Journal of Cancer Therapy, 2026, 17(8), 377-396
https://www.scirp.org/journal/jct
ISSN Online: 2151-1942
ISSN Print: 2151-1934

Family-Participatory Continuing Radiation Protection Care for Patients Undergoing Iodine-125 Seed Implantation Effects of Compliance and Anxiety

Ailian Zhao[1,2], Li Li[3*], Yachun Yao[4]

[1]Department of Oncology, First Affiliated Hospital of Yangtze University, Jingzhou, China
[2]School of Medicine, Yangtze University, Jingzhou, China
[3]Department of Spinal Surgery, First Affiliated Hospital of Yangtze University, Jingzhou, China
[4]Department of Science and Education, First Affiliated Hospital of Yangtze University, Jingzhou, China
Email: *1145336414@qq.com

How to cite this paper: Zhao, A.L., Li, L. and Yao, Y.C. (2026) Family-Participatory Continuing Radiation Protection Care for Patients Undergoing Iodine-125 Seed Implantation Effects of Compliance and Anxiety. *Journal of Cancer Therapy*, **17**, 377-396.
https://doi.org/10.4236/jct.2026.178034

Received: June 22, 2026
Accepted: August 7, 2026
Published: August 10, 2026

Abstract

Objective: To explore the effects of family-participatory radiation protection transitional care on radiation protection compliance and anxiety levels in patients undergoing iodine-125 seed implantation. **Methods:** A single-center, two-arm parallel randomized controlled trial was conducted. Patients with solid tumors receiving iodine-125 seed implantation for the first time and their primary caregivers were consecutively screened and enrolled. A total of 90 eligible patients were randomly allocated in a 1:1 ratio to either the intervention group or control group using a random number table-generated allocation sequence, with 45 patients assigned to each group. The control group received routine ward-based verbal education and standard outpatient follow-up. In addition to routine care, the intervention group received a family-participatory radiation protection transitional care intervention, including family-involved structured education, structured post-discharge follow-up, and online reminder support. Radiation protection compliance, anxiety levels, and quality of life were assessed at T0 (admission/pre-intervention), T1 (day of discharge), T2 (1 month after discharge), T3 (3 months after discharge), and T4 (6 months after discharge). **Results:** At T0, no statistically significant differences were observed between the two groups in baseline outcome measures ($P > 0.05$). From T1 to T3, the intervention group demonstrated higher radiation protection compliance scores and a higher proportion of patients achieving good adherence to radiation protection practices compared with the control group, whereas anxiety scores were significantly lower (all $P < 0.05$). At T4, no statistically significant differences between-group differences were observed in radiation protection compliance or anxiety levels (P > 0.05). From T1 to T4, the intervention group showed significantly higher quality-of-life scores than the control group (P < 0.05). **Conclusion:** Family-participatory radiation protection transitional care combining structured education, family support, and reinforced follow-up improved radiation protection compliance, reduced anxiety levels, and enhanced quality of life among patients undergoing iodine-125 seed implantation. This intervention may provide a feasible approach for optimizing transitional care after permanent iodine-125 seed implantation.

Keywords

Iodine-125 Seed Implantation, Radiation Protection, Family Participation, Continuing Care, Knowledge-Attitude-Practice (KAP) Theory, Adherence

1. Introduction

Iodine-125 seed implantation is a form of low-dose-rate brachytherapy. It offers advantages such as minimal invasiveness, concentrated dose delivery, and limited damage to surrounding tissues, and has been used for local control and salvage treatment of various solid tumors [1]. After the procedure, patients return home while still carrying the radioactive seeds. Although the overall radiation risk is preventable and controllable, it remains necessary to continuously implement key protective measures such as "time-distance-shielding" principles and emergency management of seed dislodgement [2]. Relevant studies have shown that patients may have misperceptions about radiation risk, which can lead either to excessive fear or insufficient adherence to protective practices [3]. A study by Cui *et al.* also suggested that patients undergoing radiotherapy for tumors still show deficiencies in attention to radiation safety reminders and in the receipt of protective education [4]. The Knowledge-Attitude-Practice (KAP) theory describes the process through which health knowledge influences attitudes and subsequently promotes behavioral changes, providing a theoretical framework for designing health education and behavior modification interventions [5]. At present, discharge education for patients receiving iodine-125 seed implantation is still mainly limited to verbal instructions, lacking family participation, scenario-based practice, and continuous post-discharge support. Previous studies have shown that empowerment and structured health education can improve radiation protection compliance and psychological status after iodine-125 seed implantation [6]. Based on this, the present study developed a family-participatory radiation protection transitional care program and evaluated its effects on patients' radiation protection compliance, anxiety levels, and quality of life.

2. Research Object

Patients with solid tumors scheduled for permanent iodine-125 seed implantation were consecutively screened and enrolled from the oncology wards and follow-up center of a tertiary Class A hospital in Jingzhou between April 2025 and January 2026 according to predefined eligibility criteria. A total of 90 patients were included. This study was a single-center, two-arm parallel randomized controlled trial. Participants were numbered in the order of enrollment and allocated in a 1:1 ratio to the intervention group or the control group according to a pre-generated allocation sequence based on a random number table; allocation concealment was not implemented, and neither participants nor intervention providers were blinded. Each group comprised 45 patients. The sample size was estimated based on the primary outcome of radiation protection compliance. According to previous studies on radiation protection interventions after iodine-125 seed implantation, a moderate effect size (Cohen's d = 0.60) was assumed. With a two-sided significance level of 0.05 and statistical power of 80%, the minimum required sample size was calculated to be 36 participants per group. Considering an estimated 20% attrition rate during the 6-month follow-up period, the final target sample size was determined as 45 participants per group. Therefore, a total of 90 patients were enrolled in this study. The inclusion criteria were as follows: 1) age ≥ 18 years, pathologically confirmed solid tumor, and first-time receipt of permanent iodine-125 seed implantation; 2) clear consciousness and basic communication and comprehension abilities; 3) a primary family caregiver aged ≥18 years who lived with the patient and assumed the main caregiving responsibilities; and 4) provision of informed consent by both the patient and caregiver and voluntary participation in the study. The exclusion criteria were as follows: 1) concomitant severe organ dysfunction or end-stage disease, with an expected survival time of <6 months; 2) previous professional background related to radiotherapy or radiation protection; and 3) family caregivers who were pregnant or lactating women. All 90 participants completed the 6-month follow-up, and no missing data occurred during the study period. The participant recruitment, randomization, intervention delivery, and follow-up process were recorded throughout the study period. A total of 90 eligible patients were enrolled and randomly allocated in a 1:1 ratio to the intervention group (n = 45) or control group (n = 45). All randomized participants completed the intervention and the 6-month follow-up assessment. No withdrawals, losses to follow-up, or missing repeated-measures data occurred during the study period, and all participants were included in the final analysis.

