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RADIATION DERMATITIS—CLINICAL MANIFESTATIONS AND TREATMENT. AN ANALYSIS OF CURRENT RESEARCH

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ABSTRACT

Introduction: Radiation-induced skin injury is a frequent adverse effect of radiotherapy, ranging from early erythema and desquamation to chronic fibrosis, pigment alteration, and telangiectasia. These reactions can reduce patient comfort, impair daily activities, and occasionally limit delivery of optimal cancer therapy. This review outlines current knowledge on mechanisms, prevention, and management of radiation-induced skin injury, including pharmacological, physical, and supportive strategies.
Methodology: A targeted literature search was performed in a medical research database using terms related to radiation, radiotherapy, and management of skin reactions. Recent clinical trials, observational studies, and systematic reviews meeting inclusion criteria were analyzed to identify prevailing preventive and therapeutic approaches.
Results: Skin injury results from DNA damage, inflammatory signaling, and oxidative stress affecting normal skin cells. Acute reactions typically occur within three months of exposure, whereas chronic changes may persist for years. Key risk factors include high radiation dose, sensitive anatomical sites such as thin or folded skin, and concurrent systemic cancer therapies. Evidence supports preventive measures including gentle cleansing, routine moisturization, topical corticosteroids, protective barrier films, and optimized radiation planning. Adjunctive treatments such as hyperbaric oxygen therapy, silver-based dressings, botanical products, and vitamin-based agents show potential benefit, although current evidence is limited by small sample sizes and methodological variability.
Conclusion: Radiation-induced skin injury remains a clinical problem. Multimodal management combining standardized skin care, targeted pharmacologic treatments, and supportive interventions may reduce severity and improve patient outcomes. Further studies are required to define evidence-based management guidelines.

KEYWORDS

Radiation, Radiotherapy, Radiation Dermatitis, Radiotherapy-Induced Skin Injury

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Introduction

One of the side effects of radiation therapy is radiation-induced skin injury. (RISI). [1]. Radiation is not just killing tumor cells but also damaging healthy tissue cells in the irradiation field. Nearly 85%–95% of patients experienced moderate-to-severe skin responses, which significantly lowered their quality of life and negatively impacted their ability to treat their illness. [2].

Skin is the largest organ of the human body and performs the main role as the primary barrier against external pathogens. [3]. Wound healing normally proceeds via four stages: hemostasis, inflammation, proliferation, and remodeling. Radioactive skin lesions cause damage to DNA and increase the generation of reactive oxygen species (ROS), which can lead to chromosomal aberrations, infertility, secondary cancers, and damage of internal organs. [3,4] The exposed skin frequently experiences a severe local inflammatory reaction within 2 to 7 days after receiving a cumulative radiation dosage greater than 10 Gy. A second phase of severe erythema with edema and vesiculation starts one week after exposure and lasts up to one month after the reaction peaks at 48 hours and then fades. [5]

There are two types of RISI: acute and chronic. Acute RISI (aRISI) is the first 90 days of skin damage during radiation treatment and presents as edema, dry or wet desquamation, erythema, and changes in pigmentation. Chronic RISI can manifest months to years post treatment and includes dyspigmentation, xerosis, telangiectasia, alopecia, fibrosis, ulcers, skin hypersensitivity, and radiation-induced morphea (RIM). Chronic RISI does not directly affect the efficacy of radiotherapy but can greatly impact a patient's quality of life. Numerous factors affect the risk and severity of RISI—treatment in anatomically sensitive locations like the head, neck, breast, and axilla that have thin skin or skin folds, higher radiation dose per fraction, concurrent chemotherapy or immunotherapy, and greater cumulative doses. [4]

RISI can be prevented and treated with plenty of medications and accessible dressings, which include corticosteroids, hyaluronic acid, triethanolamine, water-based cream, aloe, and calendula cream. The main problem in the treatment of RISI is the lack of large-scale, high-quality studies and universal standards. Methods of therapy often depend on personal experience. [1]

Methodology

During the process of conducting a review of the literature, we used PubMed as the main source of data. Searching included combinations of key words: "radiation," "radiotherapy," "radiation dermatitis," "radiotherapy-induced skin injury." Only articles whose abstracts met the study's assumptions were included for further analysis. Finally, the following were qualified for review: 30 articles published in the years 2017-2025.

