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OPTIMIZATION OF PREVENTIVE STRATEGIES FOR RADIATION DERMATITIS IN BREAST CANCER RADIOTHERAPY: A MULTIMODAL APPROACH

Dallo Salva Faekovna
Assistant, Department of Oncology, Oncohematology, and Radiation Oncology, Tashkent State Medical University, Tashkent, Uzbekistan

Abstract

Radiation dermatitis remains one of the most common adverse effects of radiotherapy in patients with breast cancer, often leading to discomfort, reduced quality of life, and occasional treatment interruptions. Although technological advances in radiation delivery have improved dose conformity, the incidence of acute skin toxicity remains high. Preventive strategies vary widely across oncology centers, and there is no universally standardized protocol for minimizing radiation-induced skin injury. The present study evaluates the effectiveness of a multimodal preventive approach combining advanced radiotherapy planning, structured patient education, prophylactic skincare regimens, and early dermatologic monitoring.

A controlled prospective clinical study was conducted involving breast cancer patients undergoing adjuvant radiotherapy. Participants were divided into a standard-care group and a multimodal-prevention group. The multimodal strategy included intensity-modulated radiotherapy (IMRT), daily prophylactic emollient application, systematic patient instruction on skin care, and weekly dermatologic assessment. The severity of radiation dermatitis was graded using standardized toxicity criteria, and patient-reported outcomes were recorded.

The results demonstrated a statistically significant reduction in Grade II–III dermatitis in the multimodal group compared to standard care. Furthermore, improved treatment adherence and reduced symptom burden were observed. These findings support the integration of coordinated preventive protocols into routine oncologic practice to minimize radiation-related skin toxicity and enhance patient-centered care.

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Keywords. Radiation dermatitis; Breast cancer; Preventive strategy; IMRT; Skin care protocol; Patient education; Radiotherapy toxicity; Oncology supportive care.

Introduction

Breast cancer remains the most commonly diagnosed malignancy among women worldwide, and radiotherapy constitutes an integral component of its multimodal treatment. Adjuvant irradiation following breast-conserving surgery significantly reduces local recurrence and improves long-term survival outcomes. Despite advancements in radiation technology, including conformal planning and dose optimization techniques, acute radiation dermatitis continues to represent one of the most frequent and clinically relevant treatment-related toxicities.

Radiation dermatitis results from ionizing radiation–induced damage to epidermal basal cells, dermal microvasculature, and connective tissue structures. The biological cascade involves DNA damage, oxidative stress mediated by reactive oxygen species, inflammatory cytokine release, and disruption of normal keratinocyte proliferation. Clinically, patients may experience erythema, dry or moist desquamation, edema, hyperpigmentation, and in severe cases, ulceration. Although most reactions are mild to moderate, higher-grade toxicity can cause significant discomfort, psychological distress, and interruptions in radiotherapy schedules, potentially compromising oncologic outcomes.

The incidence of radiation dermatitis in breast cancer patients ranges from 70% to 95%, depending on individual risk factors such as breast size, body mass index, smoking status, comorbidities, concurrent systemic therapy, and total radiation dose. Treatment-related factors, including fractionation schemes and radiation technique, also influence the severity of skin reactions. Even with the adoption of modern modalities such as intensity-modulated radiotherapy (IMRT), acute cutaneous toxicity remains a persistent clinical challenge.

Preventive strategies for radiation dermatitis vary considerably between institutions. Standard care often includes general hygiene recommendations and reactive treatment once symptoms appear. However, increasing evidence suggests that proactive, structured preventive protocols may reduce the severity and

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incidence of skin toxicity. Such strategies may include optimized radiotherapy planning to minimize high-dose skin exposure, prophylactic emollient use, patient education on skin protection, and systematic dermatologic monitoring.

The concept of a multimodal preventive approach integrates technological optimization with supportive dermatologic care and patient-centered education. IMRT, for example, allows improved dose homogeneity and reduction of "hot spots" within the irradiation field, thereby decreasing localized skin damage. Simultaneously, early prophylactic skincare may preserve the epidermal barrier, reduce transepidermal water loss, and mitigate inflammatory responses. Structured patient education enhances adherence to protective measures and promotes early reporting of symptoms.

Despite promising preliminary data, comprehensive clinical evaluation of coordinated multimodal preventive protocols remains limited. Most existing studies focus on single interventions rather than integrated strategies. Therefore, there is a need for prospective investigations assessing the combined effect of technological and supportive care optimization.

