared to other RT modalities.
- **Electron beam RT.** Electrons delivered using a linear accelerator and is associated with the advantage of being able to treat a large surface area with high surface dose and rapid dose fall-off to spare underlying tissue. Different energy beams can be used (typically 4–20 MeV) and selected for desired treatment depth, with higher energy electrons depositing energy deeper. When using electron beam therapy, a wider margin is required to adequate dosimetric coverage (compared to kV photon treatment). Bolus is often used to enhance the dose near the surface to improve dosimetric coverage. The disadvantage of using electrons is that dosimetry is associated with greater uncertainty, especially when treating curved surfaces. Electrons are not suitable for treating deep or thick areas. Because electron beam radiotherapy is more accessible to most RT practices compared to kV photon therapy, it is often used. However, for superficial treatment, kV photons is considered more appropriate (superficial voltage preferred over orthovoltage).

- **BT** uses gamma rays and beta particles delivered by using radioactive sources delivered through catheters placed to conform to the desired treatment area. BT can conform to uneven surfaces and may spare more surrounding tissue. It is associated with rapid dose fall-off. BT is typically delivered using surface applicators or molds. High dose rates are required to deliver treatment in short time frames. Access to a remote afterloader HDR BT delivery system and dosimetric planning system are required.

Subtopic 2/ Dose-Fractionation

In general, fractionated RT is preferred over single-fraction regimens due to improved local control and reduced risk of late toxicity. For external beam RT, total dose-fractionation schedules ranging from 12 to 20 Gy have been reported. Historically 3 to 4 Gy per fraction was considered standard. However, more recent data suggest that using a higher biologically effective dose (BED) results in lower recurrence rates.¹¹⁷ Kal et al. reported that a BED ≥ 30 Gy (α/β ratio = 10) delivered over a short interval time results in better long-term control rates (>90%). Common fractionation regimens to achieve BED ≥ 30 Gy include 13 Gy x 2, 8 Gy x 2, or 6 Gy x 3.¹¹⁸

For HDR BT, regimens with a BED of 20 to 30 Gy have been most commonly reported. Fractionated HDR BT regimens are preferred, as most of the published data has utilized fractionation, with the most common schemes consisting of 6 Gy x 2 to 3 fractions (BED 19.2-28.8 Gy)^{93,95,98,99,102}, 5 Gy x 3 to 4 fractions (BED 22.5-30 Gy)^{94,97,104}, or 3 Gy x 4 fractions (BED 15.6 Gy)^{90,101,112}. A retrospective cohort study found that the HDR BT fractionation regimen of 2 x 6 Gy (prescribed to 0.5 cm depth is equally effective as regimens using higher doses (2 x 9 Gy or 3 x 6 Gy), with a lower risk of complications.⁹³ A study by Hafkamp reported that adjuvant HDR BT using a single fraction of 13 Gy (BED 29.9 Gy) was associated with a 24% recurrence rate⁹² which is inferior compared to reported recurrence rates for 2 to 4 fraction regimens, although the study was limited by lack of patient participation (only 24 of 61 invited patients responded) and comparisons between studies are challenged by differences in follow up and recurrence definitions. Van Leeuwen et al. reported that HDR BT resulted in lower recurrence rates compared with LDR BT and external beam RT.¹¹⁹

Subtopic 3/ Timing and Sequencing

Adjuvant RT is typically delivered over 3 to 4 fractions and completed within 1 week of surgery. RT may be delivered daily or every other day.¹²⁰ The first dose of adjuvant RT should be performed as soon as possible after surgical excision, ideally within 24 hours. Data from 507 treated keloids from 8 observational studies suggest that immediate adjuvant RT delivered within 2 hours of surgical excision results in lower recurrence rates compared to 6 hours postoperatively (7% vs 16%, $P < 0.01$).¹²¹

Subtopic 4/ Simulation

The patient should be placed in a reproducible position. Depending on the location of the lesion and proximity to surrounding structures, clinical set-up is typically used for superficial targets. CT simulation can be considered for larger or deeper lesions and those that span over a curved surface. CT simulation offers a 3-dimensional evaluation and more precise estimation of the target volume¹²² to ensure adequate dosimetric coverage in such cases. A 7.4% recurrence rate has been reported in patients treated with adjuvant RT using 3-dimensional treatment planning.⁶⁶

Subtopic 5/ RT Field Design

The RT field for low-energy superficial treatments should cover the entire scar with 0.5 to 1 cm radial margin. Superficial treatments penetrates 3 to 5 mm, which targets the area at risk for hypertrophic scar/keloid formation while protecting underlying tissues. When using electron beam therapy, a wider margin (typically 1 to 2 cm radial margin) is required to adequate dosimetric coverage (compared to kV photon treatment), and treatment depth is dependent on chosen energy. The use of bolus for superficial targets treated with electrons

should be considered. The use of wedges for targets spanning curved surfaces using higher energy photons should be considered.

Topic 4/ What are the risks associated with RT?

Subtopic 1/ Secondary Malignancy Risks

Although there are theoretic concerns for RT-induced malignancy, there are no documented cases of a secondary cancer definitively attributed to hypertrophic scar/keloid RT. Secondary malignancy risks associated with RT for benign diseases are reported to be extremely rare. The risk is difficult to estimate due to low incidence which is close to the background malignancy rate, and lack of long-term follow up. The calculated incidence for risk of developing a secondary malignancy following adjuvant RT for hypertrophic scars/keloids is 0.1% to 0.335%.¹²³ Since the RT is delivered superficially, the surrounding healthy skin is deemed the organ most at risk. It is difficult to determine whether RT for hypertrophic scar/keloids increases the risk of skin cancers, which are associated with a spontaneous lifetime risk of 1 in 5 (20%) in the general population.¹²⁴ There is little evidence to suggest that a BED of 30 Gy, typically used for hypertrophic scars/keloids causes skin cancer.¹²⁵ Others have also concluded that the risk of developing secondary malignancy following RT for hypertrophic scars/keloids is very low, especially when surrounding tissues, including the thyroid and breast tissue, are shielded.^{49,126}

Subtopic 2/ Non-Malignant Risks

○ Acute Effects

Pigmentation change in the RT field is the most common side effect and may be predicted by location and size of the lesion.¹²⁷ Pigmentation changes occur in up to 61% (56% hyperpigmentation; 7% both hypopigmentation and hyperpigmentation). Pigmentation changes may persist for many months following treatment and in most cases, gradually fade to normal skin tone. Acute RT dermatitis in the RT treatment field including erythema, pruritis, and dry skin occurs in approximately 18% of patients and may persist for several weeks following RT. These symptoms typically resolve spontaneously but should be treated with topical hydrating ointments and protection from the sun.¹²⁸

○ Late Effects

Chronic hyperpigmentation, dry skin, and telangiectasia are relatively rare following adjuvant RT and more common with single doses of >5.0 Gy. Fractionation reduces the risk of hyperpigmentation and long-term sequelae. Standard fractionation using single doses $\leq$ 4.0 Gy and total doses of less than 15 Gy are not associated with these late effects.^{49,128}

Variant Cases

Variant cases (**Tables 2 - 8**) were developed as examples for these guidelines to illustrate practical applications of consensus recommendations.

CONCLUSIONS/SUMMARY OF RECOMMENDATIONS

1. The panel recommends that adjuvant RT using kV photons (superficial voltage preferred) or electron beam is usually appropriate for the typical case following resection of an earlobe keloid. In general, the use of adjuvant RT must balance the benefit of recurrence prevention with the potential risk of harm. *Caution should be used when considering RT for prevention of hypertrophic scars/keloids in patients who may be at higher risk for complications from RT. Those at risk include children and adolescents, who are actively developing, and have a longer remaining lifetime for long-term effects to manifest. Other 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 **more** severe acute and late-stage tissue toxicity,

such as extreme skin inflammation, tissue scarring (fibrosis), and disease flares in the irradiated area. [Table 2; Variant 1].

2. The panel recommends that adjuvant RT using electron beam or kV photons (superficial voltage preferred) is usually appropriate for the typical case following resection of a chest keloid following sternotomy or abdominal keloid following caesarian section.*Caution should be used when considering RT for prevention of hypertrophic scars/keloids in patient who may be at higher risk for complications from RT (see Recommendation 1.). [Table 3; Variant 2 and Table 4; Variant 3].
3. The panel recommends that adjuvant RT using electron beam, kV photons or brachytherapy using superficial applicators is usually appropriate for the typical case following resection of multiple hypertrophic scars/keloids in a burn victim and may be included in a multimodality treatment approach. Given the diffuse nature of the keloids involving multiple regions of the body, a staged surgical treatment approach and multiple treatment modalities (which may or may not include RT) may be necessary, and a multidisciplinary approach should be used to optimize treatment management [Table 5; Variant 4].
4. The panel recommends that although surgery alone is usually appropriate for the typical case of prevention of keloid formation after trauma in a patient deemed at high risk for keloid development adjuvant prophylactic RT may be appropriate in clinical situations in which the morbidity of keloid formation requiring subsequent resection significantly outweighs the potential risks of ionizing RT exposure. [Table 6; Variant 5].
5. The panel recommends that RT alone may be appropriate for the typical case of multiple keloids refractory to other therapies (such as intralesional injections, cryotherapy, and laser therapy) in a patient unable to undergo surgery [Table 7; Variant 6].
6. The panel recommends that re-irradiation may be appropriate] for the typical case of recurrent keloid following prior excision and adjuvant RT [Table 8; Variant 7].

DISCUSSION

It should be noted that much of the data supporting the use of adjuvant RT following excision of hypertrophic scars/keloids results are based on older cohort series and retrospective studies, some quite large, including a variety of lesion sizes, locations, previous treatments, RT techniques, and dose-fractionation schedules. In addition, “recurrence” is not consistently defined and follow up intervals vary, limiting comparisons of results from different series. We recognize that although our recommendations are based on available data, available literature contains insufficient high-level data to strongly inform our decisions. Future investigations and improvements in technique will likely lead to further improvements in outcomes, more consistent results and strengthened recommendations.

