# Effect of a geriatric assessment-guided nursing intervention on radiation-induced toxicity and quality of life in geriatric cancer patients receiving radiotherapy: A randomized controlled trial

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## ABSTRACT

***Background:*** Older adults (≥65 years) with cancer undergoing radiotherapy are at increased risk of treatment-related toxicity, functional decline, and reduced quality of life (QoL). This study evaluated the effectiveness of a comprehensive geriatric assessment (GA)-guided nursing intervention in improving clinical outcomes. ***Materials and Methods:*** In this prospective, single-blind, randomized controlled trial, 200 patients aged ≥65 years receiving curative or adjuvant radiotherapy for solid malignancies were randomized (1:1) to either a GA-guided nursing intervention (n = 100) or standard oncology nursing care (n = 100). The intervention included multidimensional GA, individualized nursing care plans, weekly monitoring, and telephone follow-up. The primary outcome was radiation-induced toxicity (CTCAE v5.0). Secondary outcomes included QoL (EORTC QLQ-C30), functional and nutritional status, treatment adherence, healthcare utilization, and patient satisfaction. ***Results:*** The GA-guided intervention significantly reduced grade ≥2 toxicity (29% vs. 49%, P = 0.004) and grade ≥3 toxicity (8% vs. 19%, P = 0.024). Patients in the intervention group demonstrated higher global QoL scores at 3 months (76.5 ± 9.8 vs. 66.1 ± 12.3, P < 0.001), better preservation of functional and nutritional status, fewer treatment interruptions and unplanned hospitalizations, and greater patient satisfaction (all P < 0.05). ***Conclusion:*** GA-guided nursing intervention effectively reduces radiation-induced toxicity, preserves function and QoL, and improves treatment adherence and healthcare utilization in cancer patients aged 65 years and older undergoing radiotherapy. These findings support integrating GA-guided nursing care into routine radiation oncology practice.

## INTRODUCTION

Cancer predominantly affects older adults, with over 60-70% of diagnoses occurring in individuals aged 65 years and older in many developed countries (1, 2). The global aging population has led to a substantial rise in the incidence of malignancies among the elderly, driven by increased life expectancy and cumulative exposure to risk factors. Radiotherapy remains a cornerstone of curative, adjuvant, and palliative treatment across various solid tumors, including head and neck, breast, prostate, lung, and colorectal cancers (3, 4). However, older patients undergoing radiotherapy face unique challenges due to age-related physiological decline, multimorbidity, polypharmacy, frailty, and reduced physiological reserve (5).

These factors contribute to heightened vulnerability to radiation-induced toxicities, such as dermatitis, mucositis, fatigue, and gastrointestinal disturbances, which can lead to treatment interruptions, dose reductions, functional decline, malnutrition, reduced quality of life (QoL), and increased healthcare utilization (6, 7). Traditional performance status measures like the Eastern Cooperative Oncology Group (ECOG) scale often fail to capture the heterogeneity of aging, underestimating risks in this population (8). Comprehensive Geriatric Assessment (CGA or GA) has emerged as the gold standard for evaluating older cancer patients. It encompasses multidimensional domains including functional status (ADL/IADL), nutritional status (e.g., MNA-SF), cognition (MMSE), mood (GDS), comorbidity (Charlson Index), polypharmacy, social support, and geriatric syndromes (9, 10).

Evidence supports the predictive value of GA for treatment toxicity, functional decline, and mortality in oncology settings (11). Systematic reviews and meta-analyses indicate that GA-guided interventions can reduce treatment-related toxicity (relative risk reductions of approximately 20-25%), improve


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tolerability, and enhance patient-centered outcomes, particularly when implemented early and linked to actionable management plans [12]. In radiation oncology specifically, GA parameters have been associated with radiation-induced toxicity and treatment completion rates, though data on nursing-led, GA-guided supportive care during radiotherapy remain limited compared to medical oncology or surgical settings [13, 14].

Nurses play a pivotal role in supportive care, symptom management, patient education, and care coordination [15]. GA-guided nursing interventions tailored nutritional support, exercise, medication reconciliation, psychological counseling, and proactive symptom monitoring offer a feasible, patient-centered approach to mitigate vulnerabilities throughout the radiotherapy course [3]. Despite promising findings from broader geriatric oncology trials demonstrating reduced grade ≥3 toxicities, preserved function, and better QoL with GA management, randomized evidence focused on radiotherapy-specific nursing interventions in older adults is scarce [16].

Despite growing evidence supporting comprehensive GA in geriatric oncology, its integration into routine radiation oncology practice remains limited. Most previous studies have focused on the prognostic value of GA or on physician-led interventions, whereas evidence regarding nurse-led, GA-guided interventions during radiotherapy is scarce, particularly from randomized controlled trials. Furthermore, the impact of such interventions on radiation-induced toxicity, quality of life, functional status, treatment adherence, and healthcare utilization has not been comprehensively evaluated in older adults receiving radiotherapy. Addressing this evidence gap, the present study was undertaken to determine whether a structured GA-guided nursing intervention could improve clinical and patient-centered outcomes in cancer patients aged 65 years and older undergoing curative or adjuvant radiotherapy. Although comprehensive GA has been widely recommended for the care of older adults with cancer, evidence supporting structured, nurse-led GA-guided interventions specifically during radiotherapy remains limited. Previous studies have primarily focused on the prognostic value of GA or on physician-led geriatric management, with few randomized controlled trials evaluating the effect of individualized nursing interventions on treatment-related toxicity and patient-centered outcomes. The novelty of the present study lies in its evaluation of a comprehensive, nurse-delivered GA-guided intervention integrated throughout the radiotherapy course and its assessment of multiple clinically relevant outcomes, including radiation-induced toxicity, quality of life, functional and nutritional status, treatment adherence, healthcare utilization, and patient satisfaction. By addressing these outcomes within a randomized controlled design, this study provides new evidence supporting the integration of GA-guided nursing care into routine radiation oncology practice for cancer patients aged 65 years and older.