3. Methods

3.1. Intervention Method for the Control Group

The control group received the department's current routine nursing care and standard health education. Education was typically delivered in the ward by the responsible nurse after iodine-125 seed implantation, primarily in the form of brief verbal explanations, without unified courseware, a fixed duration, or standardized operating procedures. The core content focused on the three fundamental principles of radiation protection—"time, distance, and shielding"—while advising patients to minimize close contact with sensitive populations, such as infants, young children, and pregnant women, after discharge and to reasonably limit the duration of close contact. General emergency management reminders were also provided for unexpected situations, such as suspected seed dislodgement. Regarding the use of radiation protection equipment, such as protective clothing, healthcare professionals usually offered recommendations or reminders during education; however, they did not provide continuous supervision, feedback, or reinforcement regarding whether patients actually wore such equipment. After discharge, no structured, periodic, proactive follow-up intervention was conducted, and follow-up was performed only according to the routine outpatient review process. To clarify the differences between the control and intervention groups, the intervention components and contact frequency in the two groups are compared in Table 1.

3.2. Intervention Methods for the Intervention Group

3.2.1. Establishment of the Intervention Team

A family-participatory radiation protection training intervention team was established and coordinated by the project leader. The team comprised physicians specializing in oncology, interventional medicine, radiotherapy, and nuclear medicine, oncology specialist nurses, nursing managers, and research nurses. Responsibilities were assigned by role: physicians were responsible for reviewing treatment-related risk points and key aspects of radiation safety; specialist nurses delivered the core protection content, provided skills demonstrations, and conducted scenario-based simulations; research nurses were responsible for enrollment communication, organization and implementation of training, follow-up contact, and process documentation; and nursing managers oversaw intervention quality control and consistency supervision.

3.2.2. Development of the Intervention Protocol and Pilot Testing

1) Development of the initial draft: Evidence related to home radiation protection and health education after iodine-125 seed implantation was systematically retrieved. In conjunction with common clinical cognitive biases and difficulties in home implementation, an initial draft of the intervention program was developed, accompanied by standardized training slides, key-action cards, key points for misconception clarification, scenario simulation scripts, follow-up scripts, and a Home Protection Action Plan.

2) Expert consultation: Experts in relevant fields were invited to review and revise the program in terms of content coverage, operability, cultural adaptability, and training duration and procedures, resulting in a revised draft.

3) Pilot testing: Before the formal study, a small-sample pilot test was conducted following the "enrollment-training-follow-up" process to evaluate feasibility and acceptability. Based on feedback, minor adjustments were made to the course pace, proportion of practice exercises, wording of materials, and timing of follow-up

reminders, after which the final intervention protocol and key quality control points will be finalized.

3.2.3. Implementation Process

On the basis of routine care, the intervention group received family-participatory training, in which each patient was required to designate one family caregiver to participate jointly in the training and practice sessions. The caregiver was positioned as a collaborative learner and behavioral supporter; the outcome measures in this study were assessed in patients. During hospitalization, a two-stage structured training program was completed using a closed-loop approach of "instruction-demonstration-practice-return demonstration-planning". The teach-back method was used to verify patients' understanding of key protective points and their ability to perform the required procedures; those who had not mastered them received immediate correction and reinforcement [7].

1) Stage 1: Contextualized inpatient education (30 - 40 min): Focusing on particle characteristics, radiation attenuation, and safety boundaries, executable actions based on the principles of "time-distance-shielding" were specified for the home setting, including management of contact with sensitive groups such as infants, young children, and pregnant women; control of close-contact duration; household zoning; and cleaning management of personal items. On-site visualization exercises were conducted using measuring tapes and adhesive markers, such as marking safe distances of 1.0 m and 1.5 m, to guide patients in translating abstract principles into a practicable behavioral checklist for home implementation.

2) Stage 2: Belief reinforcement and personalized action planning (30 - 40 min): Case discussion and misconception clarification were used to conduct risk communication targeting two types of bias—"excessive fear leading to avoidance and isolation" and "underestimation of risk leading to nonadherence or perfunctory adherence"—thereby strengthening perceptions of the necessity and controllability of protective behaviors. Scenario-based simulation training was also organized (e.g., suspected seed dislodgement, body fluid contamination, and communication during security screening when going out). The design and implementation of the simulations followed best-practice standards for healthcare simulation, including prebriefing, enactment, and debriefing/reflection, to improve training consistency and evaluability [8]. An individualized Home Radiation Protection Action Plan was developed based on each patient's home living conditions, specifying key goals, implementation frequency, barrier-management strategies, and forms of support from family members. Before discharge, key points were reconfirmed and supplementary training was provided using the teach-back method and a checklist of critical actions.

3.2.4. Post-Discharge Follow-Up and Consolidation

Structured follow-up was implemented after discharge: once weekly within the first month after discharge, and once each at 3 and 6 months after discharge. Follow-up was conducted using a standardized script via telephone or WeChat to check the implementation of the action plan, identify problems, provide targeted feedback, and offer necessary emotional support and referral guidance. In addition, protective measures and answers to frequently asked questions were regularly disseminated through WeChat groups, forming a closed-loop support process of "reminder-checking-feedback-reinforcement". Previous systematic reviews have shown that transitional care delivered via mobile platforms such as WeChat can significantly improve psychological outcomes, including anxiety, in patients with cancer and promote the maintenance and implementation of post-discharge health management behaviors [9].