SUMMARY OF EVIDENCE

This section summarizes the references in the evidence table.

Of the 137 references cited in the American Radium Society® Appropriate Use Criteria for Adjuvant Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids, 87 were identified through the search strategy, An additional 50 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. Of the 87 references used as evidence, 86 are categorized as therapeutic references including 3 well-designed studies (Phase II randomized and Phase III), 23 moderately well- designed studies that account for most common biases (matched cohort and Phase II studies), 50 studies with design limitations (retrospective reviews), 4 supplemental studies (not useful as primary evidence), and 7 references that are meta-analysis studies.

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.

REFERENCES:

1. Fang X, Wang Y, Chen H, et al. Hypertrophic Scarring and Keloids: Epidemiology, Molecular Pathogenesis, and Therapeutic Interventions. *MedComm* (2020). Oct 2025;6(10):e70381. doi:10.1002/mco2.70381
2. Lee SS, Yosipovitch G, Chan YH, Goh CL. Pruritus, pain, and small nerve fiber function in keloids: a controlled study. *J Am Acad Dermatol*. Dec 2004;51(6):1002-6. doi:10.1016/j.jaad.2004.07.054
3. Kang S, Hur JK, Kim D. Advances in diagnostic methods for keloids and biomarker-targeted fluorescent probes. *Analyst*. Mar 11 2019;144(6):1866-1875. doi:10.1039/c8an02421a
4. Kim HJ, Kim YH. Comprehensive Insights into Keloid Pathogenesis and Advanced Therapeutic Strategies. *Int J Mol Sci*. Aug 12 2024;25(16)doi:10.3390/ijms25168776
5. Lei R, Shen J, Zhang S, et al. Inactivating the ubiquitin ligase Parkin suppresses cell proliferation and induces apoptosis in human keloids. *J Cell Physiol*. Sep 2019;234(9):16601-16608. doi:10.1002/jcp.28332
6. Coentro JQ, Pugliese E, Hanley G, Raghunath M, Zeugolis DI. Current and upcoming therapies to modulate skin scarring and fibrosis. *Adv Drug Deliv Rev*. Jun 2019;146:37-59. doi:10.1016/j.addr.2018.08.009
7. Lin TR, Chou FH, Wang HH, Wang RH. Effects of scar massage on burn scars: A systematic review and meta-analysis. *J Clin Nurs*. Jul 2023;32(13-14):3144-3154. doi:10.1111/jocn.16420
8. Koller T. Mechanosensitive Aspects of Cell Biology in Manual Scar Therapy for Deep Dermal Defects. *Int J Mol Sci*. Mar 17 2020;21(6)doi:10.3390/ijms21062055
9. Bordoni B, Escher AR, Girgenti GT, Tobbi F, Bonanzinga R. Osteopathic Approach for Keloids and Hypertrophic Scars. *Cureus*. Sep 2023;15(9):e44815. doi:10.7759/cureus.44815
10. Lubczynska A, Garncarczyk A, Wcislo-Dziadecka D. Effectiveness of various methods of manual scar therapy. *Skin Res Technol*. Mar 2023;29(3):e13272. doi:10.1111/srt.13272
11. Powell HM, Nedelec B. Mechanomodulation of Burn Scarring Via Pressure Therapy. *Adv Wound Care (New Rochelle)*. Apr 2022;11(4):179-191. doi:10.1089/wound.2021.0061
12. Hwang SJ, Seo J, Cha JY, et al. Utility of customized 3D compression mask with pressure sensors on facial burn scars: A single-blinded, randomized controlled trial. *Burns*. Sep 2024;50(7):1885-1897. doi:10.1016/j.burns.2024.05.021
13. Harris IM, Lee KC, Deeks JJ, Moore DJ, Moiemmen NS, Dretzke J. Pressure-garment therapy for preventing hypertrophic scarring after burn injury. *Cochrane Database Syst Rev*. Jan 8 2024;1(1):CD013530. doi:10.1002/14651858.CD013530.pub2

14. De Decker I, Beeckman A, Hoeksema H, et al. Pressure therapy for scars: Myth or reality? A systematic review. *Burns*. Jun 2023;49(4):741-756. doi:10.1016/j.burns.2023.03.007
15. Zhuang L, Su J, Jiao J, Li H. Utilizing magnetic discs combined with thin silicone gel sheets for pressure therapy in earlobe keloid postexcision. *J Am Acad Dermatol*. Feb 2025;92(2):e35-e36. doi:10.1016/j.jaad.2024.06.111
16. Napavichayanun S, Vasuratna A, Santibenchakul S, Cherdchom S, Aramwit P. Evaluating efficacy and safety of the topical silicone gel containing onion extract in the treatment of post-cesarean surgical scars. *J Cosmet Dermatol*. Jul 2022;21(7):2908-2915. doi:10.1111/jocd.14524
17. De Decker I, Hoeksema H, Vanlerberghe E, et al. Occlusion and hydration of scars: moisturizers versus silicone gels. *Burns*. Mar 2023;49(2):365-379. doi:10.1016/j.burns.2022.04.025
18. Hsu KC, Luan CW, Tsai YW. Review of Silicone Gel Sheeting and Silicone Gel for the Prevention of Hypertrophic Scars and Keloids. *Wounds*. May 2017;29(5):154-158.
19. Tian F, Jiang Q, Chen J, Liu Z. Silicone gel sheeting for treating keloid scars. *Cochrane Database Syst Rev*. Jan 3 2023;1(1):CD013878. doi:10.1002/14651858.CD013878.pub2
20. Goutos I, Ogawa R. Steroid tape: A promising adjunct to scar management. *Scars Burn Heal*. Jan-Dec 2017;3:2059513117690937. doi:10.1177/2059513117690937
21. Wiseman J, Simons M, Kimble R, Ware RS, McPhail SM, Tyack Z. Effectiveness of topical silicone gel and pressure garment therapy for burn scar prevention and management in children 12-months postburn: A parallel group randomised controlled trial. *Clin Rehabil*. Aug 2021;35(8):1126-1141. doi:10.1177/02692155211020351
22. Crofton E, Meredith P, Gray P, O'Reilly S, Strong J. Non-adherence with compression garment wear in adult burns patients: A systematic review and meta-ethnography. *Burns*. Mar 2020;46(2):472-482. doi:10.1016/j.burns.2019.08.011
23. Li Q, Chen Z, Zou X, et al. Effectiveness of postoperative superficial radiotherapy following the keloid-cross-flap surgery for auricular keloid: A prospective cohort study. *Radiother Oncol*. Oct 2024;199:110425. doi:10.1016/j.radonc.2024.110425
24. Nast A, Gauglitz G, Lorenz K, et al. S2k guidelines for the therapy of pathological scars (hypertrophic scars and keloids) - Update 2020. *J Dtsch Dermatol Ges*. Feb 2021;19(2):312-327. doi:10.1111/ddg.14279
25. Haghani-Dogahe Z, Hadadi R, Esmailzadeh M, Mobayen M. Comparing intralesional triamcinolone and verapamil-triamcinolone injections in keloids: A single-blinded randomised clinical trial. *Int Wound J*. Dec 2023;20(10):4166-4174. doi:10.1111/iwj.14314
26. Sharma S, Vinay K, Bassi R. Treatment of Small Keloids Using Intralesional 5-fluorouracil and Triamcinolone Acetonide versus Intralesional Bleomycin and Triamcinolone Acetonide. *J Clin Aesthet Dermatol*. Mar 2021;14(3):17-21.
27. Ren Y, Zhou X, Wei Z, Lin W, Fan B, Feng S. Efficacy and safety of triamcinolone acetonide alone and in combination with 5-fluorouracil for treating hypertrophic scars and keloids: a systematic review and meta-analysis. *Int Wound J*. Jun 2017;14(3):480-487. doi:10.1111/iwj.12629
28. Acharya R, Agrawal S, Khadka DK, Pant AR. Efficacy and safety of intralesional triamcinolone acetonide alone and its combination with 5- fluorouracil in keloids and hypertrophic scars: Randomized, parallel group, and double blinded trial. *Skin Health Dis*. Oct 2024;4(5):e450. doi:10.1002/ski2.450
29. Sohrabi C, Goutos I. The use of botulinum toxin in keloid scar management: a literature review. *Scars Burn Heal*. Jan-Dec 2020;6:2059513120926628. doi:10.1177/2059513120926628
30. Li Z, Jin Z. Comparative effect and safety of verapamil in keloid and hypertrophic scar treatment: a meta-analysis. *Ther Clin Risk Manag*. 2016;12:1635-1641. doi:10.2147/TCRM.S118748
31. Kim WI, Kim S, Cho SW, Cho MK. The efficacy of bleomycin for treating keloid and hypertrophic scar: A systematic review and meta-analysis. *J Cosmet Dermatol*. Dec 2020;19(12):3357-3366. doi:10.1111/jocd.13390