## MATERIALS AND METHODS

### *Study design and setting*

This prospective, parallel-group, single-blind, randomized controlled trial was designed to evaluate the effect of a comprehensive geriatric assessment (GA)-guided nursing intervention on radiation-induced toxicity and quality of life in older cancer patients undergoing curative or adjuvant radiotherapy. The study was conducted between January 2024 and June 2026 at the Department of Radiation Oncology of a tertiary academic medical center. The trial was performed in accordance with the Declaration of Helsinki and the principles of Good Clinical Practice. The study protocol was reviewed and approved by the Institutional Review Board (IRB) (No. 2023ZYYC2008), and written informed consent was obtained from all participants before enrollment. The trial was prospectively registered in a recognized clinical trial registry .

### *Study population*

A total of 200 older adult cancer patients were recruited and randomly assigned in a 1:1 ratio to either the intervention group (n = 100), which received GA-guided nursing care, or the control group (n = 100), which received standard oncology nursing care throughout the radiotherapy course. Patients aged ≥65 years with histologically confirmed solid malignancies who were scheduled to receive curative or adjuvant external beam radiotherapy were consecutively screened between January 2023 and December 2024. Eligible participants had an ECOG performance status of 0–2, a life expectancy of at least 6 months, and the ability to provide informed consent. Patients receiving palliative radiotherapy, those with severe cognitive impairment, previous radiotherapy to the same treatment site, or serious uncontrolled medical or psychiatric conditions were excluded. Patients were excluded if they had severe cognitive impairment that precluded informed consent, active psychiatric disorders interfering with participation, previous radiotherapy to the same anatomical region, concurrent enrollment in another interventional supportive care study, terminal illness requiring palliative-only treatment, or severe uncontrolled comorbidities such as unstable cardiovascular disease or active systemic infection.

### *Randomization and blinding*

After baseline assessment, participants were randomly allocated using a computer-generated


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randomization sequence prepared by an independent statistician. Block randomization with variable block sizes was employed to ensure balanced group allocation throughout the recruitment period. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes that were opened only after patient enrollment. Outcome assessors and data analysts were blinded to group allocation, whereas the nursing staff delivering the intervention could not be blinded due to the nature of the study.

***Geriatric assessment***

All participants underwent an initial baseline evaluation before radiotherapy. In the intervention group, a multidimensional geriatric assessment was performed by trained oncology nurses using validated instruments. The assessment included functional status, nutritional condition, cognitive function, emotional health, comorbidity burden, medication use, social support, and fall risk. Functional status was evaluated using the Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) scales. Nutritional status was assessed using the Mini Nutritional Assessment-Short Form (MNA-SF). Cognitive performance was evaluated with the Mini-Mental State Examination (MMSE). Depression and anxiety symptoms were assessed using the Geriatric Depression Scale (GDS). Comorbidity burden was measured using the Charlson Comorbidity Index (CCI), while polypharmacy was defined as the regular use of five or more medications. The results of the geriatric assessment were used to identify vulnerable domains and to formulate individualized nursing interventions.

***Nursing intervention***

Patients allocated to the intervention group received a structured GA-guided nursing program throughout radiotherapy. The intervention was delivered by specialized oncology nurses who had completed training in geriatric oncology care. Individualized nursing plans were developed according to identified geriatric deficits. Nutritional counseling and referral to a dietitian were provided for patients at risk of malnutrition. Medication reconciliation was performed to minimize polypharmacy-related complications. Patients with impaired mobility received exercise recommendations and fall prevention education. Cognitive support strategies and caregiver education were implemented for individuals with mild cognitive impairment. Psychological counseling and stress management techniques were offered to patients with emotional distress. Weekly face-to-face assessments were conducted during radiotherapy to monitor treatment-related symptoms, reinforce educational strategies, and modify care plans when necessary. Telephone follow-up was also provided between treatment sessions to identify emerging complications early and facilitate timely intervention.

***Standard nursing care***

Patients in the control group received routine oncology nursing care according to institutional protocols. Standard care included general education regarding radiotherapy, management of common treatment-related adverse effects, routine symptom monitoring during scheduled clinic visits, and access to supportive services upon physician referral. No formal geriatric assessment or individualized geriatric care planning was implemented.

***Radiotherapy protocol***

Radiotherapy planning was performed using computed tomography (CT) simulation and delivered using three-dimensional conformal radiotherapy (3D-CRT) or intensity-modulated radiotherapy (IMRT) according to institutional protocols. Treatment planning was performed using the Eclipse™ Treatment Planning System (Varian Medical Systems, Palo Alto, CA, USA), and radiotherapy was delivered using a TrueBeam™ linear accelerator (Varian Medical Systems, Palo Alto, CA, USA). All participants received external beam radiotherapy (EBRT) with curative or adjuvant intent according to institutional treatment protocols. Treatment planning was performed using computed tomography (CT)-based simulation. Radiotherapy was delivered using either three-dimensional conformal radiotherapy (3D-CRT) or intensity-modulated radiotherapy (IMRT), depending on tumor characteristics, anatomical location, and physician preference. Treatment was administered in daily fractions of 1.8-2.0 Gy, five days per week, to a total prescribed dose of 45-70 Gy, according to tumor type, disease stage, and established clinical guidelines. Organs at risk were contoured and dose constraints were applied to minimize radiation exposure to surrounding normal tissues. Image-guided verification was performed before treatment according to institutional quality assurance protocols.

***Outcome measures***

The primary outcome was the incidence and severity of radiation-induced toxicity during treatment and within three months after completion of radiotherapy. Toxicities were graded according to the Common Terminology Criteria for Adverse Events (CTCAE), version 5.0. The secondary outcome was health-related quality of life, assessed using the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire Core 30 (EORTC QLQ-C30). Quality-of-life assessments were performed at baseline, at the end of radiotherapy, and three months after treatment completion. Additional secondary outcomes included treatment interruption


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rates, unplanned hospital admissions, emergency department visits, changes in functional status, nutritional deterioration, and overall patient satisfaction with nursing care.

### *Data collection and follow-up*

Baseline demographic and clinical characteristics, including age, sex, cancer type, tumor stage, treatment modality, comorbidities, medication history, and laboratory findings, were collected from electronic medical records. Patients were evaluated weekly during radiotherapy and subsequently followed for three months after treatment completion. All adverse events, hospitalizations, and supportive care interventions were prospectively documented by trained research nurses using standardized case report forms.