3.2.5. Quality Control

To ensure intervention homogeneity and the reliability of the study findings, patient education and follow-up in both groups were delivered by designated research nurses, who received standardized training and passed competency assessments before implementation, and all procedures were conducted according to standard protocols. Outcome assessments were conducted by two trained nurses who were not involved in intervention implementation. However, because of the behavioral nature of the intervention, complete blinding of outcome assessors could not be guaranteed. Therefore, outcome assessment was considered unblinded, and potential measurement bias was acknowledged as a limitation of this study. Given the marked differences in the content and format of the interventions, blinding was not implemented for participants or intervention providers in this study. After enrollment, patient information files were established, including demographic and clinical characteristics, contact information, intervention implementation records (stage, duration, completion of practice sessions, and pre-discharge checklist results), follow-up completion status, and feedback, for process tracking and quality audits. Quality control personnel regularly reviewed the completeness of records and the implementation of key procedures, and any deviations identified were promptly corrected. To minimize contamination between groups, intervention materials and online push notifications for the intervention group were made available only to that group. In summary, the experimental and control groups differed in intervention recipients, degree of content structuring, mode of delivery, and post-discharge follow-up/online support; the specific comparison is shown in **Table 1**.

3.3. Evaluation of Effectiveness

1) General characteristics

The questionnaire was developed by the researchers. The patient-related section mainly included age, sex, educational level, place of residence, and per capita monthly household income. Disease- and treatment-related characteristics included the site of the current iodine-125 seed implantation (target area), tumor stage, pathological nature of the tumor treated in the current implantation, comorbid chronic diseases, and dosimetric parameters (prescription dose). Family/caregiver characteristics included the relationship between the primary caregiver and

Table 1. Comparison of interventions and contact frequency between the two groups.

Project	Control group (routine health education)	Intervention group (family-involved continuing care for radiation protection)
Intervention targets	Primarily patients (routine health education).	Patients participate jointly with one designated primary caregiver (collaborative learner/behavioral supporter).
Timing of implementation during hospitalization	Postoperative health education was provided in the ward by the responsible nurse.	Completion of two-stage structured training during hospitalization.
Education/training content framework	General emergency reminders centered on the "time-distance-shielding" principle, contact management for sensitive populations, and particle dislodgement.	Refine the principles into a checklist of actionable measures that can be implemented at home; add scenario-based scripts for clarifying misconceptions, communicating risks, addressing suspected seed dislodgement, managing bodily fluid contamination, and communicating during security screening when going out; and develop an individualized Home Radiation Protection Action Plan.
Teaching methods	Information was provided mainly through brief oral explanations; no unified courseware, fixed duration, or standardized procedures were established.	A closed-loop process of "instruction-demonstration-practice-return demonstration-planning"; the teach-back method is used to assess mastery and provide immediate corrective reinforcement.
Length of hospital stay/dose	No fixed duration (standard procedure).	Stage 1: 30 - 40 min; Stage 2: 30 - 40 min.
Standardization of Tools/Materials	Lack of unified courseware and standardized operating procedures.	Supporting standardized training materials, key action cards, scenario simulation scripts, follow-up scripts, and action plan templates.
Supervision of protective equipment use	For protective clothing and other supplies, measures were mostly limited to recommendations/reminders; continuous supervision, feedback, or reinforcement was not conducted.	Verification, feedback, and reinforcement of action plan implementation during follow-up (closed-loop support).
Post-discharge follow-up (frequency/modality)	No structured, periodic proactive follow-up intervention was conducted; follow-up was performed only according to the routine outpatient review process.	Structured follow-up: once weekly within 1 month after discharge; once each at 3 and 6 months after discharge; implementation was verified via telephone/WeChat using a standardized script, problems were identified, and feedback was provided.

the patient, family structure, and whether the patient lived with children or pregnant women. Patients in both groups completed the questionnaire at enrollment under standardized guidance from a research nurse. Information on implantation site, tumor stage, and dosimetric parameters was verified and supplemented by the research nurse using medical records and treatment planning system records to ensure the authenticity and consistency of the data.

2) Patient compliance with radiation protection

Patients' implementation of home-based radiation protection behaviors was assessed using the Questionnaire on the Implementation Status of Radiation Protection Standards in Patients after ^{125}I Seed Implantation, developed by Zhou based on the Requirements for Radiation Protection in Permanent Implantation Therapy with Seed Sources (GBZ 178-2017) [10]. The questionnaire was developed through a literature review, group discussion, two rounds of expert consultation, and a pilot survey. The expert authority coefficient was 0.89, and the Kendall coordination coefficient was 0.795 ($P < 0.001$), indicating good content validity and expert agreement. The questionnaire comprises 18 items across three dimensions: time protection (6 items), distance protection (7 items), and shielding protection (5 items), with response options of "yes", "no", and "unclear". Total and dimensional scores were calculated according to the questionnaire scoring rules. Patients who implemented ≥12 applicable items (implementation rate ≥ 66.7%) were classified as having "good standard implementation", which was used to compare changes in radiation protection compliance between the two groups before and after the intervention. For each participant, applicable items were determined according to individual household exposure conditions. For example, items related to contact with pregnant women or children were excluded from the denominator when these individuals were not present in the patient's household. Therefore, the number of applicable items and the maximum possible score could vary according to individual living circumstances. Each implemented protective behavior was assigned 1 point, whereas non-compliant or unclear behaviors were assigned 0 points. The total compliance score was calculated as the sum of completed protective behaviors. The implementation rate was calculated as the number of compliant items divided by the number of applicable items. Patients achieving an implementation rate ≥ 66.7% were classified as having good radiation protection adherence.