32. Shin JY, Yun SK, Roh SG, Lee NH, Yang KM. Efficacy of 2 Representative Topical Agents to Prevent Keloid Recurrence After Surgical Excision. *J Oral Maxillofac Surg.* Feb 2017;75(2):401 e1-401 e6. doi:10.1016/j.joms.2016.10.009
33. Bijlard E, Steltenpool S, Niessen FB. Intralesional 5-fluorouracil in keloid treatment: a systematic review. *Acta Derm Venereol.* Sep 2015;95(7):778-82. doi:10.2340/00015555-2106
34. Jiang ZY, Liao XC, Liu MZ, et al. Efficacy and Safety of Intralesional Triamcinolone Versus Combination of Triamcinolone with 5-Fluorouracil in the Treatment of Keloids and Hypertrophic Scars: A Systematic Review and Meta-analysis. *Aesthetic Plast Surg.* Oct 2020;44(5):1859-1868. doi:10.1007/s00266-020-01721-2
35. Xia Y, Wang Y, Hao Y, et al. Deciphering the single-cell transcriptome network in keloids with intra-lesional injection of triamcinolone acetone combined with 5-fluorouracil. *Front Immunol.* 2023;14:1106289. doi:10.3389/fimmu.2023.1106289
36. Hietanen KE, Jarvinen TA, Huhtala H, Tolonen TT, Kuokkanen HO, Kaartinen IS. Treatment of keloid scars with intralesional triamcinolone and 5-fluorouracil injections - a randomized controlled trial. *J Plast Reconstr Aesthet Surg.* Jan 2019;72(1):4-11. doi:10.1016/j.bjps.2018.05.052
37. Chen XE, Liu J, Bin Jameel AA, et al. Combined effects of long-pulsed neodymium-yttrium-aluminum-garnet laser, diprospan and 5-fluorouracil in the treatment of keloid scars. *Exp Ther Med.* Jun 2017;13(6):3607-3612. doi:10.3892/etm.2017.4438
38. Apfelberg DB, Maser MR, White DN, Lash H. Failure of carbon dioxide laser excision of keloids. *Lasers Surg Med.* 1989;9(4):382-8. doi:10.1002/lsm.1900090411
39. Wen J, Li Z, Liu W, Yu N, Wang X. Dual-wavelength dye laser combined with betamethasone injection for treatment of keloids: protocol of a randomised controlled trial. *BMJ Open.* Jul 9 2024;14(7):e084939. doi:10.1136/bmjopen-2024-084939
40. Al-Mohamady Ael S, Ibrahim SM, Muhammad MM. Pulsed dye laser versus long-pulsed Nd:YAG laser in the treatment of hypertrophic scars and keloid: A comparative randomized split-scar trial. *J Cosmet Laser Ther.* Aug 2016;18(4):208-12. doi:10.3109/14764172.2015.1114648
41. Hashemi DA, Tao J, Wang JV, Geronemus RG. The 595-nm Wavelength Pulsed Dye Laser for Pediatric Port-Wine Birthmarks and Infantile Hemangiomas: A Systematic Review. *Lasers Surg Med.* Jan 2025;57(1):27-36. doi:10.1002/lsm.23864
42. Kivi MK, Jafarzadeh A, Hosseini-Baharanchi FS, Salehi S, Goodarzi A. The efficacy, satisfaction, and safety of carbon dioxide (CO2) fractional laser in combination with pulsed dye laser (PDL) versus each one alone in the treatment of hypertrophic burn scars: a single-blinded randomized controlled trial. *Lasers Med Sci.* Feb 20 2024;39(1):69. doi:10.1007/s10103-024-03976-6
43. Barara M, Mendiratta V, Chander R. Cryotherapy in treatment of keloids: evaluation of factors affecting treatment outcome. *J Cutan Aesthet Surg.* Jul 2012;5(3):185-9. doi:10.4103/0974-2077.101376
44. O'Boyle CP, Shayan-Arani H, Hamada MW. Intralesional cryotherapy for hypertrophic scars and keloids: a review. *Scars Burn Heal.* Jan-Dec 2017;3:2059513117702162. doi:10.1177/2059513117702162
45. Ogawa R, Akaishi S, Huang C, et al. Clinical applications of basic research that shows reducing skin tension could prevent and treat abnormal scarring: the importance of fascial/subcutaneous tensile reduction sutures and flap surgery for keloid and hypertrophic scar reconstruction. *J Nippon Med Sch.* 2011;78(2):68-76. doi:10.1272/jnms.78.68
46. Arima J, Dohi T, Kuribayashi S, Akaishi S, Ogawa R. Z-plasty and Postoperative Radiotherapy for Anterior Chest Wall Keloids: An Analysis of 141 Patients. *Plast Reconstr Surg Glob Open.* Mar 2019;7(3):e2177. doi:10.1097/GOX.0000000000002177
47. Tsuge T, Aoki M, Akaishi S, Dohi T, Yamamoto H, Ogawa R. Geometric modeling and a retrospective cohort study on the usefulness of fascial tensile reductions in severe keloid surgery. *Surgery.* Feb 2020;167(2):504-509. doi:10.1016/j.surg.2019.07.028
48. Seth I, Gibson D, Marcaccini G, et al. Post-excisional radiotherapy for keloid treatment: A systematic review and meta-analysis. *J Plast Reconstr Aesthet Surg.* Feb 2026;113:459-531. doi:10.1016/j.bjps.2025.11.016

49. Mankowski P, Kanevsky J, Tomlinson J, Dyachenko A, Luc M. Optimizing Radiotherapy for Keloids: A Meta-Analysis Systematic Review Comparing Recurrence Rates Between Different Radiation Modalities. *Ann Plast Surg.* Apr 2017;78(4):403-411. doi:10.1097/SAP.0000000000000989
50. Yossi S, Krhili S, Mesgouez-Nebout N, et al. [Adjuvant treatment of keloid scars: electrons or brachytherapy?]. *Cancer Radiother.* Feb 2013;17(1):21-5. Traitement postopératoire des cicatrices chéloïdes : électrons ou irradiation interstitielle ? doi:10.1016/j.canrad.2012.11.002
51. Flickinger JC. A radiobiological analysis of multicenter data for postoperative keloid radiotherapy. *Int J Radiat Oncol Biol Phys.* Mar 15 2011;79(4):1164-70. doi:10.1016/j.ijrobp.2009.12.019
52. Garcia-Barros M, Paris F, Cordon-Cardo C, et al. Tumor response to radiotherapy regulated by endothelial cell apoptosis. *Science.* May 16 2003;300(5622):1155-9. doi:10.1126/science.1082504
53. Lee SY, Park J. Postoperative electron beam radiotherapy for keloids: treatment outcome and factors associated with occurrence and recurrence. *Ann Dermatol.* Feb 2015;27(1):53-8. doi:10.5021/ad.2015.27.1.53
54. Caccialanza M, Piccinno R, Schiera A. Postoperative radiotherapy of keloids: a twenty-year experience. *Eur J Dermatol.* Jan-Feb 2002;12(1):58-62.
55. Levy DS, Salter MM, Roth RE. Postoperative irradiation in the prevention of keloids. *AJR Am J Roentgenol.* Sep 1976;127(3):509-10. doi:10.2214/ajr.127.3.509
56. Page MJ, Moher D, Bossuyt PM, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ.* Mar 29 2021;372:n160. doi:10.1136/bmj.n160
57. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* Mar 29 2021;372:n71. doi:10.1136/bmj.n71
58. Fitch K, Bernsein S, Aguilar M, et al. The RAND/UCLA Appropriateness Method User's Manual. Santa Monica: Rand Corporation. 2001
59. Ogawa R, Akaishi S, Kuribayashi S, Miyashita T. Keloids and Hypertrophic Scars Can Now Be Cured Completely: Recent Progress in Our Understanding of the Pathogenesis of Keloids and Hypertrophic Scars and the Most Promising Current Therapeutic Strategy. *J Nippon Med Sch.* 2016;83(2):46-53. doi:10.1272/jnms.83.46.
60. Hsueh WT, Hung KS, Chen YC, et al. Adjuvant Radiotherapy After Keloid Excision: Preliminary Experience in Taiwan. *Ann Plast Surg.* Jan 2019;82(1S Suppl 1):S39-S44. doi:10.1097/SAP.0000000000001728
61. Bhattacharya N, Bhattacharya K, Chandran TC. Treatment of Keloids with Surgery and Immediate Postoperative Radiotherapy: Knowledge Gained Over 17 Years. *Indian J Plast Surg.* Jun 2023;56(3):251-259. doi:10.1055/s-0043-1761599
62. Shen J, Lian X, Sun Y, et al. Hypofractionated electron-beam radiation therapy for keloids: retrospective study of 568 cases with 834 lesions. *J Radiat Res.* Sep 2015;56(5):811-7. doi:10.1093/jrr/rrv031
63. Kim J, Lee SH. Therapeutic results and safety of postoperative radiotherapy for keloid after repeated Cesarean section in immediate postpartum period. *Radiat Oncol J.* Jun 2012;30(2):49-52. doi:10.3857/roj.2012.30.2.49
64. Ogawa R, Tosa M, Dohi T, Akaishi S, Kuribayashi S. Surgical excision and postoperative radiotherapy for keloids. *Scars Burn Heal.* Jan-Dec 2019;5:2059513119891113. doi:10.1177/2059513119891113
65. Han SH, Ha B, Chang CH, Park TH. Efficacy of Immediate Postoperative Single Fractional 10 Gy Radiotherapy for Earlobe Keloids. *J Craniofac Surg.* Feb 12 2024;doi:10.1097/SCS.00000000000010002
66. Hwang NH, Lee NK, Chae JH, Park SH, Yoon ES. The Efficacy of CT-Based Conformal Electron Beam Radiation Therapy After Keloid Excision. *Dermatol Surg.* Apr 1 2022;48(4):435-440. doi:10.1097/DSS.0000000000003398
67. Wen P, Wang T, Zhou Y, Yu Y, Wu C. A retrospective study of hypofractionated radiotherapy for keloids in 100 cases. *Sci Rep.* Feb 11 2021;11(1):3598. doi:10.1038/s41598-021-83255-4