### *Sample size calculation*

The sample size was calculated based on the expected reduction in grade 2 or higher radiation-induced toxicity. Assuming a toxicity rate of 50% in the standard care group and a reduction to 30% in the intervention group, with a two-sided alpha level of 0.05 and statistical power of 80%, a minimum of 91 participants per group was required. To compensate for an anticipated dropout rate of approximately 10%, a total of 200 patients were enrolled.

### *Statistical analysis*

Data analysis was performed using IBM SPSS Statistics for Windows, Version 29.0 (IBM Corp., Armonk, NY, USA) and R statistical software, Version 4.3 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were expressed as mean ± standard deviation or median with interquartile range, whereas categorical variables were presented as frequencies and percentages. Baseline characteristics between groups were compared using the independent samples t-test or Mann-Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables. Repeated measures analysis of variance was used to evaluate longitudinal changes in quality-of-life scores. Logistic regression analysis was performed to identify factors independently associated with severe radiation-induced toxicity. All analyses followed the intention-to-treat principle. Missing data were handled using multiple imputation methods. A two-sided P value of less than 0.05 was considered statistically significant.

## RESULTS

### *Participant flow and baseline characteristics*

Between January 2024 and June 2026, a total of 248 patients were screened for eligibility. Forty-eight patients were excluded (31 did not meet inclusion criteria, 10 declined participations, and 7 were excluded for other reasons). A total of 200 participants were randomized, with 100 assigned to the GA-guided nursing intervention group and 100 assigned to the standard care group. During follow-up, 4 patients in the intervention group and 6 patients in the control group withdrew or were lost to follow-up. All randomized participants were included in the intention-to-treat analysis. The mean age of the study population was 73.2 ± 5.8 years, and 54.5% were male. Baseline demographic, clinical, and geriatric characteristics were comparable between groups, with no statistically significant differences observed (table 1 and 2). A total of 248 patients were screened for eligibility between January 2024 and June 2026. Of these, 48 patients were excluded, and 200 eligible participants were randomized in a 1:1 ratio to either the geriatric assessment (GA)-guided nursing intervention group (n = 100) or the standard nursing care group (n = 100).

**Table 1.** Baseline demographic and clinical characteristics.

| Variable | Intervention (n=100) | Control (n=100) | P-value |
|---|---|---|---|
| **Age (years), mean ± SD** | 73.4 ± 5.7 | 73.0 ± 5.9 | 0.642 |
| **Male sex, n (%)** | 56 (56.0) | 53 (53.0) | 0.671 |
| **ECOG 0–1, n (%)** | 78 (78.0) | 75 (75.0) | 0.617 |
| **ECOG 2, n (%)** | 22 (22.0) | 25 (25.0) | 0.617 |
| **Charlson Comorbidity Index** | 4.1 ± 1.5 | 4.2 ± 1.6 | 0.731 |
| **Polypharmacy (≥5 medications), n (%)** | 48 (48.0) | 50 (50.0) | 0.776 |
| **Concurrent chemotherapy, n (%)** | 39 (39.0) | 42 (42.0) | 0.668 |
| **Baseline MNA-SF score** | 10.8 ± 1.9 | 10.7 ± 2.0 | 0.752 |
| **Baseline MMSE score** | 26.9 ± 2.4 | 26.6 ± 2.7 | 0.423 |

Abbreviations: ECOG, Eastern Cooperative Oncology Group; BMI, body mass index; CCI, Charlson Comorbidity Index; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; MNA-SF, Mini Nutritional Assessment–Short Form; MMSE, Mini-Mental State Examination; GDS, Geriatric Depression Scale.

### *Radiation-induced toxicity*

Radiation-induced toxicities were observed less frequently among patients receiving the GA-guided nursing intervention. Overall toxicity of any grade occurred in 63.0% of intervention patients compared with 74.0% of controls, although this difference did not reach statistical significance (P=0.095). However, clinically significant toxicities were substantially reduced in the intervention group. Grade ≥2 toxicities occurred in 29.0% of patients receiving GA-guided care versus 49.0% receiving standard care (P=0.004), while Grade ≥3 toxicities were observed in only 8.0% and 19.0% of patients, respectively (P=0.024). Among specific toxicities, radiation dermatitis occurred significantly less frequently in the intervention group (21.0% vs. 36.0%, P=0.018), as did mucositis (14.0% vs. 28.0%, P=0.015). Fatigue was the most common constitutional symptom and was reported by 27.0% of intervention patients compared with 44.0% of controls (P = 0.012). Additionally, anorexia and clinically significant weight loss were markedly reduced among patients receiving GA-guided nursing support. Although gastrointestinal and hematologic


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toxicities were numerically lower in the intervention group, these differences did not reach statistical significance. No treatment-related deaths occurred in either study arm. The overall toxicity profile demonstrates that individualized geriatric assessment–guided nursing care improved treatment tolerance and reduced the burden of clinically significant radiation-related adverse events in older adults undergoing radiotherapy (table 3).

**Table 2.** Cancer characteristics of the study population. Baseline cancer-related characteristics were well balanced between the intervention and control groups. No statistically significant differences were observed in tumor type distribution, disease stage, radiotherapy technique, treatment intent, concurrent chemotherapy use, or prescribed radiation dose (all P>0.05), indicating successful randomization.

| Variable | Intervention Group (n = 100) | Control Group (n = 100) | P-value |
|---|---|---|---|
| **Tumor Type**, n (%) | | | **0.865** |
| Head and Neck Cancer | 24 (24.0) | 21 (21.0) | |
| Breast Cancer | 23 (23.0) | 25 (25.0) | |
| Prostate Cancer | 18 (18.0) | 19 (19.0) | |
| Lung Cancer | 17 (17.0) | 16 (16.0) | |
| Colorectal Cancer | 10 (10.0) | 11 (11.0) | |
| Other Solid Tumors | 8 (8.0) | 8 (8.0) | |
| **Tumor Stage**, n (%) | | | **0.774** |
| Stage I | 18 (18.0) | 16 (16.0) | |
| Stage II | 34 (34.0) | 36 (36.0) | |
| Stage III | 38 (38.0) | 37 (37.0) | |
| Stage IV (limited/metastatic treated with curative intent) | 10 (10.0) | 11 (11.0) | |
| **Radiotherapy Technique**, n (%) | | | **0.658** |
| 3D-Conformal Radiotherapy (3D-CRT) | 39 (39.0) | 43 (43.0) | |
| Intensity-Modulated Radiotherapy (IMRT) | 61 (61.0) | 57 (57.0) | |
| **Radiotherapy Intent**, n (%) | | | **0.721** |
| Curative | 67 (67.0) | 64 (64.0) | |
| Adjuvant/Postoperative | 33 (33.0) | 36 (36.0) | |
| **Concurrent Chemotherapy**, n (%) | 39 (39.0) | 42 (42.0) | **0.668** |
| Yes | 39 (39.0) | 42 (42.0) | |
| No | 61 (61.0) | 58 (58.0) | |
| **Prescribed Radiation Dose (Gy)** | | | **0.812** |
| Mean ± SD | 60.8 ± 7.4 | 61.1 ± 7.2 | |
| Median (Range) | 60 (45-70) | 60 (45-70) | |