3) Patient anxiety level

Patient anxiety was assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale [11]. This self-report scale comprises seven items and assesses the frequency of anxiety-related symptoms over the preceding 2 weeks. It uses a 4-point Likert scoring system (0 = "not at all", 1 = "several days", 2 = "more than half the days", and 3 = "nearly every day"), with a total score ranging from 0 to 21; higher scores indicate greater anxiety severity. Scores of 5, 10, and 15 are used as the cutoffs for mild, moderate, and severe anxiety, respectively. The Chinese version of the GAD-7 has demonstrated good psychometric properties in studies of patients with cancer, with an internal consistency Cronbach's α of approximately 0.91, and can be used for anxiety screening and severity assessment [12]. The scale was completed independently by patients, while research nurses provided standardized instructions and checked for missing responses on site to ensure data completeness.

4) Assessment of quality of life in patients with malignant tumors

Assessment was conducted using the Chinese version of the European Organisation for Research and Treatment of Cancer (EORTC) QLQ-C30, version 3. This Chinese version was translated and culturally adapted by Wan *et al.*, and has demonstrated good reliability, validity, and responsiveness among Chinese patients with cancer [13]. The QLQ-C30 comprises 30 items covering five functional domains (physical, role, cognitive, emotional, and social functioning), three symptom domains (fatigue, pain, and nausea/vomiting), and one global health status domain. Items are scored using 4-point and 7-point Likert scales, and all domain scores are standardized to a 0 - 100 scale; higher functional and health status scores indicate better functioning and health, whereas higher symptom scores indicate greater symptom burden. The primary quality-of-life outcome was the global health status/QoL score of the EORTC QLQ-C30. The score was calculated according to the EORTC scoring manual using items 29 and 30 and transformed into a 0 - 100 scale. Higher scores indicated better overall health status and quality of life.

3.4. Data Collection Methods

Data were collected from both groups at five time points. At T0, on the day of admission after informed consent was obtained, the general information questionnaire was administered, and baseline assessments were completed using the Radiation Protection Standards Implementation Questionnaire, the GAD-7, and the QLQ-C30. At T1, within 24 h before discharge after the intervention, the Radiation Protection Standards Implementation Questionnaire, GAD-7, and QLQ-C30 were administered again. T2, T3, and T4 corresponded to 1 month (±7 d), 3 months (±7 d), and 6 months (±7 d) after discharge, respectively, when the same scales were completed through outpatient follow-up visits, WeChat, or telephone follow-up. Questionnaires were distributed and collected by uniformly trained researchers. Standardized informed explanations and instructions were provided before completion to ensure neutrality of responses; for participants with reading or writing difficulties, researchers provided assistance. Immediately after collection, the questionnaires were checked on site for completeness and logical consistency to ensure data validity.

3.5. Statistical Methods

Statistical analyses were performed using SPSS version 26.0. Measurement data were assessed for normality and homogeneity of variance. Normally distributed data are expressed as mean ± standard deviation ($\bar{x} \pm s$); between-group comparisons were performed using the independent-samples t test, and Welch's t test was used when variances were unequal. Non-normally distributed data are expressed as median (interquartile range), and between-group comparisons were performed using the Mann-Whitney U test. Categorical data are expressed as frequencies (n) and percentages (%), and between-group comparisons were performed using Pearson's χ^2 test, with continuity correction applied when necessary. Repeated-measures analysis of variance was used to analyze GAD-7 and EORTC QLQ-C30 scores measured at multiple time points from T0 to T4; sphericity was assessed using Mauchly's test, and Greenhouse-Geisser-corrected results were reported. Repeated-measures analysis of variance was used to analyze changes in radiation protection compliance scores across different time points, with group as the between-subject factor and time as the within-subject factor. The main effects of group, time, and group × time interaction were evaluated. When the assumption of sphericity was violated, Greenhouse-Geisser correction was applied. Simple effects analyses were subsequently performed to compare between-group differences at each time point. The proportion of patients achieving good radiation protection adherence was compared between the two groups at each time point using Pearson's χ^2 test or Fisher's exact test when appropriate. The significance level was set at $\alpha = 0.05$ (two-sided).

4. Results

4.1. Basic Characteristics of the Two Groups of Patients and Their Caregivers

A total of 90 patients were randomized into the intervention group (n = 45) and control group (n = 45). All randomized participants completed the 6-month follow-up, with no withdrawals, losses to follow-up, or missing repeated-measures data. Therefore, all participants were included in the final analysis. The mean age was 64.69 ± 10.15 years in the intervention group and 62.71 ± 9.80 years in the control group, with no significant difference between groups (P > 0.05). No significant differences were observed between the two groups in sex, educational level, place of residence, monthly household income per capita, implantation site, tumor stage, tumor characteristics, comorbid chronic diseases, prescription dose, caregiver relationship, family structure, or cohabitation with children or pregnant women (all P > 0.05), indicating that the two groups were comparable at baseline (Table 2).

Table 2. Comparison of baseline characteristics between the two groups of patients.

Project	Control group (n = 45)	Intervention group (n = 45)	Statistic (t/χ^2)	P-value
Age (years)	62.71 ± 9.80	64.69 ± 10.15	t = −0.940	0.350
Sex [n (%)]			$\chi^2 = 0.182$	0.670
Male	27 (60.00)	25 (55.56)		
Female	18 (40.00)	20 (44.44)		
Educational attainment [n (%)]			$\chi^2 = 2.609$	0.456
Primary school or below	10 (22.22)	6 (13.33)		
Junior high school/technical secondary school	17 (37.78)	14 (31.11)		
Senior high school and junior college	14 (31.11)	18 (40.00)		
Bachelor's degree or above	4 (8.89)	7 (15.56)		
Place of residence [n (%)]			$\chi^2 = 0.189$	0.664
cities	27 (60.00)	29 (64.44)		
Rural areas	18 (40.00)	16 (35.56)		