68. Rishi KS, Sarkar N, Kesari P, et al. Single Institution Experience of Postoperative Electron Beam Radiation Therapy in the Treatment of Keloids. *Adv Radiat Oncol*. Mar-Apr 2021;6(2):100596. doi:10.1016/j.adro.2020.10.009
69. Wang Y, Ma J, Zhang Z, Shen H. Combined surgical excision and electron external beam radiation improves the treatment of keloids: A descriptive study. *Dermatol Ther*. Jul 2020;33(4):e13494. doi:10.1111/dth.13494
70. Liu CL, Yuan ZY. Retrospective study of immediate postoperative electron radiotherapy for therapy-resistant earlobe keloids. *Arch Dermatol Res*. Aug 2019;311(6):469-475. doi:10.1007/s00403-019-01922-z
71. Sruthi K, Chelakkot PG, Madhavan R, Nair RR, Dinesh M. Single-fraction radiation: A promising adjuvant therapy to prevent keloid recurrence. *J Cancer Res Ther*. Oct-Dec 2018;14(6):1251-1255. doi:10.4103/jcrt.JCRT_20_17
72. Renz P, Hasan S, Gresswell S, Hajjar RT, Trombetta M, Fontanesi J. Dose Effect in Adjuvant Radiation Therapy for the Treatment of Resected Keloids. *Int J Radiat Oncol Biol Phys*. Sep 1 2018;102(1):149-154. doi:10.1016/j.ijrobp.2018.05.027
73. Khalid FA, Farooq UK, Saleem M, et al. The efficacy of excision followed by intralesional 5-fluorouracil and triamcinolone acetonide versus excision followed by radiotherapy in the treatment of ear keloids: A randomized control trial. *Burns*. Sep 2018;44(6):1489-1495. doi:10.1016/j.burns.2018.02.017
74. Hoang D, Reznik R, Orgel M, Li Q, Mirhadi A, Kulber DA. Surgical Excision and Adjuvant Brachytherapy vs External Beam Radiation for the Effective Treatment of Keloids: 10-Year Institutional Retrospective Analysis. *Aesthet Surg J*. Feb 2017;37(2):212-225. doi:10.1093/asj/sjw124
75. Carvajal CC, Ibarra CM, Arbulo DL, Russo MN, Sole CP. Postoperative radiotherapy in the management of keloids. *Ecancermedicalscience*. 2016;10:690. doi:10.3332/ecancer.2016.690
76. Song C, Wu HG, Chang H, Kim IH, Ha SW. Adjuvant single-fraction radiotherapy is safe and effective for intractable keloids. *J Radiat Res*. Sep 2014;55(5):912-6. doi:10.1093/jrr/rru025
77. Sakamoto T, Oya N, Nagata Y, Hiraoka M. The outcome and the adverse effect of postoperative radiotherapy for keloids: A prospective study with a total dose of 20 Gy. *International Journal of Radiation Oncology*Biophysics*. 2004;60(1):s549. doi:10.1016/S0360-3016(04)01825-5
78. Chen F, Kuo YR, Huang CJ, Tang JY, Chiang CH, Huang MY. Lesion Site Is the Key Prognostic Factor for Keloid Patients Receiving Surgery With Adjuvant Radiotherapy. *Ann Plast Surg*. Dec 1 2022;89(6):626-630. doi:10.1097/SAP.0000000000003315
79. Katano A, Minamitani M, Yamashita H. Risk factors for local recurrence of keloids and hypertrophic scars after postoperative electron beam radiotherapy. *J Cancer Res Ther*. Jan 1 2024;20(1):163-166. doi:10.4103/jcrt.jcrt_1861_22
80. Liu C. Risk factors for recurrence after keloid surgery with electron radiotherapy. *Medicine (Baltimore)*. Oct 27 2023;102(43):e35683. doi:10.1097/MD.00000000000035683
81. Yang X, Shao Y, Yu W, et al. A Novel Radiotherapy Approach for Keloids with Intrabeam. *Biomed Res Int*. 2019;2019:4693528. doi:10.1155/2019/4693528
82. Speranza G, Sultanem K, Muanza T. Descriptive study of patients receiving excision and radiotherapy for keloids. *Int J Radiat Oncol Biol Phys*. Aug 1 2008;71(5):1465-9. doi:10.1016/j.ijrobp.2007.12.015
83. Ponteriero A, Potami A, Iati G, et al. Post-operative radiotherapy of keloids. A 10-years experience of kilovoltage irradiation. *International Journal of Radiation Research*. 2015;13(3):201-204. doi:10.7508/ijrr.2015.03.001
84. Mohammadi AA, Mohammadian Panah M, Pakyari MR, et al. Surgical excision followed by low dose rate radiotherapy in the management of resistant keloids. *World J Plast Surg*. Jun 2013;2(2):81-6.
85. Ramelyte E, Welte M, Gardin F, Maul JT, Dummer R, Imhof L. Post-Excision Soft X-Ray Radiotherapy for Keloids: Experience in a Tertiary Referral Center. *Dermatology*. 2024;240(4):572-580. doi:10.1159/000539782

86. Tsai SL, Tsai YC, Weng YT, Huang WY, Wang CH. Keloid Excision With Primary Closure Combined With Superficial Radiation Therapy (SRT-100). *Ann Plast Surg.* Mar 1 2025;94(3S Suppl 1):S18-S23. doi:10.1097/SAP.0000000000004187
87. Jones ME, Ganzer CA, Bennett D, Finizio A. Surgical Excision of Keloids Followed by In-office Superficial Radiation Therapy: Prospective Study Examining Clinical Outcomes. *Plast Reconstr Surg Glob Open.* May 2019;7(5):e2212. doi:10.1097/GOX.0000000000002212
88. Malaker K, Zaidi M, Franka MR. Treatment of earlobe keloids using the cobalt 60 teletherapy unit. *Ann Plast Surg.* Jun 2004;52(6):602-4. doi:10.1097/01.sap.0000095408.74866.f1
89. Lin YF, Shueng PW, Roan TL, et al. Tomotherapy as an Alternative Irradiative Treatment for Complicated Keloids. *J Clin Med.* Nov 20 2020;9(11)doi:10.3390/jcm9113732
90. Barragan VV, Garcia AIA, Garcia JF, Marin MJ, Vivas J, Rijo GJ. Perioperative interstitial high-dose-rate brachytherapy for keloids scar. *J Contemp Brachytherapy.* Feb 2022;14(1):29-34. doi:10.5114/jcb.2022.113547
91. Anderson EM, David J, Phillips T, et al. Interstitial high-dose-rate brachytherapy in the treatment of keloids: Moving toward a volumetric approach. *Brachytherapy.* Jan-Feb 2021;20(1):185-188. doi:10.1016/j.brachy.2020.07.008
92. Hafkamp CJH, Lapid O, Davila Fajardo R, et al. Postoperative single-dose interstitial high-dose-rate brachytherapy in therapy-resistant keloids. *Brachytherapy.* Mar-Apr 2017;16(2):415-420. doi:10.1016/j.brachy.2016.12.009
93. Bijlard E, Verduijn GM, Harmeling JX, et al. Optimal High-Dose-Rate Brachytherapy Fractionation Scheme After Keloid Excision: A Retrospective Multicenter Comparison of Recurrence Rates and Complications. *Int J Radiat Oncol Biol Phys.* Mar 1 2018;100(3):679-686. doi:10.1016/j.ijrobp.2017.10.044
94. Manjunath KN, Venkatesh MS, Alva R, et al. Efficacy of Surgical Excision and Adjuvant High-dose Rate Brachytherapy in Treatment of Keloid: Our Experience. *J Cutan Aesthet Surg.* Jul-Sep 2021;14(3):337-343. doi:10.4103/JCAS.JCAS_120_16
95. Daurade M, Breton P, Rouard N, Lorchel F, Ibrahim B, Sigaux N. Efficacy of Surgical Excision and Brachytherapy in the Treatment of Keloids: A Retrospective Cohort Study. *Adv Skin Wound Care.* Nov 2020;33(11):1-6. doi:10.1097/01.ASW.0000717228.02752.4e
96. De Cicco L, Vischioni B, Vavassori A, et al. Postoperative management of keloids: low-dose-rate and high-dose-rate brachytherapy. *Brachytherapy.* Sep-Oct 2014;13(5):508-13. doi:10.1016/j.brachy.2014.01.005
97. Arneja JS, Singh GB, Dolynchuk KN, Murray KA, Rozzelle AA, Jones KD. Treatment of recurrent earlobe keloids with surgery and high-dose-rate brachytherapy. *Plast Reconstr Surg.* Jan 2008;121(1):95-99. doi:10.1097/01.prs.0000293755.64918.22
98. van Leeuwen MCE, Stokmans SC, Bulstra AJ, Meijer OWM, van Leeuwen PAM, Niessen FB. High-dose-rate brachytherapy for the treatment of recalcitrant keloids: a unique, effective treatment protocol. *Plast Reconstr Surg.* Sep 2014;134(3):527-534. doi:10.1097/PRS.0000000000000415
99. Jiang P, Geenen M, Siebert FA, et al. Efficacy and the toxicity of the interstitial high-dose-rate brachytherapy in the management of recurrent keloids: 5-year outcomes. *Brachytherapy.* May-Jun 2018;17(3):597-600. doi:10.1016/j.brachy.2017.12.002
100. Taheri A, Molaei H, Aghili M, Rahmanpanah N, Mirmohseni A. Outcomes of Surgical Excision and Brachytherapy in Intractable Keloids. *World J Plast Surg.* Sep 2017;6(3):280-284.
101. Franzetti J, Durante S, Mastroleo F, et al. Post-operative KEloids iRradiation (POKER): does the surgery/high-dose interventional radiotherapy association make a winning hand? *Radiol Med.* Feb 2024;129(2):328-334. doi:10.1007/s11547-024-01756-4
102. Jiang P, Baumann R, Dunst J, et al. Perioperative Interstitial High-Dose-Rate Brachytherapy for the Treatment of Recurrent Keloids: Feasibility and Early Results. *Int J Radiat Oncol Biol Phys.* Mar 1 2016;94(3):532-6. doi:10.1016/j.ijrobp.2015.11.008