Abbreviations: CTCAE, Common Terminology Criteria for Adverse Events; RT, radiotherapy.

### *Quality of life outcomes*

Quality-of-life outcomes assessed using the EORTC QLQ-C30 demonstrated significant benefits associated with the GA-guided nursing intervention. Baseline scores were comparable between groups across all domains (all P>0.05). At the end of radiotherapy and at the 3-month follow-up, patients in the intervention group exhibited significantly higher Global Health Status/QoL scores than controls (76.5 ± 9.8 vs. 66.1 ± 12.3 at 3 months, P<0.001). Significant improvements were observed in physical, role, emotional, cognitive, and social functioning domains among intervention participants (all group-by-time P<0.01). Furthermore, symptom burden was substantially reduced in the intervention group, with lower fatigue, pain, appetite loss, insomnia, nausea/vomiting, constipation, and diarrhea scores during follow-up (all P<0.05). Financial difficulties did not differ significantly between groups (P=0.421). These findings indicate that GA-guided nursing care not only improved overall quality of life but also preserved functional independence and mitigated treatment-related symptom burden in older adults undergoing radiotherapy (table 4). Global health status/QoL was significantly higher in the intervention group than in the control group (76.5 ± 9.8 vs. 66.1 ± 12.3, *P*<0.001). Improvements were also observed in physical, role, emotional, cognitive, and social functioning (all *P*<0.05), whereas symptom scores for fatigue, pain, appetite loss, and insomnia were significantly lower (all *P*<0.05).

**Table 3.** Radiation-induced toxicity during and within 3 months after radiotherapy.

| Toxicity Outcome | Intervention Group (n = 100) | Control Group (n = 100) | Relative Risk (95% CI) | P-value |
|---|---|---|---|---|
| **Overall Toxicity** | | | | |
| Any toxicity (Grade 1-5), n (%) | 63 (63.0) | 74 (74.0) | 0.85 (0.71-1.01) | 0.095 |
| Grade ≥2 toxicity, n (%) | 29 (29.0) | 49 (49.0) | 0.59 (0.41-0.85) | 0.004* |
| Grade ≥3 toxicity, n (%) | 8 (8.0) | 19 (19.0) | 0.42 (0.19-0.93) | 0.024* |
| Grade 4 toxicity, n (%) | 1 (1.0) | 5 (5.0) | 0.20 (0.02-1.67) | 0.096 |
| Treatment-related death (Grade 5), n (%) | 0 (0.0) | 0 (0.0) | — | — |
| **Dermatologic Toxicity** | | | | |
| Radiation dermatitis (all grades), n (%) | 21 (21.0) | 36 (36.0) | 0.58 (0.37-0.91) | 0.018* |
| Grade ≥2 dermatitis, n (%) | 9 (9.0) | 21 (21.0) | 0.43 (0.21-0.88) | 0.020* |
| **Mucosal Toxicity** | | | | |
| Mucositis (all grades), n (%) | 14 (14.0) | 28 (28.0) | 0.50 (0.28-0.88) | 0.015* |
| Grade ≥2 mucositis, n (%) | 6 (6.0) | 15 (15.0) | 0.40 (0.16-0.98) | 0.044* |
| Xerostomia, n (%) | 11 (11.0) | 20 (20.0) | 0.55 (0.28-1.08) | 0.079 |
| **Gastrointestinal Toxicity** | | | | |
| Gastrointestinal toxicity (all grades), n (%) | 12 (12.0) | 22 (22.0) | 0.55 (0.29-1.03) | 0.059 |
| Nausea/Vomiting, n (%) | 10 (10.0) | 19 (19.0) | 0.53 (0.26-1.06) | 0.071 |
| Diarrhea, n (%) | 7 (7.0) | 15 (15.0) | 0.47 (0.20-1.10) | 0.081 |
| **Constitutional Toxicity** | | | | |
| Fatigue, n (%) | 27 (27.0) | 44 (44.0) | 0.61 (0.41-0.91) | 0.012* |
| Grade ≥2 fatigue, n (%) | 11 (11.0) | 25 (25.0) | 0.44 (0.23-0.85) | 0.014* |
| Anorexia, n (%) | 13 (13.0) | 27 (27.0) | 0.48 (0.26-0.89) | 0.019* |
| Weight loss >5%, n (%) | 13 (13.0) | 29 (29.0) | 0.45 (0.24-0.84) | 0.006* |
| **Hematologic Toxicity** | | | | |
| Anemia, n (%) | 9 (9.0) | 16 (16.0) | 0.56 (0.26-1.21) | 0.137 |
| Neutropenia, n (%) | 5 (5.0) | 12 (12.0) | 0.42 (0.15-1.15) | 0.088 |
| Thrombocytopenia, n (%) | 3 (3.0) | 8 (8.0) | 0.38 (0.10-1.39) | 0.127 |

Abbreviations: EORTC QLQ-C30, European Organization for Research and Treatment of Cancer Quality of Life Questionnaire-Core 30; QoL, quality of life; CI, confidence interval. Note: Toxicities were assessed weekly during radiotherapy and up to 3 months following treatment completion according to CTCAE version 5.0. Grade ≥2 and Grade ≥3 toxicities were considered clinically significant adverse events.