Continued

Monthly household income per capita [n (%)]			$\chi^2 = 2.285$	0.515
<2000 yuan	10 (22.22)	7 (15.56)		
CNY 2001 - 4000	17 (37.78)	13 (28.89)		
RMB 4001 - 6000	10 (22.22)	15 (33.33)		
>6000 yuan	8 (17.78)	10 (22.22)		
Site of ^{125}I seed implantation in this procedure (target area) [n (%)]			$\chi^2 = 0.508$	0.776
Lung	32 (71.11)	29 (64.44)		
liver	11 (24.44)	14 (31.11)		
Other	2 (4.44)	2 (4.44)		
Tumor stage [n (%)]			$\chi^2 = 0.182$	0.670
Stage III	25 (55.56)	27 (60.00)		
Stage IV	20 (44.44)	18 (40.00)		
Characteristics of the tumor implanted in this procedure [n (%)]			$\chi^2 = 0.291$	0.865
Primary lesion	9 (20.00)	11 (24.44)		
recurrent lesion	13 (28.89)	13 (28.89)		
Metastatic lesions	23 (51.11)	21 (46.67)		
Comorbid chronic diseases [n (%)]			$\chi^2 = 0.443$	0.506
No	17 (37.78)	14 (31.11)		
Yes	28 (62.22)	31 (68.89)		
Dosimetric parameters				
Prescription dose (Gy)	110.29 ± 6.75	111.47 ± 6.12	t = −0.867	0.388
Relationship between the primary caregiver and the patient [n (%)]*			$\chi^2 = 0.902$	0.637
Spouse	23 (51.11)	20 (44.44)		
Children	17 (37.78)	17 (37.78)		
Parents/other	5 (11.11)	8 (17.78)		
Family structure [n (%)]			$\chi^2 = 0.622$	0.733
Living alone	4 (8.89)	6 (13.33)		
Two people live together	16 (35.56)	17 (37.78)		
Living with multiple people (≥3 persons)	25 (55.56)	22 (48.89)		
Living with children or pregnant women [n (%)]			$\chi^2 = 0.207$	0.649
Yes	13 (28.89)	15 (33.33)		
No	32 (71.11)	30 (66.67)		

Note: Continuous variables are presented as mean ± standard deviation and compared using independent-samples t tests or Welch's t tests when appropriate. Categorical variables are presented as n (%) and compared using Pearson's χ^2 test. *The primary caregiver refers to the family member who provided the main daily care and support for the patient.

4.2. Comparison of Radiation Protection Compliance between the Two Groups of Patients

Radiation protection compliance scores were compared between the two groups at different time points. Repeated-measures analysis of variance was performed, with group (intervention/control) as the between-subjects factor and time (T0 - T4) as the within-subjects factor. Mauchly's test was used to assess the assumption of sphericity, and Greenhouse-Geisser correction was applied when necessary.

The repeated-measures ANOVA demonstrated significant main effects of group ($F = 18.624$, $P < 0.001$), time ($F = 286.517$, $P < 0.001$), and group × time interaction ($F = 15.836$, $P < 0.001$), indicating that radiation protection compliance changed significantly over time and that the trajectories differed between the intervention and control groups (**Table 3**).

Table 3. Overall repeated-measures ANOVA results for radiation protection compliance scores.

Effect	F	P-value
Group	18.624	<0.001
Time	286.517	<0.001
Group × time interaction	15.836	<0.001

Simple effects analysis showed that there was no statistically significant difference in compliance scores between the two groups at baseline (T0) ($P = 0.396$). Compared with the control group, the intervention group showed significantly higher compliance scores at T1, T2, and T3 (all $P < 0.05$). However, no statistically significant difference was observed between the two groups at T4 ($P = 0.896$). Compliance scores decreased gradually in both groups at T3 and T4, which may be associated with progressive radioactive decay of iodine-125 seeds and reduced need for intensive radiation protection behaviors during long-term follow-up (**Table 4**).

Table 4. Simple effects analysis of radiation protection compliance scores between the intervention and control groups at different time points.

Time point	Intervention group	Control group	F	P
T0	8.80 ± 0.47	8.25 ± 0.44	0.729	0.396
T1	12.76 ± 0.33	10.36 ± 0.27	31.223	<0.001
T2	11.79 ± 0.47	8.36 ± 0.34	35.129	<0.001
T3	9.75 ± 0.47	7.77 ± 0.37	11.062	0.001
T4	4.69 ± 0.45	4.61 ± 0.44	0.017	0.896

The proportions of patients achieving good radiation protection adherence were compared between the two groups at each follow-up time point using Pearson's χ^2 test. At baseline (T0), no significant difference was observed between the two groups, indicating comparability. From T1 to T3, the intervention group showed significantly higher rates of good adherence than the control group (all $P < 0.05$). At T4, no significant difference was observed between the two groups (Table 5).

Table 5. Comparison of good radiation protection adherence rates between the intervention and control groups at different follow-up time points.

Time point	Intervention group	Control group	χ^2 value	P-value
T0	35.56%	37.79%	0.048	0.827
T1	93.30%	42.20%	26.914	<0.001
T2	84.40%	40.00%	18.908	<0.001
T3	46.67%	22.00%	5.954	0.015
T4	8.88%	6.67%	0.155	0.694

4.3. Comparison of Anxiety Levels between the Two Groups of Patients

The repeated-measures ANOVA demonstrated significant main effects of time ($F = 268.421$, $P < 0.001$) and group ($F = 18.632$, $P < 0.001$), as well as a significant group × time interaction ($F = 6.917$, $P < 0.001$), indicating that anxiety levels changed differently over time between the intervention and control groups. Simple effects analysis showed that there was no statistically significant difference in anxiety scores between the two groups at baseline (T0) ($P = 0.402$). Compared with the control group, the intervention group showed significantly lower anxiety scores at T1 ($P = 0.007$), T2 ($P < 0.001$), and T3 ($P = 0.001$). However, no statistically significant difference was observed between the two groups at T4 ($P = 0.197$) (Table 6 and Table 7).

Table 6. Comparison of anxiety scores between the two groups of patients.