Results

Clinical manifestations

RISI is classified into two types: acute and chronic. The severity of these injuries can also be categorized into other sections, which help with the creation and execution of suitable treatment strategies. The National Cancer Institute Common Terminology Criteria for Adverse Events (NCI CTCAE) version 3.0 classifies acute radiation-induced skin damage into five grades from 0 to IV. Table 1 displays the specific skin damage and its symptoms. [3] Skin hypersensitivity, dyspigmentation, xerosis, telangiectasia, alopecia, fibrosis, ulcers, and radiation-induced morphea (RIM) are some of the signs of chronic RISI, which might manifest months to years after treatment. Radiation-induced tissue fibrosis leads to irreversible tissue and organ damage, which also includes healthy tissue around the tumor. This chronic side effect of radiation is limiting options for radiotherapy frequency and dose. [4,6] The American Cancer Radiation Therapy Association Group formed criteria for grading chronic radiation dermatitis. According to these guidelines, the condition is usually divided into six categories, ranging from 0 to V degrees. (table 2). [3]

Table 1. Acute radiation dermatitis Grading System

Damage Grade	G0	G1	G2	G3	G4
Skin changes	No change	Erythema, dry desquamation	Moderate erythema or edema, patchy moist desquamation	Moist desquamation or pitted edema in areas other than skin folds	Full thickness skin necrosis or ulceration

Table 2. Chronic radiation dermatitis grading system

Damage Grade	G0	G1	G2	G3	G4	G5
Skin changes	No change	Mild atrophy, hyperpigmentation, mild hair loss	Complete hair exfoliation, moderate capillary dilatation, lamellar atrophy	Marked atrophy, marked telangiectasia	Ulceration	Death

Prevention

Prevention of radiation dermatitis (RD) involves a multifaceted approach starting before radiotherapy and continuing throughout treatment. Proactive skin care, including the use of gentle cleansers and regular application of emollient creams from the beginning of radiotherapy, helps maintain skin barrier function and reduces the severity of skin reactions such as erythema and desquamation [2,7]. Topical corticosteroids, including mometasone furoate or betamethasone, have been shown to decrease the incidence and severity of acute RD, likely due to their anti-inflammatory properties [8]. Non-steroidal agents have demonstrated significant efficacy in lowering the risk of high-grade dermatitis in breast cancer patients, whereas trolamine and hyaluronic acid show inconsistent benefits [9]. Physical barrier methods, particularly film-based dressings,

provide a moist protective environment and prevent severe RD more effectively than standard care [7,10]. Additionally, clinical guidelines emphasize patient education, weekly skin assessments, and careful radiation planning to minimize skin toxicity [2].

Skin care and washing

Prevention and management of skin care during radiotherapy emphasize gentle daily washing, as emerging evidence supports its protective role. A recent meta-analysis showed that washing the irradiated skin, with or without soap, significantly reduced the risk of severe radiation dermatitis and moist desquamation (odds ratio [OR] 0.32 and OR 0.25, respectively) compared to no washing and was associated with improved quality of life for patients [11]. Randomized controlled trials in nasopharyngeal cancer patients likewise demonstrated that washing with water alone, or water plus mild soap, lowered the incidence of grade 2–3 dermatitis, delayed its onset, reduced moist desquamation, and relieved itching, without increasing pain [12]. Clinical practice guidelines from the Oncology Nursing Society (ONS) strongly recommend a standard washing and skin care regimen, using lukewarm water and gentle cleansers, over more experimental topical, nonsteroidal agents in patients without dermatitis symptoms [13]. Furthermore, consensus-based recommendations advocate for daily washing, preferably with lukewarm water, gentle drying, and the use of mild, fragrance-free soaps; they also discourage aggressive scrubbing or use of harsh irritants [14]. These skin hygiene strategies help maintain the skin barrier, reduce frictional trauma, and ultimately minimize the severity of radiation-induced skin toxicity.