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**Table 4.** EORTC QLQ-C30 global health status scores.

| EORTC QLQ-C30 Domain | Baseline Intervention | Baseline Control | End of RT Intervention | End of RT Control | 3-Month Intervention | 3-Month Control | Group × Time P -value |
|---|---|---|---|---|---|---|---|
| Global Health Status/QoL | 68.4±11.2 | 67.9±10.8 | 71.8±10.5 | 63.9±11.6 | 76.5±9.8 | 66.1±12.3 | <0.001* |
| Physical Functioning | 79.6±10.4 | 80.1±10.8 | 78.5±10.9 | 71.3±12.7 | 81.7±9.5 | 73.2±12.1 | <0.001* |
| Role Functioning | 76.8±12.6 | 77.3±11.9 | 74.9±12.4 | 67.1 ± 13.8 | 79.6 ± 10.8 | 69.4±12.7 | <0.001* |
| Emotional Functioning | 72.4±11.5 | 71.8±12.1 | 77.1±10.6 | 68.2±12.8 | 82.4±9.7 | 70.1±11.9 | <0.001* |
| Cognitive Functioning | 80.2±10.3 | 79.8±10.7 | 81.5±9.8 | 76.3±11.4 | 84.6±8.5 | 77.8±10.9 | 0.002* |
| Social Functioning | 74.1±12.7 | 74.5±12.4 | 76.8±11.6 | 67.7±13.1 | 81.9±10.3 | 69.5±12.8 | <0.001* |
| Fatigue | 31.8±14.5 | 32.4±15.1 | 34.5±13.7 | 47.8±16.2 | 27.9±12.6 | 42.1±15.8 | <0.001* |
| Pain | 28.5±15.4 | 29.2±14.8 | 26.1±14.7 | 35.8±15.3 | 22.4±13.5 | 32.6±15.1 | <0.001* |
| Nausea/Vomiting | 10.6±9.4 | 11.1±9.8 | 12.9±10.1 | 19.8±12.4 | 8.3±8.7 | 15.7±11.2 | 0.003* |
| Appetite Loss | 22.8±14.3 | 23.1±14.8 | 24.9±15.2 | 36.4±16.1 | 18.7±13.1 | 31.5±15.8 | <0.001* |
| Insomnia | 27.5±15.6 | 28.2±15.1 | 29.8±15.3 | 36.7±16.4 | 22.6±13.9 | 33.9±15.7 | 0.001* |
| Dyspnea | 18.3±12.1 | 18.7±12.5 | 19.4±12.6 | 24.8±13.7 | 16.8±11.4 | 22.9±13.1 | 0.021* |
| Constipation | 16.5±11.8 | 17.2±12.4 | 17.1±12.3 | 23.6±13.5 | 14.2±10.9 | 20.5±12.7 | 0.018* |
| Diarrhea | 11.8±9.6 | 12.1±10.1 | 14.3±10.7 | 19.2±12.8 | 10.4±8.8 | 16.8±11.3 | 0.029* |
| Financial Difficulties | 25.6±16.7 | 24.9±16.3 | 24.8±16.2 | 26.9±17.4 | 23.5±15.6 | 25.8±16.8 | 0.421 |

Abbreviations: ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; MNA-SF, Mini Nutritional Assessment–Short Form; BMI, body mass index. Note: Higher scores on functional scales and global health status indicate better functioning and quality of life, whereas higher scores on symptom scales indicate greater symptom burden. P-values were derived from repeated-measures ANOVA assessing group-by-time interactions.

### *Functional and nutritional outcomes*

Functional and nutritional outcomes were significantly improved among patients receiving GA-guided nursing care. Functional decline, defined as a decrease of at least one point in ADL score, occurred in 14.0% of intervention patients compared with 31.0% of controls (P=0.004). Similarly, deterioration in IADL performance was less frequent in the intervention group (18.0% vs. 37.0%, P=0.003). New dependency in at least one daily activity and increased fall risk were also significantly reduced among patients receiving individualized geriatric interventions. Regarding nutritional outcomes, deterioration in nutritional status (MNA-SF decrease ≥2 points) occurred in 16.0% of intervention patients versus 35.0% of controls (P=0.002). Clinically significant weight loss exceeding 5% of baseline body weight was observed in 13.0% and 29.0% of patients, respectively (P=0.006). Furthermore, severe weight loss (>10%), development of malnutrition, and need for nutritional supplementation were significantly less common in the intervention group. Mean body weight decreased by only 1.4±2.3 kg in the intervention arm compared with 3.2 ± 3.1 kg in the standard care group (P<0.001). These findings suggest that GA-guided nursing interventions effectively preserved functional independence and nutritional status during radiotherapy in older cancer patients (table 5).

### *Healthcare utilization and treatment completion*

Healthcare utilization and treatment compliance outcomes favored the GA-guided nursing intervention group. Treatment interruption exceeding three days occurred in only 9.0% of intervention patients compared with 22.0% of controls (P = 0.011), while interruptions exceeding seven days were also significantly less frequent (3.0% vs. 11.0%, P = 0.027). Premature discontinuation of radiotherapy occurred in one patient (1.0%) in the intervention group and seven patients (7.0%) in the control group (P = 0.031). Consequently, completion of the prescribed radiotherapy course was significantly higher among intervention participants (96.0% vs. 88.0%, P = 0.037). The GA-guided nursing program was associated with reduced healthcare utilization. Emergency department visits were reported in 11.0% of intervention patients compared with 25.0% of controls (P = 0.009), while unplanned hospitalizations occurred in 8.0% and 20.0% of patients, respectively (P = 0.015). Furthermore, hospitalized patients in the intervention group experienced shorter hospital stays (3.8 ± 2.4 vs. 6.7 ± 4.1 days, P = 0.002). Readmission rates within 90 days were also significantly lower among patients receiving GA-guided care (4.0% vs. 12.0%, P = 0.035). Utilization of supportive care services, including nutritional support, rehabilitation programs, and psychosocial counseling, was significantly greater in the intervention group, reflecting proactive management of geriatric vulnerabilities identified during assessment. Collectively, these findings demonstrate that GA-guided nursing care improved treatment adherence while reducing acute healthcare utilization during and after radiotherapy (table 6).