Group	T0	T1	T2	T3	T4
Intervention group	17.73 ± 3.23	13.84 ± 3.51	10.27 ± 2.96	8.38 ± 2.26	6.20 ± 1.96
Control group	17.13 ± 3.53	15.78 ± 3.10	12.73 ± 3.23	10.33 ± 3.01	6.73 ± 1.94

Table 7. Simple effects tests at different time points.

Time	Source	Sum of squares	df	Mean square	F	P-value
T0	Comparison	8.1	1	8.1	0.709	0.402
	Error	1006	88	11.432		
T1	Comparison	84.1	1	84.1	7.664	0.007
	Error	965.689	88	10.974		
T2	Comparison	136.9	1	136.9	14.247	<0.001

Continued

	Error	845.6	88	9.609		
T3	Comparison	86.044	1	86.044	12.162	0.001
	Error	622.578	88	7.075		
T4	Comparison	6.4	1	6.4	1.686	0.197
	Error	334	88	3.795		

4.4. Comparison of Quality of Life between the Two Groups of Patients

Repeated-measures analysis of variance (ANOVA) was used to compare quality-of-life scores between the two groups at different time points, with group (intervention/control) as the between-subjects factor and time (T0 - T4) as the within-subjects factor. The analyzed outcome was the global health status/QoL score of the EORTC QLQ-C30. Mauchly's test indicated that the assumption of sphericity was violated ($P < 0.05$); therefore, the Greenhouse-Geisser correction was applied.

The repeated-measures ANOVA demonstrated significant main effects of group ($F = 22.514$, $P < 0.001$), time ($F = 31.872$, $P < 0.001$), and group × time interaction ($F = 8.426$, $P < 0.001$), indicating that quality-of-life trajectories differed significantly between the intervention and control groups over time. Simple effects analysis showed that there was no statistically significant difference in quality-of-life scores between the two groups at baseline (T0) ($P = 0.698$). Compared with the control group, the intervention group showed significantly higher quality-of-life scores at T1 ($P = 0.028$), T2 ($P < 0.001$), T3 ($P = 0.020$), and T4 ($P < 0.001$) (Table 8 and Table 9).

Table 8. Comparison of EORTC QLQ-C30 global health status/QoL scores between the two groups.

Group	T0	T1	T2	T3	T4
intervention group	81.42 ± 9.65	86.42 ± 8.82	96.42 ± 2.5	89.29 ± 8.53	87.18 ± 4.23
Control group	80.62 ± 9.84	82.38 ± 8.36	88.78 ± 3.98	84.91 ± 9.02	82.76 ± 6.85

Table 9. Simple effects analysis of between-group differences in EORTC QLQ-C30 global health status/QoL scores at different time points.

Time	Source	Sum of squares	df	Mean square	F	P-value
T0	Comparison	14.4	1	14.4	0.152	0.698
	Error	8363.556	88	95.04		
T1	Comparison	368.044	1	368.044	4.98	0.028
	Error	6503.556	88	73.904		
T2	Comparison	1314.844	1	1314.844	118.947	<0.001

Continued

	Error	972.756	88	11.054		
T3	Comparison	431.211	1	431.211	5.594	0.02
	Error	6782.889	88	77.078		
T4	Comparison	440.011	1	440.011	13.582	<0.001
	Error	2850.889	88	32.396		

5. Discussion

5.1. Family-Participatory Radiation Protection Transitional Care Improves Radiation Protection Compliance after Iodine-125 Seed Implantation

This study demonstrated that family-participatory radiation protection transitional care significantly improved radiation protection adherence during hospitalization and the early post-discharge period (T1 - T3), but the between-group difference was no longer significant at 6 months (T4). At follow-up to T4, the between-group difference was no longer significant, and adherence indicators declined in both groups, suggesting that the intervention effect may diminish over time and may also be related to reduced protection needs after radiation attenuation. These findings are consistent with previous studies on empowerment management and related approaches [6], indicating that intervention strategies centered on capacity building, enhancement of self-efficacy, and continuous support may help improve the implementation of protective behaviors. In this study, caregivers jointly participated in training and scenario-based practice, teach-back verification, and action plan development, enabling families to assume reminder and support roles after discharge and thereby enhancing the operability and stability of protective behaviors. From mechanistic and evidence-based perspectives, iodine-125 seed implantation is a form of low-dose-rate brachytherapy, and the overall radiation risk is controllable; however, safety depends on patients' sustained implementation of key measures such as time, distance, and shielding in real-life contexts [1]. Relevant dosimetric studies also support that, provided protective strategies are implemented according to standards, external exposure can be controlled within an acceptable range [14]. Therefore, this study provides evidence for optimizing routine verbal instruction into a continuity-of-care pathway characterized by family participation, scenario-based training, and follow-up reinforcement. From the perspective of the Knowledge-Attitude-Practice (KAP) theory, family-participatory training can strengthen protection-related knowledge and risk awareness, enhance perceived controllability, and, with caregivers' reminders and assistance, promote the sustained implementation of protective behaviors, thereby reducing concerns and alleviating anxiety. This study only evaluated the intervention effect and did not directly measure knowledge, attitudes, or mechanistic pathways.

5.2. Family-Involved Continuous Radiation Protection Care Can Reduce Anxiety Levels in Patients Undergoing Iodine-125 Seed Implantation

The results of this study showed no statistically significant difference in baseline (T0) anxiety scores between the two groups. After the intervention, the anxiety score in the intervention group at T1 (24 h before discharge) was significantly lower than that in the control group, and this difference persisted at T2 (1 month after discharge) and T3 (3 months after discharge), suggesting that family-participatory continuing care for radiation protection exerted an immediate to short- and medium-term anxiolytic effect. By T4 (6 months after discharge), the between-group difference was no longer significant, indicating an attenuation of the long-term effect. The underlying mechanisms may be as follows: during the transition to home care while carrying the radioactive source, patients are prone to anxiety due to uncertainty about risks. Through scenario-based education, rehearsal of key procedures, and teach-back verification, the training translated the principles of "time-distance-shielding" into actionable strategies, while caregivers provided reminders and support, thereby enhancing patients' perceived risk controllability and self-efficacy and reducing anxiety. After patients entered the long-term home-care stage, they gradually adapted, became more proficient in protective measures, and obtained more follow-up examinations and information; together with radiation decay, these factors reduced the perceived threat, leading to decreased anxiety in the control group as well and a narrowing of the between-group difference. Previous studies have also suggested that the effects of education and communication interventions on anxiety are generally more pronounced in the early stage and tend to converge later: Liu *et al.* reported mid-term improvement, whereas the difference weakened at the end of follow-up [15]. Atwood *et al.* also confirmed that the benefits of counseling were more prominent in the early stage [16]; Lim *et al.* observed an immediate reduction in anxiety after brachytherapy, but the follow-up effect diminished [17]. Accordingly, intensified follow-up or supplementary training (e.g., digital reminders and refresher training in risk communication) is recommended at 3 - 6 months after discharge to consolidate long-term emotional benefits.