103. Ahmad M, H. A, Khattack M, et al. Postoperative single versus multiple fractions high-dose rate iridium-192 surface mould brachytherapy for keloid treatment: a comparative study. *J Radiother Pract.* 2018;17:60-65. doi:10.1017/S1460396917000395
104. Kuribayashi S, Miyashita T, Ozawa Y, et al. Post-keloidectomy irradiation using high-dose-rate superficial brachytherapy. *J Radiat Res.* 2011;52(3):365-8. doi:10.1269/jrr.10159
105. Arnault JP, Peiffert D, Latarche C, Chassagne JF, Barbaud A, Schmutz JL. Keloids treated with postoperative Iridium 192* brachytherapy: a retrospective study. *J Eur Acad Dermatol Venereol.* Jul 2009;23(7):807-13. doi:10.1111/j.1468-3083.2009.03190.x
106. Chen S, Mu X, Zhang L, et al. Retrospective study comparing three approaches for keloids: surgery + radiotherapy, surgery + pharmacological injection, and surgery alone. *BMC Surg.* Aug 23 2025;25(1):386. doi:10.1186/s12893-025-03095-1
107. Gao Y, Li W, Li Z, Wu F, Wang J. Clinical Efficacy Analysis of Botulinum Toxin Type A Combined with Superficial Radiotherapy after Chest Keloid Surgery. *Aesthetic Plast Surg.* Nov 2025;49(22):6333-6338. doi:10.1007/s00266-025-04886-w
108. Malaker K, Vijayraghavan K, Hodson I, Al Yafi T. Retrospective analysis of treatment of unresectable keloids with primary radiation over 25 years. *Clin Oncol (R Coll Radiol).* Jun 2004;16(4):290-8. doi:10.1016/j.clon.2004.03.005
109. Yuce Sari S, Yilmaz MT, Yazici G, Uzun H, Yedekci FY, Ozyigit G. A hesitated approach: primary radiotherapy for keloids-a case series. *Strahlenther Onkol.* Oct 2021;197(10):909-915. doi:10.1007/s00066-020-01736-3
110. Fernandes J, Liao D, Dasgupta A, Tsao MN, Barnes EA. A Single-Institution Review of the Use of Radiation in the Adjuvant and Definitive Management of Keloids. *Clin Oncol (R Coll Radiol).* Jun 2024;36(6):e163-e167. doi:10.1016/j.clon.2024.03.018
111. Tsai TL, Huang YC, Chang YH, et al. Outcomes of Primary Radiation Therapy for Patients With Widespread or Unresectable Keloids. *Pract Radiat Oncol.* Feb 26 2026;doi:10.1016/j.prro.2026.02.007
112. Guix B, Henriquez I, Andres A, Finestres F, Tello JI, Martinez A. Treatment of keloids by high-dose-rate brachytherapy: A seven-year study. *Int J Radiat Oncol Biol Phys.* May 1 2001;50(1):167-72. doi:10.1016/s0360-3016(00)01563-7
113. Deng K, Xiao H, Liu X, Ogawa R, Xu X, Liu Y. Strontium-90 brachytherapy following intralesional triamcinolone and 5-fluorouracil injections for keloid treatment: A randomized controlled trial. *PLoS One.* 2021;16(3):e0248799. doi:10.1371/journal.pone.0248799
114. Ma QY, Yang YT, Chen ZA, et al. Laser Combined with Radiotherapy for Keloid Treatment: A Novel and Efficient Comprehensive Therapy with a Lower Recurrence Rate. *Plast Reconstr Surg.* Dec 1 2023;152(6):1022e-1029e. doi:10.1097/PRS.00000000000010376
115. Wu B, Zhang B, Xiao H, Xu X. Combining Steroid Plus 5-Fluorouracil Injection with Radiotherapy Versus Injection Alone for Keloids: A 4-Year Retrospective Study. *Aesthetic Plast Surg.* Dec 2025;49(23):6743-6755. doi:10.1007/s00266-025-04927-4
116. Hadedeya D, Shalaby M, Akkera M, et al. Prophylactic external beam radiation therapy for keloid prevention in thyroid surgery patients. *Gland Surg.* Jan 2021;10(1):65-72. doi:10.21037/gs-20-511
117. Hwang NH, Chang JH, Lee NK, Yang KS. Effect of the biologically effective dose of electron beam radiation therapy on recurrence rate after keloid excision: A meta-analysis. *Radiother Oncol.* Aug 2022;173:146-153. doi:10.1016/j.radonc.2022.06.003
118. Kal HB, Veen RE. Biologically effective doses of postoperative radiotherapy in the prevention of keloids. Dose-effect relationship. *Strahlenther Onkol.* Nov 2005;181(11):717-23. doi:10.1007/s00066-005-1407-6
119. van Leeuwen MC, Stokmans SC, Bulstra AE, et al. Surgical Excision with Adjuvant Irradiation for Treatment of Keloid Scars: A Systematic Review. *Plast Reconstr Surg Glob Open.* Jul 2015;3(7):e440. doi:10.1097/GOX.0000000000000357
120. Zhou W, Li B, Yin Y, et al. Treatment outcomes of surgery followed by short-course every other day radiotherapy in keloid. *Radiat Oncol.* Jul 17 2024;19(1):91. doi:10.1186/s13014-024-02488-5

121. Peng Q, Lu Y, Huang R, Chen R. Should We Do Postoperative Radiotherapy After Keloid Excision as Soon as Possible? A Systematic Review and Meta-Analysis. *Aesthetic Plast Surg*. Aug 2025;49(16):4671-4682. doi:10.1007/s00266-025-04869-x
122. Maemoto H, Ishigami K, Iraha S, et al. Analyses of size and computed tomography densitometry parameters for prediction of keloid recurrence after postoperative electron beam radiation therapy. *Skin Res Technol*. Jan 2020;26(1):125-131. doi:10.1111/srt.12775
123. Goutos I, Ogawa R. Brachytherapy in the adjuvant management of keloid scars: literature review. *Scars Burn Heal*. Jan-Dec 2017;3:2059513117735483. doi:10.1177/2059513117735483
124. Rigel DS, Friedman RJ, Kopf AW. Lifetime risk for development of skin cancer in the U.S. population: current estimate is now 1 in 5. *J Am Acad Dermatol*. Dec 1996;35(6):1012-3. doi:10.1016/s0190-9622(96)90139-5
125. Nestor MS, Berman B, Goldberg D, et al. Consensus Guidelines on the Use of Superficial Radiation Therapy for Treating Nonmelanoma Skin Cancers and Keloids. *J Clin Aesthet Dermatol*. Feb 2019;12(2):12-18.
126. Ogawa R, Yoshitatsu S, Yoshida K, Miyashita T. Is radiation therapy for keloids acceptable? The risk of radiation-induced carcinogenesis. *Plast Reconstr Surg*. Oct 2009;124(4):1196-1201. doi:10.1097/PRS.0b013e3181b5a3ae
127. Li L, Yuan C, Zhang X, Wang B, Yan Y. Superficial X-ray-induced hyperpigmentation in postoperative keloid radiotherapy: A study of 70 keloids to identify clinical features and risk factors. *J Cosmet Dermatol*. Sep 2021;20(9):2880-2886. doi:10.1111/jocd.14308
128. Berman B, Nestor MS, Gold MH, Goldberg DJ, Weiss ET, Raymond I. A Retrospective Registry Study Evaluating the Long-Term Efficacy and Safety of Superficial Radiation Therapy Following Excision of Keloid Scars. *J Clin Aesthet Dermatol*. Oct 2020;13(10):12-16.
129. Duan Q, Liu J, Luo Z, Hu C. Postoperative brachytherapy and electron beam irradiation for keloids: A single institution retrospective analysis. *Mol Clin Oncol*. May 2015;3(3):550-554. doi:10.3892/mco.2015.498
130. Bischof M, Krempien R, Debus J, Treiber M. Postoperative electron beam radiotherapy for keloids: objective findings and patient satisfaction in self-assessment. *Int J Dermatol*. Sep 2007;46(9):971-5. doi:10.1111/j.1365-4632.2007.03326.x
131. Doornbos JF, Stoffel TJ, Hass AC, et al. The role of kilovoltage irradiation in the treatment of keloids. *Int J Radiat Oncol Biol Phys*. Apr 1990;18(4):833-9. doi:10.1016/0360-3016(90)90405-9
132. Kovalic JJ, Perez CA. Radiation therapy following keloidectomy: a 20-year experience. *Int J Radiat Oncol Biol Phys*. Jul 1989;17(1):77-80. doi:10.1016/0360-3016(89)90373-8
133. Borok TL, Bray M, Sinclair I, Plafker J, LaBirth L, Rollins C. Role of ionizing irradiation for 393 keloids. *Int J Radiat Oncol Biol Phys*. Oct 1988;15(4):865-70. doi:10.1016/0360-3016(88)90119-8
134. Grobien M, Quero L, Chaouat M, et al. Treatment of refractory keloid by postoperative HDR brachytherapy: An 89-month median follow-up retrospective study. *Brachytherapy*. Nov-Dec 2025;24(6):940-948. doi:10.1016/j.brachy.2025.08.003
135. Viani GA, Stefano EJ, Afonso SL, De Fendi LI. Postoperative strontium-90 brachytherapy in the prevention of keloids: results and prognostic factors. *Int J Radiat Oncol Biol Phys*. Apr 1 2009;73(5):1510-6. doi:10.1016/j.ijrobp.2008.07.065
136. Wagner W, Alfrink M, Micke O, Schafer U, Schuller P, Willich N. Results of prophylactic irradiation in patients with resected keloids--a retrospective analysis. *Acta Oncol*. 2000;39(2):217-20. doi:10.1080/028418600430806
137. Escarmant P, Zimmermann S, Amar A, et al. The treatment of 783 keloid scars by iridium 192 interstitial irradiation after surgical excision. *Int J Radiat Oncol Biol Phys*. May 20 1993;26(2):245-51. doi:10.1016/0360-3016(93)90204-9