### *Patient satisfaction*

Patient satisfaction with nursing care was significantly higher among participants receiving the GA-guided nursing intervention. The intervention group reported superior scores across all evaluated domains, including communication (92.4 ± 6.1 vs. 83.5 ± 8.4, P < 0.001), symptom management (90.8 ± 7.2 vs. 79.7 ± 9.1, P < 0.001), and emotional support (91.6 ± 6.8 vs. 77.9 ± 10.5, P < 0.001). Significant differences were also observed for information and education, accessibility of nursing staff, responsiveness to patient needs, involvement in care decisions, confidence in the care team, and



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coordination of supportive care services (all P < 0.001). The largest between-group difference was observed in the emotional support domain, where intervention participants scored nearly 14 points higher than controls. Overall satisfaction with nursing care was significantly greater in the intervention group (91.2 ± 5.9) compared with the standard care group (80.6 ± 8.7), corresponding to a mean difference of 10.6 points (95% CI: 8.7–12.5; P < 0.001). These findings indicate that individualized geriatric assessment–guided nursing care substantially enhanced patient experiences and perceptions of care quality throughout radiotherapy and follow-up (table 7).

**Table 5.** Functional status and nutritional outcomes during radiotherapy and follow-up.

| Outcome | Intervention Group (n = 100) | Control Group (n = 100) | P-value |
|---|---|---|---|
| **Functional Outcomes** | | | |
| ADL decline ≥1 point, n (%) | 14 (14.0) | 31 (31.0) | 0.004* |
| IADL decline ≥2 points, n (%) | 18 (18.0) | 37 (37.0) | 0.003* |
| New dependency in ≥1 ADL activity, n (%) | 9 (9.0) | 22 (22.0) | 0.011* |
| Increased fall risk during follow-up, n (%) | 12 (12.0) | 26 (26.0) | 0.010* |
| Falls requiring medical attention, n (%) | 4 (4.0) | 11 (11.0) | 0.049* |
| Mean ADL score change | -0.3 ± 0.8 | -0.9 ± 1.2 | <0.001* |
| Mean IADL score change | -0.5 ± 1.1 | -1.4 ± 1.6 | <0.001* |
| **Nutritional Outcomes** | | | |
| Nutritional deterioration (MNA-SF decrease ≥2 points), n (%) | 16 (16.0) | 35 (35.0) | 0.002* |
| Weight loss >5%, n (%) | 13 (13.0) | 29 (29.0) | 0.006* |
| Weight loss >10%, n (%) | 4 (4.0) | 13 (13.0) | 0.021* |
| Development of malnutrition (MNA-SF <8), n (%) | 8 (8.0) | 21 (21.0) | 0.009* |
| Requirement for nutritional supplementation, n (%) | 19 (19.0) | 36 (36.0) | 0.007* |
| Mean body weight change (kg) | -1.4 ± 2.3 | -3.2 ± 3.1 | <0.001* |
| Mean MNA-SF score change | -0.8 ± 1.5 | -2.1 ± 2 | |

Abbreviations: ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; MNA-SF, Mini Nutritional Assessment-Short Form. Note: Negative values indicate decline from baseline. Statistical significance was defined as P < 0.05.

### *Multivariable logistic regression for grade ≥3 toxicity*

Multivariable logistic regression analysis was performed to identify independent predictors of Grade ≥3 radiation-induced toxicity during radiotherapy and follow-up. After adjustment for demographic, clinical, treatment-related, and geriatric variables, participation in the GA-guided nursing intervention remained independently associated with a significantly lower risk of severe toxicity (adjusted OR = 0.36, 95% CI: 0.15–0.83, P = 0.017), representing an approximate 64% reduction in risk. Several factors were independently associated with an increased likelihood of severe toxicity. Patients with ECOG performance status 2 had more than twice the risk of Grade ≥3 toxicity compared with those with ECOG 0–1 (adjusted OR = 2.11, 95% CI: 1.03–4.32, P = 0.041). Concurrent chemotherapy was also a significant predictor (adjusted OR = 2.58, 95% CI: 1.24–5.39, P = 0.011), as was baseline malnutrition risk identified by MNA-SF assessment (adjusted OR = 2.31, 95% CI: 1.09–4.89, P = 0.029). Age, sex, comorbidity burden, polypharmacy, cognitive impairment, advanced disease stage, and radiotherapy technique were not independently associated with severe toxicity after adjustment. The final regression model demonstrated good calibration (Hosmer–Lemeshow P = 0.624) and discrimination (AUC = 0.81, 95% CI: 0.74–0.88), indicating satisfactory predictive performance. These findings support the role of geriatric assessment–guided nursing care as an effective strategy for reducing severe treatment-related toxicity among older adults undergoing radiotherapy (table 8). The proposed mechanistic pathway through which geriatric assessment (GA)-guided nursing care improved clinical outcomes is illustrated in figure 2. Comprehensive assessment enabled early identification of geriatric vulnerabilities and implementation of individualized supportive interventions, resulting in reduced radiation-induced toxicity, preservation of functional and nutritional status, and improved quality of life.

**Table 6.** Healthcare utilization and treatment compliance outcomes.

| Outcome | Intervention Group (n = 100) | Control Group (n = 100) | P-value |
|---|---|---|---|
| **Treatment-Related Outcomes** | | | |
| Treatment interruption >3 days, n (%) | 9 (9.0) | 22 (22.0) | 0.011* |
| Treatment interruption >7 days, n (%) | 3 (3.0) | 11 (11.0) | 0.027* |
| Premature discontinuation of radiotherapy, n (%) | 1 (1.0) | 7 (7.0) | 0.031* |
| Completed prescribed RT course, n (%) | 96 (96.0) | 88 (88.0) | 0.037* |
| Relative treatment adherence (%) | 98.1 ± 3.6 | 93.7 ± 7.9 | <0.001* |
| **Healthcare Utilization** | | | |
| Emergency department visits, n (%) | 11 (11.0) | 25 (25.0) | 0.009* |
| Number of ED visits per patient | 0.14 ± 0.42 | 0.37 ± 0.71 | 0.004* |
| Unplanned hospitalization, n (%) | 8 (8.0) | 20 (20.0) | 0.015* |
| Length of hospital stay (days) | 3.8 ± 2.4 | 6.7 ± 4.1 | 0.002* |
| Readmission within 90 days, n (%) | 4 (4.0) | 12 (12.0) | 0.035* |
| Additional outpatient supportive care visits, n (%) | 28 (28.0) | 18 (18.0) | 0.093 |
| Use of nutritional support services, n (%) | 31 (31.0) | 14 (14.0) | 0.004* |
| Use of physical rehabilitation services, n (%) | 24 (24.0) | 10 (10.0) | 0.008* |
| Use of psychosocial counseling services, n (%) | 27 (27.0) | 12 (12.0) | 0.007* |

Abbreviations: RT, radiotherapy; ED, emergency department. Note: Treatment adherence was calculated as the proportion of prescribed radiotherapy fractions completed within the planned treatment schedule. Statistical significance was defined as P < 0.05.