Hyperbaric oxygen therapy

Hyperbaric oxygen therapy (HBOT) has gained attention as a supportive treatment for radiation-induced skin injury, including chronic radiation dermatitis and fibrosis. Recent evidence shows that HBOT may improve tissue quality and enhance healing of irradiated skin. A pilot study in breast cancer survivors reported that a course of HBOT (average 43 sessions at 243 kPa) significantly increased skin elasticity and reduced radiation-related fibrosis, suggesting partial reversibility of late tissue damage [15]. Similarly, clinical observations indicated that HBOT facilitated healing of chronic radiation lesions, reducing necrosis and ulceration in patients treated for various malignancies [16]. Moreover, a systematic review of late radiation toxicity in breast cancer found that HBOT improved several skin-related outcomes, including pain and wound healing, although the overall evidence quality remained limited due to small sample sizes and methodological heterogeneity [17]. While robust randomized trials are still lacking, current findings suggest that HBOT is a safe and biologically plausible adjunctive therapy that may ameliorate radiation-induced skin injury and enhance patient quality of life.

Herbal options

Studies have explored the potential of herbal treatments to prevent or alleviate radiation dermatitis in patients undergoing radiotherapy. A randomized controlled trial assessed an herbal gel applied prophylactically, finding that it significantly reduced patient-reported symptoms such as itching, burning, and pain, even though it did not lower the overall incidence of dermatitis [14]. A systematic review and meta-analysis found that topical Chinese herbal medicine (TCHM) significantly reduced the severity of radiodermatitis, especially higher-grade lesions, supporting its use as a preventative strategy [18]. Another clinical trial evaluated three herbal creams containing extracts of Centella asiatica, cucumber (Cucumis sativus), and Thunbergia laurifolia; although these formulations did not prevent acute skin reactions versus no treatment, cucumber cream was shown to aid in faster recovery of skin integrity in the post-radiation period [19]. Additionally, a recent experimental study demonstrated that ozonated aloe vera oil promoted healing of radiation-induced skin injury, likely via its antioxidant and anti-inflammatory effects [20]. Collectively, these findings suggest that herbal and phytochemical therapies may offer a safe, complementary approach to managing radiation-induced skin toxicity, though larger and more rigorous trials are needed to confirm their clinical efficacy and establish standardized formulations.

Vitamins

Emerging evidence suggests that specific vitamins may play a role in mitigating radiation-induced skin toxicity in patients undergoing radiotherapy. High-dose vitamin D has been reported in case-based and observational data to reduce pain, erythema, and desquamation in acute radiation dermatitis. A case report conducted in 2023 described two patients receiving 100,000 IU of ergocalciferol weekly who experienced marked symptomatic relief. [21] Vitamin D has known roles in keratinocyte differentiation, barrier repair, immune modulation, and anti-inflammatory responses, making it a biologically plausible intervention for irradiated skin. [22] Although randomized controlled trials remain scarce, early formulations of vitamin D-enriched topical lotions in breast cancer radiotherapy settings show promise in reducing dermatitis severity and improving skin condition. [23] Nonetheless, dosing strategies, long-term effects, and comparative efficacy versus standard skin care remain poorly characterized. Consequently, vitamins such as vitamin D represent accessible adjunctive options for radiation dermatitis but require rigorous clinical trials to establish optimal regimen, safety, and impact on clinical outcomes.