The present study aims to evaluate the clinical effectiveness of a structured multimodal preventive strategy in reducing the severity of radiation dermatitis among breast cancer patients undergoing adjuvant radiotherapy, with particular emphasis on treatment continuity and patient-reported outcomes.

Materials and Methods

This prospective controlled clinical study was conducted at a tertiary oncology center between 2023 and 2025 to evaluate the effectiveness of a multimodal preventive strategy for radiation dermatitis in breast cancer patients undergoing adjuvant radiotherapy. The study protocol was approved by the institutional ethics committee, and all participants provided written informed consent prior to enrollment.

A total of 140 female patients aged 18–75 years with histologically confirmed breast cancer were included in the study. All patients had undergone breast-conserving surgery or mastectomy and were scheduled to receive postoperative external beam radiotherapy. Eligibility criteria included ECOG performance

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status 0–2 and absence of severe pre-existing dermatologic disorders within the irradiation field. Patients receiving concurrent chemotherapy, those with autoimmune skin diseases, uncontrolled diabetes mellitus, or prior thoracic radiotherapy were excluded.

Participants were allocated into two groups: a standard-care group (n = 70) and a multimodal-prevention group (n = 70). Both groups received comparable radiotherapy doses ranging from 45 to 50 Gy delivered in daily fractions of 1.8–2 Gy, five days per week. In the standard-care group, patients received routine recommendations including general hygiene measures and symptomatic treatment initiated after the onset of skin reactions.

The multimodal-prevention group underwent a structured preventive protocol that combined technological optimization and supportive dermatologic measures. Radiotherapy was delivered using intensity-modulated radiotherapy (IMRT) with careful dose homogeneity planning to minimize high-dose skin exposure. Patients were instructed to apply a prophylactic non-fragranced emollient twice daily beginning on the first day of radiotherapy. Additionally, participants received standardized written and verbal education regarding skin care, avoidance of mechanical irritation, protection from ultraviolet exposure, and early reporting of symptoms. Weekly dermatologic monitoring was performed throughout the treatment course to detect early signs of toxicity and adjust supportive care when necessary.

Skin toxicity was evaluated weekly during radiotherapy and two weeks after treatment completion using the RTOG/EORTC Acute Radiation Morbidity Scoring Criteria. Patient-reported symptoms, including pain, pruritus, burning sensation, and discomfort, were assessed using a Visual Analog Scale (VAS). Treatment interruptions related to skin toxicity were documented.

Statistical analysis was performed using SPSS software (version 26.0). Quantitative variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Intergroup comparisons were performed using the independent samples t-test for continuous variables and the chi-square test for categorical data. A p-value of less than 0.05 was considered statistically significant.

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Results

All 140 enrolled patients completed the study protocol. Baseline demographic and clinical characteristics, including age, body mass index, tumor stage, type of surgery, and total radiation dose, were comparable between the standard-care and multimodal-prevention groups, with no statistically significant differences ($p > 0.05$). The mean age of participants was 52.8 ± 9.1 years.

Radiation dermatitis of any grade developed in 91.4% of patients in the standard-care group and in 78.6% of patients in the multimodal-prevention group. Although mild Grade I reactions were observed in both groups with similar frequency, significant differences were noted in the incidence of moderate-to-severe toxicity. Grade II dermatitis occurred in 44.3% of patients receiving standard care compared to 27.1% in the multimodal group ($p = 0.032$). Grade III dermatitis was recorded in 15.7% of the standard-care group, whereas only 5.7% of patients in the multimodal group progressed to Grade III toxicity ($p = 0.041$). No Grade IV reactions were observed in either group.

The mean time to onset of the first visible skin reaction was significantly delayed in the multimodal-prevention group (19.6 ± 3.5 days) compared to the standard-care group (15.8 ± 3.1 days) ($p = 0.018$). Furthermore, the duration of moderate dermatitis was shorter in the multimodal group by an average of 4.2 days.

Patient-reported outcomes demonstrated clinically relevant improvements in the multimodal-prevention group. The mean Visual Analog Scale score for pain and burning sensation was 2.3 ± 1.4 in the multimodal group compared to 3.9 ± 1.7 in the standard-care group ($p = 0.009$). Pruritus intensity was also significantly reduced in patients receiving structured preventive care.

Treatment interruption due to skin toxicity occurred in 12.9% of patients in the standard-care group, whereas only 4.3% of patients in the multimodal-prevention group required temporary modification of radiotherapy ($p = 0.038$). Overall treatment adherence was higher in the multimodal group.