Table 1. Select Studies Evaluating Adjuvant RT for Prevention of Recurrent Hypertrophic Scars/Keloids

Author	Year	Study Type (Study Quality)	Number Keloids	Radiation Technique	Dose/ Fractionation	Recurrence Rate
Seth ⁴⁸	2026	Meta-analysis (M)	10,745 106 Studies	Electrons Photons Brachytherapy	NR	Electrons 16% Photons 18% Brachytherapy 14%
Han ⁶⁵	2024	Retrospective (3)	71	Electrons	10 Gy x 1	0% (earlobes only)
Hwang ⁶⁶	2022	Prospective nonrandomized (2)	136	Electrons	5 – 6 Gy x 3 fractions Total dose 15 – 18 Gy	Ear 5.4% Other sites 11.4%
Wen ⁶⁷	2021	Retrospective (3)	100	Electrons	4 Gy x 5 Total dose 20 Gy	15%
Rishi ⁶⁸	2021	Retrospective (3)	40	Electrons	4 Gy x 5 Total dose 20 Gy (95%) or 8 Gy x 1 (5%)	10% NR
Wang ⁶⁹	2020	Prospective nonrandomized (2)	58	Electrons	3 - 4 Gy x 4 Total dose 12 – 16 Gy	8.6%
Arima ⁴⁶	2019	Prospective nonrandomized (2)	141	Electrons	6 Gy x 3 Total dose 18 Gy	10.6% (chest wall keloids only)
Ogawa ⁶⁴	2019	Retrospective (3)	494	Electrons	8 Gy x 1 or 6 Gy x 3, Total dose 18 Gy	9%
Liu ⁷⁰	2019	Retrospective (3)	30	Electrons	4 Gy x 3 Total dose 12 Gy	13%
Hsueh ⁶⁰	2019	Retrospective (3)	47	Electrons	5 Gy x 3 - 4 fractions Total dose 15 – 20 Gy	32%
Sruthi ⁷¹	2018	Retrospective (3)	37	Electrons	5 Gy x 1 or 4 Gy x 3, Total dose 12 Gy	16%
Renz ⁷²	2018	Retrospective (3)	250	Electrons	4 Gy x 3 - 5 fractions Total dose 12 – 20 Gy	5.6% *lowest in 20 Gy group
Khalid ⁷³	2018	Prospective randomized (1)	30	Electron cohort (vs 5-fluoruracil)	5 Gy x 2 Total dose 10 Gy	57%
Hoang ⁷⁴	2017	Case-controlled (2)	264	Electron cohort (197)	3 Gy x 10 (Electron cohort)	19% (Electron cohort))
Carvajal ⁷⁵	2016	Retrospective (3)	103	Electrons	5 Gy x 3 Total dose 15 Gy	32%
Duan ¹²⁹	2015	Retrospective (3)	116	Brachytherapy Electrons	¹⁹² Ir Brachytherapy 8 Gy x 1 or 9 Gy x 3 (22) 5 Gy x 4 (22) ⁶⁰ Co Brachytherapy 5 Gy x 4 (17) 3 Gy x 6 (17) Electrons 2 Gy x 13 (18) 2 Gy x 15 (20)	12.6% 4.5% 11.7% 17.6% 33.3% 15% 12.5% if > 2 Gy per fraction 14.7% if < 2 Gy per fraction
Lee ⁵³	2015	Retrospective (3)	37	Electrons	3 - 4 Gy x 3 – 4 fractions Total dose 12-18 Gy	19%
Shen ⁶²	2015	Retrospective (3)	834	Electrons	9 Gy x 2 Total dose 18 Gy	9.6%

Song ⁷⁶	2014	Prospective nonrandomized (2)	16	Electrons	10 Gy x 1	0%
Kim ⁶³	2012	Retrospective (3)	26	Electrons	4 - 5 Gy x 3 Total dose 12-15 Gy	23%
Bischof ¹³⁰	2007	Prospective nonrandomized (2)	60	Electrons	3 – 5 Gy / fraction Total dose 12 – 18 Gy	7% total recurrence + 8% partial recurrence
Sakamoto ⁷⁷	2004	Prospective nonrandomized (2)	235	Electrons or Photons (low energy)	4 Gy x 5 Total dose 20 Gy	11%
Tsai ⁸⁶	2025	Retrospective (3)	16	Photons (low energy)	5 Gy x 2 - 3 fractions Total dose 10 – 15 Gy	0%
Li ²³	2024	Prospective Cohort (2)	123	Photons (low energy)	4 Gy x 3 Total dose 12 Gy	13.5% (auricular only)
Ramelyte ⁸⁵	2024	Retrospective (3)	104	Photons (low energy)	2 Gy x 6 Total dose 12 Gy	51.1%
Lin ⁸⁹	2020	Prospective nonrandomized (2)	11	Photons (high energy)	4.5 Gy x 3 Total dose 13.5 Gy	9%
Yang ⁸¹	2019	Prospective nonrandomized (2)	15	Photons (low energy)	4 - 5 Gy x 2 Total dose 8 – 10 Gy	0%
Jones ⁸⁷	2019	Prospective nonrandomized (2)	48	Photons (low energy)	6 Gy x 3 Total dose 18 Gy	19%
Pontoriero ⁸³	2015	Retrospective (3)	62	Photons (low energy)	4 Gy x 3 Total dose 12 Gy	16%
Mohammadi ⁸⁴	2013	Retrospective (3)	26	Photons (low energy)	3 Gy x 5 Total dose 15 Gy	0%
Speranza ⁸²	2008	Retrospective (3)	234	Photons (low energy)	3 Gy x 5 Total dose 15 Gy	59%
Malakar ⁸⁸	2004	Prospective nonrandomized (2)	47	Photons (high energy)	4 Gy x 4 Total dose 16 Gy	12%
Doornbos ¹³¹	1990	Retrospective (3)	203	Photon (low energy)	Total dose 15 Gy	90%
Kovalic ¹³²	1989	Prospective nonrandomized (2)	113	Photons (low energy)	4 Gy x 3 Total dose 12 Gy	54% size > 2 cm 15% size < 2 cm
Borok ¹³³	1988	Retrospective (3)	393	Photons (low energy)	4 Gy x 1 (11%) or 3 Gy x 3* Total dose 9 Gy (66%) or 4 Gy x 3* Total dose 12 Gy (12%) or 4 Gy x 4* Total dose 16 Gy (1%) *Fractionation Weekly (63%) 2-week interval (14%) Every other day (23%)	2.4 %
Grobien ¹³⁴	2025	Retrospective (3)	87	Brachytherapy HDR	4 – 6 Gy x 2 Total dose 8 – 12 Gy	39%
Franzetti ¹⁰¹	2024	Prospective nonrandomized (2)	135	Brachytherapy HDR	3 Gy x 4 Total dose 12 Gy	20.7%
Bhattacharya ⁶¹	2023	Retrospective (3)	50	Brachytherapy HDR	5 Gy x 4 Total dose 20 Gy	6%

Barragan ⁹⁰	2022	Retrospective (3)	61	Brachytherapy HDR	3 Gy x 4 Total dose 12 Gy	4.9%
Anderson ⁹¹	2021	Retrospective (3)	20	Brachytherapy HDR	8 Gy x 1	0%
Manjunath ⁹⁴	2021	Prospective nonrandomized (2)	71	Brachytherapy HDR	5 Gy x 3 Total dose 15 Gy	2%
Daurade ⁹⁵	2020	Retrospective (3)	67	Brachytherapy HDR	6 Gy x 3 Total dose 18 Gy	6%
Bijlard ⁹³	2018	Retrospective (3)	86	Brachytherapy HDR	9 Gy x 2 Total dose 18 Gy or 6 Gy x 3 Total dose 18 Gy or 6 Gy x 2 Total dose 12 Gy	9% total recurrence + 13% partial recurrence 3% total recurrence + 20% partial recurrence 13.5% total recurrence + 11.5% partial recurrence
Ahmad ¹⁰³	2018	Prospective nonrandomized (2)	65	Brachytherapy HDR	8 Gy x 1 or 10 Gy x 1 or 5 Gy x 3 Total dose 15 Gy or 6 Gy x 3 Total dose 18 Gy	43% 10.5% 15% 10.5%
Jiang ⁹⁹	2018	Prospective nonrandomized (2)	37	Brachytherapy HDR	6 Gy x 3 Total dose 18 Gy	8%
Taheri ¹⁰⁰	2017	Retrospective (3)	10	Brachytherapy HDR	4 Gy x 3 Total dose 12 Gy	20%
Hoang ⁷⁴	2017	Case-controlled (2)	264	Brachytherapy HDR cohort (23)	9 Gy x 1	23%
Jiang ¹⁰²	2016	Prospective nonrandomized (2)	32	Brachytherapy HDR	6 Gy x 3 Total dose 18 Gy	6%
van Leeuwen ⁹⁸	2014	Prospective nonrandomized (2)	67	Brachytherapy HDR	6 Gy x 2 Total dose 12 Gy	3%
De Cicco ⁹⁶	2014	Retrospective (3)	96	Brachytherapy LDR 46 HDR 50	LDR 16 – 18 Gy HDR 3 Gy x 3-4 fractions Total dose 9 -12 Gy	30% LDR 38% HDR
Kuribayashi ¹⁰⁴	2011	Prospective nonrandomized (2)	36	Brachytherapy HDR	5 Gy x 3 - 4 fractions Total dose 15 – 20 Gy	9.7%
Arnault ¹⁰⁵	2009	Retrospective (3)	82	Brachytherapy LDR	LDR 17.9 Gy	24%
Viani ¹³⁵	2009	Retrospective (3)	892	Brachytherapy HDR	2 Gy x 10 Total dose 20 Gy	12.4%
Arneja ⁹⁷	2008	Retrospective (3)	25	Brachytherapy HDR	5 Gy x 3 Total dose 15 Gy	8%
Guix ¹¹²	2001	Prospective nonrandomized (2)	159	Brachytherapy HDR	3 Gy x 4 Total dose 12 Gy	4.7%
Wagner ¹³⁶	2000	Retrospective (3)	166	Brachytherapy	Median dose 14 Gy (7.5 – 28.5 Gy)	2% face/neck 49% thorax
Escarmant ¹³⁷	1993	Retrospective (3)	855	Brachytherapy HDR	NR	21%