Endogenous agents

Endogenous cytokines and immunoregulatory molecules have been highlighted as promising therapeutic strategies for radiation-induced skin injury. In particular, interleukin-10 (IL-10) has been shown to attenuate radiation dermatitis. A fusion IL-10 protein reduced reactive oxygen species, preserved mitochondrial and endoplasmic reticulum integrity in irradiated keratinocytes, and significantly decreased skin fibrosis in a mouse model of radiation injury. [24] IL-10's anti-inflammatory and antioxidant effects make it a biologically plausible candidate for mitigating both acute and chronic dermal damage. Additionally, emerging reviews of radiation dermatitis pathogenesis emphasize the role of keratinocyte senescence and the senescence-associated secretory phenotype (SASP), whereby stressed skin cells secrete chemokines and cytokines that propagate inflammation. [25] According to Rübe et al., these secreted mediators may amplify immune recruitment and exacerbate inflammatory skin injury after irradiation, suggesting that modulation of endogenous immune signaling could restore barrier function. [25] Given the complex immunological changes in irradiated skin, harnessing or supplementing endogenous factors such as IL-10 may provide a more targeted and physiologically congruent approach to ameliorate radiation dermatitis, although translation to clinical use will require careful dose optimization and safety evaluation.

Pharmaceuticals

Pharmaceutical interventions have increasingly been investigated for managing radiation dermatitis, with topical corticosteroids being the most studied class. In a phase III randomized trial among head and neck cancer patients, once-daily 0.1% betamethasone valerate cream significantly reduced the incidence of ≥ grade 2 dermatitis compared to standard care (33.3% vs. 50.7%, $p = 0.032$) [24]. A systematic review and meta-analysis of randomized trials confirmed that topical steroids, including betamethasone and mometasone, lower the risk of higher-grade radiation skin reactions, particularly moist desquamation (relative risk reduction reported) [25,26]. Further, more recent meta-analyses in breast cancer populations showed that topical corticosteroids decrease the likelihood of moist desquamation and grade ≥2 dermatitis and improve patient-reported symptom scores (e.g., erythema, pain) [27]. In addition to steroids, other pharmaceuticals such as topical phenytoin have shown promise: a double-blind RCT comparing topical phenytoin versus placebo in breast cancer patients reported reduced severity of acute radiation dermatitis in the treatment arm [28]. Together, these data suggest that pharmaceutical agents, particularly potent topical steroids and selected skin-directed medications, offer a clinically relevant strategy to mitigate radiation-induced skin toxicity, though optimal timing, dosing, and comparative efficacy remain areas for further investigation.

Metallic ointments and dressings SSD

The role of silver-based therapies, such as silver sulfadiazine (SSD), has been confirmed in managing radiation-induced skin toxicity. A network meta-analysis compared 19 interventions and found that SSD remains a commonly used metallic intervention, although other barrier and dressing options ranked more favorably for preventing severe dermatitis. [29] A comprehensive literature review highlighted that semipermeable dressings with antimicrobial properties, including silver dressings, may aid in both the prevention and treatment of acute radiation dermatitis by maintaining a moist environment and reducing bacterial colonization. [7] Clinical nursing guidelines from 2020 also continue to endorse SSD as a standard-of-care option for treatment of moist desquamation, despite the low certainty of evidence, indicating that silver-

based ointments are still integrated into supportive skin care protocols. [30] Taken together, these data suggest that metallic agents, particularly silver in cream or dressing form, offer a biologically plausible and clinically utilized adjunct for radiation dermatitis, but high-quality randomized trials comparing silver dressings to modern film dressings are still needed to establish their relative effectiveness.

Discussion

Radiation-induced skin injury remains a prevalent and clinically significant complication of radiotherapy, affecting the majority of patients and often influencing both quality of life and treatment adherence. The findings summarized in this review confirm that RISI is a multifactorial condition driven by direct DNA damage, oxidative stress, inflammatory cascades, immune dysregulation, and long-term alterations in skin structure and function. These mechanisms explain the broad clinical spectrum ranging from erythema to fibrosis, ulceration, and functional impairment.