These findings indicate that the implementation of a coordinated multimodal preventive protocol significantly reduces the severity of radiation dermatitis, delays its onset, decreases symptom burden, and improves treatment continuity in breast cancer patients undergoing radiotherapy.

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Discussion

The present study demonstrates that a structured multimodal preventive strategy significantly reduces the severity and clinical impact of radiation dermatitis in breast cancer patients undergoing adjuvant radiotherapy. Compared with standard care, the integration of intensity-modulated radiotherapy (IMRT), prophylactic skincare, systematic patient education, and weekly dermatologic monitoring resulted in lower rates of Grade II–III toxicity, delayed onset of skin reactions, reduced symptom burden, and fewer treatment interruptions.

The reduction in moderate-to-severe dermatitis observed in the multimodal group can be partially attributed to improved dose homogeneity achieved with IMRT. Conventional radiotherapy techniques may create localized “hot spots” within the treatment field, particularly in patients with larger breast volumes, leading to higher skin dose exposure. IMRT allows for more precise dose distribution and better sparing of superficial tissues, thereby decreasing the intensity of cutaneous damage. The significant delay in dermatitis onset observed in the multimodal group supports the protective effect of optimized radiation planning.

In addition to technological optimization, prophylactic skincare played an essential role in preserving the epidermal barrier. Early and consistent application of emollients likely reduced transepidermal water loss and maintained skin hydration, mitigating inflammatory responses triggered by radiation exposure. Radiation disrupts keratinocyte turnover and damages the dermal microvasculature, leading to barrier dysfunction. Proactive moisturization may counteract these processes and enhance tissue resilience.

Structured patient education also contributed to improved outcomes. Patients who received detailed instructions regarding hygiene, avoidance of mechanical friction, protection from ultraviolet radiation, and early reporting of symptoms demonstrated better adherence to preventive measures. This highlights the importance of patient engagement and empowerment in supportive oncology care. Effective communication between healthcare providers and patients may facilitate early intervention and prevent progression of mild reactions into more severe forms.

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The reduction in treatment interruptions observed in the multimodal group has particular clinical significance. Continuity of radiotherapy is crucial for optimal tumor control, and unplanned breaks may negatively affect therapeutic efficacy. By minimizing severe skin toxicity, multimodal prevention strategies may indirectly contribute to improved oncologic outcomes.

These findings are consistent with emerging literature suggesting that preventive, rather than reactive, approaches are more effective in managing radiation-induced skin injury. However, many previous studies have focused on isolated interventions. The present study emphasizes the value of an integrated model combining technological precision with supportive dermatologic care and patient-centered education.

Several limitations should be acknowledged. The study was conducted at a single center, which may limit generalizability. Although the sample size was sufficient to demonstrate statistically significant differences, larger multicenter trials are required to confirm these findings. Long-term follow-up was not included; therefore, chronic radiation-induced skin changes and fibrosis were not evaluated. Future studies incorporating objective biophysical skin measurements and molecular biomarkers could provide deeper insight into mechanistic pathways.

Despite these limitations, the results support the routine implementation of structured multimodal preventive protocols in breast cancer radiotherapy. The combination of optimized radiation delivery, early skincare intervention, and systematic patient education represents a clinically effective strategy for reducing radiation dermatitis and improving patient-centered outcomes.

Conclusion

Radiation dermatitis remains a highly prevalent adverse effect in breast cancer patients undergoing adjuvant radiotherapy and continues to represent a significant clinical challenge despite technological advances in treatment delivery. The findings of this study demonstrate that a structured multimodal preventive approach significantly reduces the severity and incidence of moderate-to-severe skin toxicity compared to standard care.

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The integration of intensity-modulated radiotherapy for optimized dose distribution, early prophylactic skincare, structured patient education, and systematic dermatologic monitoring proved effective in delaying the onset of dermatitis, reducing symptom intensity, and minimizing treatment interruptions. These improvements contribute not only to enhanced patient comfort and quality of life but also to improved treatment adherence, which is essential for maintaining oncologic efficacy.

The results highlight the importance of shifting from reactive management to proactive prevention in radiation-induced skin injury. Multimodal preventive strategies represent a clinically practical and evidence-based model that can be incorporated into routine oncology practice.

Future large-scale multicenter studies with long-term follow-up are necessary to evaluate chronic toxicity outcomes and to further refine personalized preventive protocols. Nonetheless, the present study provides strong clinical support for implementing coordinated preventive care pathways in breast cancer radiotherapy.

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