Abbreviations:

Gy: Gray
NR: Not reported
LDR: Low-dose rate
HDR: High-dose rate

Study Quality Category Definitions:

Category 1 The study is well-designed and accounts for common biases.
Category 2 The study is moderately well-designed and accounts for most common biases.
Category 3 There are important study design limitations.
Category M Meta-analysis

Table 2. Variant 1: Earlobe Keloid Following Piercing

A 23 year-old male presents 2 months after ear piercing with a 1.4 cm raised keloid involving both the anterior and posterior aspects of the helical rim of the ear. The lesion is asymptomatic, without associated pain or pruritus, but is of cosmetic concern. The patient has not received any prior therapy.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
Surgery alone	M	0	1	1	9	0	0	0	0	0	4		S	↑
RT alone	U	5	5	1	0	0	0	0	0	0	2		S	↑
Surgery + adjuvant electron beam RT	A	0	0	0	0	0	0	9	2	0	7		S	↑
Surgery + adjuvant kV photon RT	A	0	0	0	0	0	1	9	1	0	7		S	↑
Surgery + adjuvant MV photon RT		0	1	0	9	1	0	0	0	0	4	X	S	↓
Surgery + BT (superficial applicator)		0	0	0	0	1	3	6	1	0	7	X	S	↓

Variant Discussion:

A conservative approach with initial non-surgical management including intralesional steroids should be discussed in this case. Specifically, for an adolescent patient there may be an increased risk of RT-induced malignancy, although supporting data is lacking. This panel recommends extreme caution when considering RT for recurrent keloid prevention in an adolescent or young adult in the absence of compelling reasons. Surgical resection alone is associated with high rates of recurrence. Surgical resection with adjuvant kV photon RT or electron beam RT would be appropriate treatment approaches. Superficial voltage is preferred for superficial resected target volumes. Brachytherapy delivered with superficial surface applicators can also be considered. Higher energy MV photon therapy should be avoided given increased exposure of deeper tissues.

Adjuvant RT is typically delivered over 2 to 5 fractions and completed within 1 week of surgery. RT may be delivered daily or every other day. The first dose of adjuvant RT should be performed as soon as possible after surgical excision, ideally within 24 hours. For external beam RT, various dose fractionations are appropriate with goal to achieve BED ≥ 30 Gy (α/β ratio = 10) delivered with examples including 16 Gy in 2 fractions or 18 Gy in 3 fractions, for example. The RT field should cover the entire scar plus a 1 cm radial margin, typically with 0.5-1 cm depth, depending on surgical excision. For HDR BT, (BED) ≥ 20 Gy is recommended prescribed to 0.5 cm in fractionated treatments with example including 12 Gy in 2 fractions. For external beam treatments, clinical set up is typically used for superficial treatments. CT simulation with 3-dimensional treatment planning can be considered for larger or deeper lesions or those located on curved surfaces to ensure adequate dosimetric coverage. CT simulation is recommended when treating with brachytherapy.

- When utilizing electron beam RT, typically energies of 4–20 MeV can be used depending on desired treatment depth. Skin collimation or shielding can be utilized to limit exposure outside targeted tissue. When using electron beam therapy, a wider margin is required to adequate dosimetric coverage of depth (compared to kV photon treatment). Bolus should be utilized with thickness dependent on depth of target and energy utilized.
- When utilizing kV photon RT, typically energies of 50 – 500 kVp can be used depending on desired treatment depth; skin collimation can be utilized to limit exposure outside targeted tissue. Superficial voltage preferred for superficial targets. Bolus is not recommended.

Table 3. Variant 2: Chest Keloid Following Sternotomy

A 56 year-old female presents with a 12 x 6 x 2 cm raised keloid of the anterior chest wall, developing 3 months after median sternotomy for cardiac surgery. The lesion has been refractory to 6 months of intralesional corticosteroid injections and laser therapy. It is associated with progressive enlargement, skin tightness, and pain.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
Surgery alone	U	0	2	8	1	0	0	0	0				S	↑
RT alone	U	1	6	3	1	0	0	0	0				S	↑
Surgery + adjuvant electron beam RT	A	0	0	0	0	0	0	10	1				S	↑
Surgery + adjuvant kV photon RT	A	0	0	0	0	0	1	9	1				S	↑
Surgery + adjuvant MV photon RT	M	0	0	0	0	3	6	2	0				S	↑
Surgery + BT (superficial applicator)	A	0	0	0	0	0	1	7	3				S	↑

Variant Discussion:

Following attempted conservative management with intralesional steroids and laser therapy, surgical resection with adjuvant RT would be appropriate. Superficial voltage is preferred for superficial target volumes following resection. Surgical resection alone is associated with high rates of recurrence. RT alone would not be appropriate.

Special considerations for RT technique:

- Size of clinical target area, whether target can be encompassed within a single field
- Choice of energy should consider depth of clinical target and underlying organs at risk. Higher energy en face MV photon therapy should be avoided given increased exposure of deeper tissues
- Location, including body contour at clinical target area, and if high-quality dosimetry is feasible with chosen technique
- CT simulation is recommended in this case to assess depth of target, body contour and dose to underlying organs (heart/lung)
- Dose fractionation should be chosen to minimize potential toxicity to underlying organs

Table 4. Variant 3: Abdominal Keloid Following Caesarian Section

A 22 year-old female presents with a 10 x 4 x 1 cm raised keloid of the lower abdomen, arising 2 months after caesarian section. The lesion has been refractory to 3 months of intralesional corticosteroids and laser therapy. It is symptomatic, with associated pruritus and tenderness.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
Surgery alone	U	2	2	7	0	0	0	0	0	0	3		S	↑
RT alone	U	3	7	1	0	0	0	0	0	0	2		S	↑
Surgery + adjuvant electron beam RT	A	0	0	0	1	0	1	9	0	0	7		S	↑
Surgery + adjuvant kV photon RT	A	0	0	0	1	0	1	9	0	0	7		S	↑
Surgery + adjuvant MV photon RT	M	0	0	1	5	4	1	0	0	0	4		S	↑
Surgery + BT (superficial applicator)	A	0	0	0	1	0	1	9	0	0	7		S	↑

Variant Discussion:

In a patient with symptomatic keloid refractory to conservative management, surgical resection and adjuvant therapy is appropriate. Superficial voltage is preferred for superficial target volumes following resection. Surgical resection alone is associated with high rates of recurrence.

In younger patients there may be an increased risk of RT-induced malignancy, although supporting data is lacking.

Pregnancy test and contraception counseling should be performed in a premenopausal female.

Special considerations for RT technique:

- Size of clinical target area, whether target can be encompassed within a single field
- Choice of energy should consider depth of clinical target and underlying organs at risk. In this case dose to ovaries should be considered. Higher energy en face MV photon therapy should be avoided given increased exposure of deeper tissues.
- Location, including body contour at clinical target area, and if high-quality dosimetry is feasible with chosen technique
- CT simulation is recommended in this case to assess depth of target, body contour and dose to underlying organs
- Dose fractionation should be chosen to minimize potential toxicity to underlying organs

Table 5. Variant 4: Multiple Hypertrophic Scars in a Burn Victim

A 28 year-old male presents with multiple disfiguring hypertrophic scars of varying size involving the face, chest, and back, which developed approximately 1 year following a severe burn injury affecting 80% of the total body surface area. The lesions have been refractory to prior treatment with topical therapies, intralesional corticosteroid injections, and laser therapy. The patient reports significant psychosocial distress, including symptoms of depression and social withdrawal related to the cosmetic disfigurement.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
Surgery alone	U	0	4	5	1	0	0	1	0	0	3		S	↑
RT alone	U	0	2	8	0	0	0	0	0	0	3		S	↑
Surgery + adjuvant electron beam RT	A	0	0	0	0	1	1	9	0	0	7		S	↑
Surgery + adjuvant kV photon RT		0	0	0	0	1	2	8	0	0	7	X	S	↓
Surgery + adjuvant MV photon RT	A	1	0	0	0	0	0	10	0	0	7		S	↑
Surgery + BT (superficial applicator)	A	0	0	0	0	1	1	9	0	0	7		S	↑

Variant Discussion:

A multidisciplinary approach should be taken to optimize treatment management.

Given the diffuse nature of the keloids involving multiple regions of the body, a staged surgical treatment approach is likely necessary. Surgical resection followed by adjuvant RT is appropriate. Superficial voltage is preferred for superficial target volumes following resection. Surgical resection alone is associated with high rates of recurrence.