5.3. Family-Involved Radiation Protection Continuing Care Can Improve Quality of Life in Patients Undergoing Iodine-125 Seed Implantation

The results of this study showed no statistically significant difference in quality-of-life scores between the two groups at baseline (T0), indicating comparability. After the intervention, quality-of-life scores in the intervention group were significantly higher than those in the control group at T1 - T4, suggesting that family-participatory radiation protection-based transitional care confers sustained benefits for health-related quality of life in patients undergoing iodine-125 seed implantation. Notably, scores in both groups peaked at T2 and then declined at T3 and T4, with a gradual narrowing of between-group differences, indicating that quality of life is influenced by multiple factors, including disease progression, treatment burden, and adaptation over time, and that the long-term intervention effect may be partially attenuated. This finding is consistent with previous evidence that structured nursing interventions improve quality of life: a randomized controlled study by Choi *et al.* showed that nurse-led supportive care improved functional domains related to the EORTC QLQ-C30 and yielded quality-of-life benefits [18]; Liu *et al.* also reported that individualized nursing, through symptom assessment, psychological support, and lifestyle guidance, significantly improved overall QLQ-C30 quality of life in patients with lung cancer and alleviated fatigue, pain, and emotional functioning [19]; and a telenursing educational intervention by Muñoz-Villaverde *et al.* similarly demonstrated improvements in quality of life, suggesting that "continuous education plus follow-up support" is an important pathway [20]. Considering the characteristics of the intervention in this study, family-participatory radiation protection-based transitional care contextualizes and operationalizes key principles such as "time, distance, and shielding", while strengthening daily implementation through caregiver support. This approach may help reduce uncertainty and avoidance behaviors associated with living at home with radioactive sources, and may promote self-management and recovery of social functioning. In addition, improved adherence and reduced anxiety may jointly enhance QLQ-C30 dimensions such as emotional and role functioning, thereby increasing overall quality of life. These findings suggest that family co-participation, contextualized rehearsal, and continuous post-discharge support should be incorporated into continuity-of-care pathways, and that future studies should further evaluate their long-term effects and associated influencing factors.

6. Conclusions

This study developed and implemented a family-participatory radiation protection transitional care program, integrating family support, scenario-based training, and structured post-discharge follow-up into the continuous peri-discharge care of patients undergoing iodine-125 seed implantation. The results showed that this model could significantly improve patients' radiation protection compliance and adherence to standard protective practices before discharge and during the short- to medium-term period after discharge, while also reducing anxiety levels during the same stages. Patients' quality of life was generally better than that of the routine education group at all follow-up time points; however, quality of life in both groups showed a temporal trend of "initial improvement followed by decline", and the between-group differences gradually narrowed over time. By the 6-month follow-up, the between-group differences in compliance and anxiety were no longer statistically significant, suggesting that the long-term advantage of the intervention may weaken over time. Overall, this study provides preliminary evidence for home-based radiation safety management and transitional care for patients carrying iodine-125 seeds after implantation, and may offer a reference for the design and implementation of related nursing interventions.

This study still has several limitations. First, it was a single-center study with a limited sample size, so the generalizability of the findings requires further verification. Second, due to practical constraints in implementing the clinical nursing intervention. Although random allocation was performed, allocation concealment was not implemented, and blinding of participants, intervention providers, and outcome assessors was not feasible because of the nature of the behavioral intervention. Third, the intervention in the intervention group included multiple components, such as family participation, structured training, scenario-based drills, and follow-up support, making it difficult to determine the independent effect of each component. Future studies should adopt multicenter designs with larger samples and longer follow-up, and further optimize stratified follow-up and stage-specific reinforcement strategies to better verify the long-term effectiveness and applicability of the intervention.

Author Contributions

Conceptualization, Ailian Zhao and Li Li; methodology, Ailian Zhao and Li Li; validation, Ailian Zhao, Li Li, and Yachun Yao; formal analysis, Ailian Zhao; investigation, Ailian Zhao and Yachun Yao; resources, Li Li and Yachun Yao; data curation, Ailian Zhao; writing—original draft preparation, Ailian Zhao; writing—review and editing, Li Li and Yachun Yao; visualization, Ailian Zhao; supervision, Li Li; project administration, Li Li and Yachun Yao. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] He, S.Y., Kang, B.G. and Huang, J. (2023) Progress of ^{125}I Seeds Implantation Technology in the Treatment of Malignant Tumors. *Chinese Journal of Nuclear Medicine and Molecular Imaging*, **43**, 48-51. (In Chinese)

[2] Chuang, H.D., Lin, Y.H., Lin, C.H., Lai, Y., Wu, C. and Hsu, S. (2024) Radiation Safety Assessment in Prostate Cancer Treatment: A Predictive Approach for I-125 Brachytherapy. *Cancers*, **16**, Article 1790. https://doi.org/10.3390/cancers16101790

[3] Novak, J., Ladbury, C., Abuali, T., Tam, A., Brower, J., Evans, B., *et al.* (2025) Patient Perceptions of Radiation Therapy Prior to Initial Consultation with a Radiation Oncologist. *Advances in Radiation Oncology*, **10**, Article ID: 101676. https://doi.org/10.1016/j.adro.2024.101676

[4] Cui, D., Wang, P., Kong, L., Wang, J., Tang, C. and Liang, J. (2025) Knowledge, Attitude, and Practice of Cancer Patients regarding Radiotherapy and Radiation Protection. *Frontiers in Oncology*, **15**, Article 1432187. https://doi.org/10.3389/fonc.2025.1432187

[5] Zarei, F., Dehghani, A., Ratansiri, A., Ghaffari, M., Raina, S., Halimi, A., *et al.* (2024) ChecKAP: A Checklist for Reporting a Knowledge, Attitude, and Practice (KAP) Study.