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**Table 7.** Patient satisfaction with nursing care at 3-month follow-up.

| Satisfaction Domain (0–100) | Intervention Group (n = 100) | Control Group (n = 100) | Mean Difference (95% CI) | P-value |
|---|---|---|---|---|
| Communication | 92.4 ± 6.1 | 83.5 ± 8.4 | 8.9 (6.9-10.9) | <0.001* |
| Information and Education | 91.8 ± 6.5 | 81.4 ± 9.2 | 10.4 (8.2-12.6) | <0.001* |
| Symptom Management | 90.8 ± 7.2 | 79.7 ± 9.1 | 11.1 (8.9-13.3) | <0.001* |
| Accessibility of Nursing Staff | 92.9 ± 5.8 | 84.2 ± 8.6 | 8.7 (6.8-10.6) | <0.001* |
| Responsiveness to Patient Needs | 91.5 ± 6.3 | 80.1 ± 9.4 | 11.4 (9.2-13.6) | <0.001* |
| Emotional Support | 91.6 ± 6.8 | 77.9 ± 10.5 | 13.7 (11.2-16.2) | <0.001* |
| Involvement in Care Decisions | 89.7 ± 7.4 | 78.8 ± 9.8 | 10.9 (8.5-13.3) | <0.001* |
| Confidence in Care Team | 93.1 ± 5.6 | 84.5 ± 8.1 | 8.6 (6.8-10.4) | <0.001* |
| Coordination of Care Services | 90.9 ± 6.7 | 79.2 ± 9.6 | 11.7 (9.4-14.0) | <0.001* |
| Overall Satisfaction | 91.2 ± 5.9 | 80.6 ± 8.7 | 10.6 (8.7-12.5) | <0.001* |

Abbreviation: CI, confidence interval. Note: Satisfaction scores ranged from 0 to 100, with higher scores indicating greater satisfaction with nursing care and supportive services. Scores were collected using a standardized patient satisfaction questionnaire administered at the 3-month follow-up visit.

**Table 8.** Multivariable logistic regression analysis for predictors of grade ≥3 radiation-induced toxicity.

| Variable | Adjusted OR | 95% CI | B Coefficient | Standard Error | Wald $\chi^2$ | P-value |
|---|---|---|---|---|---|---|
| GA-guided nursing intervention | 0.36 | 0.15-0.83 | -1.02 | 0.43 | 5.62 | 0.017* |
| Age (per year increase) | 1.04 | 0.98-1.11 | 0.04 | 0.03 | 1.77 | 0.183 |
| Male sex | 1.12 | 0.56-2.23 | 0.11 | 0.35 | 0.10 | 0.751 |
| ECOG 2 vs. ECOG 0-1 | 2.11 | 1.03-4.32 | 0.75 | 0.37 | 4.18 | 0.041* |
| Charlson Comorbidity Index ≥5 | 1.79 | 0.88-3.66 | 0.58 | 0.36 | 2.58 | 0.108 |
| Concurrent chemotherapy | 2.58 | 1.24-5.39 | 0.95 | 0.38 | 6.46 | 0.011* |
| Polypharmacy (≥5 medications) | 1.51 | 0.75-3.06 | 0.41 | 0.36 | 1.30 | 0.254 |
| Baseline malnutrition risk (MNA-SF ≤11) | 2.31 | 1.09-4.89 | 0.84 | 0.39 | 4.77 | 0.029* |
| MMSE <24 | 1.68 | 0.71-3.95 | 0.52 | 0.44 | 1.41 | 0.235 |
| Advanced disease stage (III-IV) | 1.72 | 0.83-3.56 | 0.54 | 0.37 | 2.13 | 0.144 |
| IMRT vs. 3D-CRT | 0.81 | 0.39-1.67 | -0.21 | 0.37 | 0.32 | 0.572 |

## DISCUSSION

This randomized controlled trial demonstrates that a comprehensive geriatric assessment (GA)-guided nursing intervention significantly improves key clinical outcomes in older adults (≥65 years) undergoing curative or adjuvant radiotherapy for solid malignancies. Compared to standard care, the intervention reduced clinically significant radiation-induced toxicities (grade ≥2: 29% vs. 49%, P=0.004; grade ≥3: 8% vs. 19%, P=0.024), enhanced health-related quality of life (QoL) across multiple EORTC QLQ-C30 domains, preserved functional and nutritional status, improved treatment adherence, decreased healthcare utilization, and increased patient satisfaction with nursing care. These findings align with and extend the growing body of evidence supporting GA-driven supportive care in geriatric oncology [17]. The observed reduction in toxicity is consistent with meta-analyses and RCTs showing that GA-guided interventions lower treatment-related adverse events by 20-25% in older cancer patients, primarily through early identification and management of vulnerabilities such as malnutrition, polypharmacy, functional impairment, and psychosocial distress. In radiation oncology specifically, where data on nursing-led GA programs have been more limited than in medical or surgical settings, our results corroborate smaller studies and reviews indicating that GA parameters predict radiation dermatitis, mucositis, fatigue, and treatment interruptions [17, 18]. The nursing-driven model incorporating weekly assessments, individualized plans (nutritional counseling, exercise, medication reconciliation, psychological support), and proactive telephone follow-up proved feasible and effective, leveraging nurses' central role in symptom management and care coordination [11]. Mechanistically, GA facilitates personalized interventions that mitigate age-related decline in physiologic reserve, thereby enhancing treatment tolerance [18]. Reduced anorexia, weight loss, and functional decline likely contributed to better radiotherapy completion rates (96% vs. 88%) and fewer unplanned hospitalizations. Multivariable analysis confirmed the intervention's independent protective effect (adjusted OR 0.36 for grade ≥3 toxicity), even after adjusting for ECOG status, chemotherapy, and malnutrition highlighting its added value beyond routine performance status assessment.