Special considerations for RT technique:

- In this case, there are likely wide variations in clinical target parameters and adjuvant RT may include multiple RT modalities and techniques
- Special consideration may be necessary to avoid overlap given multiple treatment fields
- Choice of energy should consider depth of clinical target(s) and underlying organs at risk
- Location, including body contour at clinical target area(s), and if high-quality dosimetry is feasible with chosen technique
- CT simulation may be used in this case to assess depth of target(s), body contour and dose to underlying organs
- Dose fractionation should be chosen to minimize potential toxicity to underlying organs

Table 6. Variant 5: Prevention of Keloid Formation After Trauma in a Patient Deemed High Risk for Keloid Development

A 35 year-old African American male with a known history of keloid formation following tattooing presents after sustaining a traumatic facial laceration, for which he undergoes plastic surgical repair. He expresses concern regarding cosmesis should keloid develop on his face.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
Surgery alone	A	0	0	1	0	0	0	7	3	0	7		M	↑
Surgery + adjuvant kV photon RT	M	0	0	1	6	3	0	1	0	0	4		M	-
Surgery + adjuvant electron beam RT	M	0	0	1	6	3	0	1	0	0	4		M	-
Surgery + BT (superficial applicator)	U	0	3	6	0	1	1	0	0	0	3		M	↑

Variant Discussion:

Limited data exists regarding the use of prophylactic RT following surgery in a patient deemed high risk for keloid development. While prophylactic RT is generally not recommended due to paucity of data, prophylactic RT can be considered in unique clinical situations in which the morbidity of keloid formation requiring subsequent resection significantly outweighs the potential risks of ionizing RT exposure. If prophylactic treatment is pursued, RT techniques including dose and fractionation would follow recommendations for RT used in the adjuvant setting.

Table 7. Variant 6: Multiple Keloids in a Patient Unable Undergo Surgery

A 46 year-old female presents with diffuse, painful keloids of varying size involving the majority of the trunk surface area. The lesions have been refractory to 6 months of treatment with intralesional injections, cryotherapy, and laser therapy. Multidisciplinary evaluation by dermatology and plastic surgery determined that surgical excision is not feasible given the extensive surface area of involvement.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
Electron beam RT	M	0	0	0	0	1	8	2	0	0	6		M	-
kV photon RT	M	0	0	0	0	1	8	2	0	0	6		M	-
MV photon RT	M	0	0	0	1	4	5	1	0	0	6		M	-
BT (superficial applicator)	M	0	0	0	0	1	8	2	0	0	6		M	-

Variant Discussion:

In patients with symptomatic unresectable keloids refractory to other therapies, definitive RT can be used with the intention of symptomatic relief, scar regression, and improvement in cosmesis as shown in small series. Various external beam dose fractionation schemes have been used including 37.5 Gy in 5 fractions once weekly, 24 Gy in 3 fractions daily, 25 Gy in 5 fractions daily, and 30 Gy in 6 fractions daily. HDR BT utilizing 18 Gy over 6 fractions TID over 1.5 days has also been reported.

Table 8. Variant 7: Recurrent Keloid Following Prior Excision and Adjuvant RT

A 30 year-old female with a history of earlobe keloid previously treated with surgical excision and adjuvant electron beam RT treatment presents with a 1.5 cm local recurrence arising 3 years after initial treatment. The lesion has been refractory to subsequent management with intralesional injections, cryotherapy, and laser therapy. She reports associated pain and dissatisfaction with cosmetic appearance.

Treatment	Rating Category	Final Tabulations									Group Median Rating	Disagree	SOE	SOR
		1	2	3	4	5	6	7	8	9				
Surgery alone	M	0	0	0	9	1	1	0	0	0	4		M	EC
Surgery + adjuvant electron beam re-RT	M	0	0	0	0	3	7	1	0	0	6		L	EC
Surgery + adjuvant kV photon re-RT	M	0	0	0	0	3	7	1	0	0	6		L	EC
Surgery + adjuvant MV photon re-RT	M	0	0	0	4	3	4	0	0	0	5		L	EC
Surgery + BT (superficial applicator)	M	0	0	0	0	3	7	0	1	0	6		L	EC

Variant Discussion:

Limited data has been published on the outcomes of adjuvant re-irradiation for recurrent keloids. For patients with symptomatic recurrent keloids refractory to conservative therapy, re-resection followed by adjuvant RT would be an appropriate treatment option given the high risk of recurrence. If adjuvant re-irradiation treatment is pursued, RT techniques including dose and fractionation would be similar to RT used in the adjuvant setting, with consideration for dose escalation and reassessment of RT modality, dosimetry, and treatment field.

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

Abbreviation Key:

RT: radiotherapy

MV: megavoltage

BT: brachytherapy

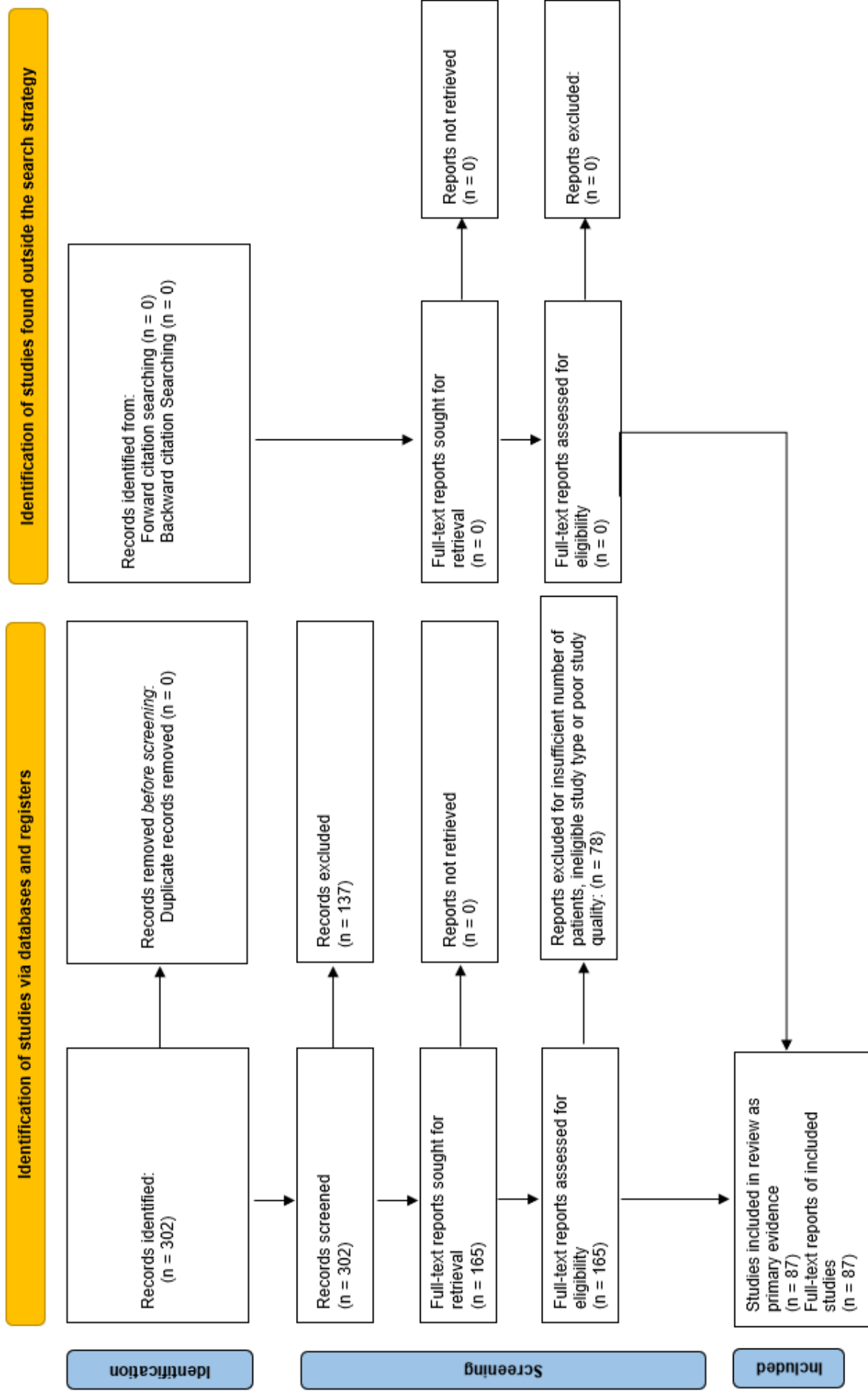
Appendix A: ARS AUC for Adjuvant Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids

Performed on 05/05/2026

Embase, Medline (PubMed), PubMed Central, Scopus, Web of Science

Search	Query	Results
#5	Search: (("Cicatrix, Hypertrophic/radiotherapy"[Mesh])) OR "Keloid/radiotherapy"[Mesh] Filters: English, Humans, MEDLINE, from 1980/1/1 - 2026/4/22 Sort by: Most Recent	302
#4	Search: (("Cicatrix, Hypertrophic/radiotherapy"[Mesh])) OR "Keloid/radiotherapy"[Mesh] Filters: Humans, MEDLINE, from 1980/1/1 - 2026/4/22 Sort by: Most Recent	347
#3	Search: (("Cicatrix, Hypertrophic/radiotherapy"[Mesh])) OR "Keloid/radiotherapy"[Mesh] Filters: MEDLINE, from 1980/1/1 - 2026/4/22 Sort by: Most Recent	354
#2	Search: (("Cicatrix, Hypertrophic/radiotherapy"[Mesh])) OR "Keloid/radiotherapy"[Mesh] Filters: from 1980/1/1 - 2026/4/22 Sort by: Most Recent	354
#1	Search: (("Cicatrix, Hypertrophic/radiotherapy"[Mesh])) OR "Keloid/radiotherapy"[Mesh] Sort by: Most Recent	412

Appendix B: PRISMA 2020 Study Selection Flow Diagram for Adjuvant Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids





Appendix D: PRISMA 2020 Checklist for Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids

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			
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			
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 Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids

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 1-7 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 1-7 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 Radiotherapy for the Prevention of Recurrent Hypertrophic Scars/Keloids

Section and Topic	Item #	Checklist item	Location where item is reported
OTHER INFORMATION			
Registration and protocol	23d	Discuss implications of the results for practice, policy, and future research.	N/A
	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.americanradiumsociety.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/"}