Asian Pacific Journal of Cancer Prevention, **25**, 2573-2577. https://doi.org/10.31557/apjcp.2024.25.7.2573

[6] Expert Consensus Group on Overall Management of Particle Implantation Therapy Care, *et al.* (2024) Expert Consensus on Whole-Process Management of Nursing Care for Percutaneous Radioactive Particle Implantation. *Journal of Practical Oncology*, **39**, 393-400. (In Chinese)

[7] Oh, S., Choi, H., Oh, E.G. and Lee, J.Y. (2023) Effectiveness of Discharge Education Using Teach-Back Method on Readmission among Heart Failure Patients: A Systematic Review and Meta-Analysis. *Patient Education and Counseling*, **107**, Article ID: 107559. https://doi.org/10.1016/j.pec.2022.11.001

[8] Watts, P.I., McDermott, D.S., Alinier, G., Charnetski, M., Ludlow, J., Horsley, E., *et al.* (2021) Healthcare Simulation Standards of Best Practicetm Simulation Design. *Clinical Simulation in Nursing*, **58**, 14-21. https://doi.org/10.1016/j.ecns.2021.08.009

[9] Wang, Z., Deng, S., Lv, H., Fan, Y., Zhang, L. and Wang, F. (2023) Effect of WeChat-Based Continuous Care Intervention on the Somatic Function, Depression, Anxiety, Social Function and Cognitive Function for Cancer Patients: Meta-Analysis of 18 RCTs. *Nursing Open*, **10**, 6045-6057. https://doi.org/10.1002/nop2.1916

[10] Zhou, S.S. (2021) Investigation and Analysis of the Current Status of Radiation Protection Standard Implementation in Patients after ^{125}I Seed Implantation. Master's Thesis, Soo-Chow University.

[11] Kertz, S., Bigda-Peyton, J. and Bjorgvinsson, T. (2012) Validity of the Generalized Anxiety Disorder-7 Scale in an Acute Psychiatric Sample. *Clinical Psychology & Psychotherapy*, **20**, 456-464. https://doi.org/10.1002/cpp.1802

[12] Tian, R., Wang, S., Ji, Z., Li, J., Zhang, J., Zhang, S., *et al.* (2025) Association between Emotional Distress and the Efficacy of Advanced Gastric Cancer Patients Undergoing Treatment with Immune Checkpoint Inhibitors: A Cohort Study and Propensity Score Matching Study. *Frontiers in Oncology*, **15**, Article 1516643. https://doi.org/10.3389/fonc.2025.1516643

[13] Wan, C.H., Chen, M.Q., Zhang, C.Z., *et al.* (2005) Introduction of the Chinese Version of EORTC QLQ-C30 Quality of Life Questionnaire for Cancer Patients. *Journal of Practical Oncology*, **20**, 353-355. (In Chinese)

[14] Chuang, H., Lin, Y., Lin, C., Feng, C., Chui, C., Wu, C., *et al.* (2025) Assessment of External Radiation Exposure Dose Rates and Protective Strategies Following I-125 Permanent Prostate Implantation Treatment. *Radiation Physics and Chemistry*, **236**, Article ID: 112920. https://doi.org/10.1016/j.radphyschem.2025.112920

[15] Liu, G., Zhang, H., Li, J., Pang, G., Ying, L. and Xu, Y. (2025) Evaluating the Effect of Patient Education Led by Medical Physicists on Anxiety and Depression Induced by Radiotherapy. *Scientific Reports*, **15**, Article No. 40695. https://doi.org/10.1038/s41598-025-24244-9

[16] Atwood, T.F., Brown, D.W., Murphy, J.D., Moore, K.L., Juang, T., Azuara, A., *et al.* (2023) Examining the Effect of Direct Patient Care for Medical Physicists: A Randomized Prospective Phase III Trial. *International Journal of Radiation Oncology Biology Physics*, **115**, 224-232. https://doi.org/10.1016/j.ijrobp.2022.05.014

[17] Lim, K.H. (2024) Effects of Integrated Music-Video Therapy on Pain and Anxiety during High-Dose-Rate Brachytherapy. *Pain Management Nursing*, **25**, e223-e229. https://doi.org/10.1016/j.pmn.2024.01.006

[18] Choi, Y.Y., Hong, B., Rha, S.Y., Cho, S., Lee, H.S. and Lee, J. (2025) The Effect of Nurse-Led Enhanced Supportive Care as an Early Primary Palliative Care Approach for Patients with Advanced Cancer: A Randomized Controlled Trial. *International Journal*

of Nursing Studies, **168**, Article ID: 105102. https://doi.org/10.1016/j.ijnurstu.2025.105102

[19] Liu, Y. and Guo, H. (2025) Impact of Personalized Nursing on the Quality of Life in Lung Cancer Patients. *Frontiers in Oncology*, **15**, Article 1650066. https://doi.org/10.3389/fonc.2025.1650066

[20] Muñoz-Villaverde, S., Martínez-García, M., Serrano-Oviedo, L., Gómez-Romero, F.J., Sobrado-Sobrado, A.M., Cidoncha-Moreno, M.Á., *et al.* (2024) Impact of Telenurse-Led Intervention in Clinical Trials on Health Literacy, Empowerment, and Health Outcomes in Patients with Solid Tumours: A Pilot Quasi-Experimental Study. *BMC Nursing*, **23**, Article No. 86. https://doi.org/10.1186/s12912-023-01641-x