Strengths of this study include its prospective randomized design, adequate powering, intention-to-treat analysis, blinded outcome assessment, and comprehensive evaluation of patient-centered outcomes (toxicity, QoL, function, utilization, satisfaction) over an appropriate follow-up period. The heterogeneous cancer population and real-world radiotherapy protocols enhance generalizability within tertiary centers.

The present study demonstrates that a nurse-led GA-guided intervention can improve clinical and patient-centered outcomes among older adults


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receiving radiotherapy. Rather than simply identifying frailty, the structured GA enabled individualized interventions targeting nutrition, functional impairment, psychological health, medication management, and social support, thereby improving patients' ability to tolerate treatment. These findings are consistent with those of Slaaen *et al.*, who reported that integrating GA with multidisciplinary management improved treatment completion and supportive care in older patients undergoing radiotherapy. Similarly, Giger *et al.* demonstrated that GA-guided interventions preserved physical function and quality of life in older adults with cancer, emphasizing the value of personalized geriatric care throughout treatment [19, 20].

Our findings also agree with previous observational studies showing that frailty, malnutrition, and impaired functional status are important predictors of treatment-related toxicity in older patients receiving radiotherapy. By addressing these modifiable risk factors before and during treatment, GA-guided nursing care may reduce complications and minimize treatment interruptions. Unlike many previous studies that primarily evaluated the prognostic value of GA, our randomized controlled trial assessed the effectiveness of a comprehensive nurse-led intervention across multiple clinically relevant outcomes, including toxicity, quality of life, functional status, healthcare utilization, and patient satisfaction. This broader evaluation provides new evidence supporting the routine integration of GA-guided nursing care into radiation oncology practice. Nevertheless, multicenter studies with longer follow-up are required to confirm these findings and determine their long-term clinical and economic benefits. The multivariable logistic regression analysis demonstrated that the geriatric assessment (GA)-guided nursing intervention was independently associated with a lower risk of severe radiation-induced toxicity after adjustment for potential confounding variables. This finding indicates that the beneficial effect of the intervention was not solely attributable to differences in baseline patient characteristics but reflected the effectiveness of individualized, multidisciplinary nursing care based on comprehensive geriatric assessment. Similar findings have been reported in previous studies showing that GA-guided interventions improve treatment tolerance and reduce treatment-related complications in older adults with cancer. Slaaen *et al.* reported that integrating GA with multidisciplinary management optimized supportive care and improved treatment outcomes, while Giger *et al.* demonstrated that GA-based interventions improved functional outcomes and reduced adverse events in older patients undergoing cancer treatment [15]. In contrast, poor performance status, malnutrition, and concurrent chemotherapy were independently associated with an increased risk of severe radiation-induced toxicity. These observations are consistent with previous studies identifying frailty, impaired nutritional status, and reduced functional reserve as major predictors of treatment intolerance among older adults receiving radiotherapy. Patients with poor nutritional status and functional impairment have diminished physiological reserve, making them more susceptible to acute radiation-related adverse events and treatment interruptions. Likewise, concurrent chemotherapy is well recognized to potentiate radiation toxicity through additive effects on normal tissues. The findings of the multivariable analysis strengthen the present study's overall conclusions by demonstrating that GA-guided nursing intervention remained an independent protective factor even after controlling for established clinical risk factors. This emphasizes the importance of incorporating comprehensive geriatric assessment into routine radiation oncology practice to identify vulnerable patients, implement individualized supportive interventions, and improve treatment safety in older adults undergoing radiotherapy.

This study has several limitations. First, it was conducted at a single center, which may limit the generalizability of the findings. Second, the inclusion of multiple cancer types may have introduced heterogeneity in radiation-induced toxicity because toxicity varies according to tumor site and treatment characteristics. Third, the follow-up period was limited to three months, precluding assessment of long-term outcomes. Finally, cost-effectiveness and implementation across different healthcare settings were not evaluated. Despite these limitations, the randomized controlled design and comprehensive assessment of clinically relevant outcomes strengthen the validity of our findings.

Future perspectives should focus on scaling and optimizing GA-guided care. Multicenter, multinational RCTs are needed to confirm generalizability across diverse healthcare systems, tumor types, and radiotherapy regimens (including hypofractionation and advanced techniques like proton therapy). Integration of electronic GA tools and artificial intelligence for risk stratification could improve efficiency and accessibility. Research should explore hybrid models combining specialist nursing with primary care coordination or telehealth to address resource limitations, particularly in low- and middle-income countries. Long-term studies evaluating survival, cognitive trajectories, caregiver burden, and cost-utility are essential. Training programs for radiation oncology nurses in geriatric principles, as advocated by SIOG and others, will be critical for workforce development. In conclusion, this trial provides robust evidence that GA-guided nursing interventions enhance treatment tolerance


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and patient-centered outcomes in older adults receiving radiotherapy. Widespread adoption, supported by policy changes and further research, has the potential to transform supportive care in geriatric radiation oncology, ultimately improving equity and quality of life for this rapidly growing population.

## CONCLUSION

A nurse-led geriatric assessment-guided intervention significantly reduced radiation-induced toxicity and improved quality of life, functional status, treatment adherence, and patient satisfaction in cancer patients aged 65 years and older undergoing radiotherapy. These findings support the integration of comprehensive geriatric assessment into routine radiation oncology practice to optimize treatment tolerance and patient-centered outcomes. Further multicenter studies with longer follow-up are warranted to confirm these findings and evaluate their long-term clinical impact.

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***Conflicts of interest***: Declared none

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***Ethical approval***: The study protocol was reviewed and approved by the Institutional Review Board (IRB) of Shanxi Administration of Traditional Chinese Medicine, China (No. 2023ZYYC2008). The study was conducted in accordance with the Declaration of Helsinki and the principles of Good Clinical Practice. Written informed consent was obtained from all participants before enrollment.

***Author contributions***: All authors contributed equally in all aspects of research and preparation of manuscript. All authors read and approved final version of manuscript for publication.

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