Consistent with previous literature, this review highlights that preventive strategies are more effective than reactive treatment alone. Basic skin care measures, gentle washing and moisturization are now strongly supported by recent meta-analyses and clinical guidelines. The evidence that routine washing reduces the incidence of severe dermatitis challenges outdated recommendations that discouraged skin cleansing and underscores the importance of maintaining barrier integrity during radiotherapy. Patient education and regular skin assessment remain critical components of prevention, especially in high-risk anatomical areas.

Among pharmacological interventions, topical corticosteroids emerge as the most consistently supported therapy for preventing and reducing the severity of acute radiation dermatitis. Multiple randomized trials and meta-analyses demonstrate their efficacy in lowering rates of grade ≥2 dermatitis and moist desquamation, particularly in breast and head-and-neck cancer populations. Nevertheless, uncertainty persists regarding optimal potency, duration, and timing of steroid use, highlighting the need for standardized protocols to balance efficacy with long-term safety.

Adjunctive and supportive therapies—including barrier films, silver-based dressings, and modern wound care products—play an important role, particularly in managing moist desquamation. While silver sulfadiazine remains widely used in clinical practice, emerging evidence suggests that advanced film dressings may offer superior protection and improve patient comfort. However, heterogeneity in study designs limits direct comparison between dressing types.

More novel approaches, such as hyperbaric oxygen therapy, endogenous cytokine modulation, vitamin supplementation, and herbal preparations, demonstrate promising biological plausibility and preliminary clinical benefit, particularly in chronic radiation-induced skin injury. HBOT, in particular, shows potential in improving tissue elasticity and reversing aspects of radiation fibrosis, though its accessibility and cost may restrict widespread use. Similarly, vitamin D and herbal therapies appear safe and accessible but remain supported primarily by small trials and observational data. These modalities should therefore be considered complementary rather than first-line therapies until stronger evidence becomes available.

A recurring limitation across nearly all therapeutic categories is the lack of large, well-powered randomized controlled trials and standardized outcome measures. Variability in grading systems, patient populations, radiation techniques, and concurrent systemic therapies complicates interpretation and limits the development of universal guidelines. Additionally, most studies focus on acute dermatitis, while chronic radiation-induced skin injury—despite its long-term impact—remains underrepresented in clinical research.

Overall, the evidence supports a multimodal, individualized approach to radiation dermatitis that integrates standardized skin care, evidence-based pharmacologic prevention, and selected adjunctive therapies based on patient risk factors and clinical presentation. Future research should prioritize high-quality comparative trials, long-term follow-up of chronic skin toxicity, and mechanistically driven therapies targeting inflammation, fibrosis, and immune dysregulation. Establishing consensus-based, evidence-driven clinical pathways will be essential to improving outcomes for patients undergoing radiotherapy.

Conclusions

Radiation-induced skin injury remains one of the most common and challenging side effects of radiotherapy, affecting the majority of patients and significantly impacting their comfort and quality of life. Current evidence shows that RISI results from complex biological processes involving DNA damage, oxidative stress, inflammation, and alterations in the skin microbiome, leading to a spectrum of acute and chronic clinical manifestations.

Current preventive and therapeutic strategies—such as standardized skin care, topical corticosteroids, barrier films and dressings, vitamins, herbal options, hyperbaric oxygen therapy, and emerging biologic agents—show varying degrees of effectiveness. However, the lack of consistent treatment guidelines and the variety of study designs restrict the evidence that is currently available.

To develop evidence-based, standardized management strategies, more high-quality randomized controlled trials are required due to the high prevalence and clinical significance of RISI. Until such guidelines are available, a multimodal, individualized approach remains essential for mitigating skin damage and improving outcomes in patients undergoing radiotherapy.

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