



## Original Article

# Enhancing self-care implementation and reducing marker detachment rates in cancer radiotherapy patients through diverse nursing care strategies

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## ABSTRACT

**Objectives:** During radiation therapy, clear and stable body-surface markers are essential for accurate patient positioning. Peer benchmarking across four Taiwanese tertiary centers (January 2023–Mar 2024) revealed marker detachment rates of 0.8%–10.7%, whereas our in-house audit documented 15%, underscoring a significant quality gap (unpublished institutional quality assurance data). Marker detachment or fading commonly occurs due to daily activities, hygiene routines, and patient-specific factors, adversely affecting treatment accuracy, prolonging treatment duration, and increasing patient anxiety and medical costs. This study aimed to reduce the rate of marker detachment in radiotherapy patients from the previous level of approximately 15% to below 5%, thereby decreasing repositioning time, treatment delays, patient anxiety, family inconvenience, and hospital resource expenditure. **Materials and Methods:** This was a single-center pre–post comparative study conducted from January to June 2023. Two hundred cancer patients undergoing radiation therapy participated in this study. Patients were classified using an in-house-developed red–green light marking system based on body mass index (BMI >25 or ≤25), educational level (high school or below and above high school), and presence of a specific caregiver. Patients with higher risk (BMI >25, education level ≤ high school, and no specific caregiver) received weekly education sessions emphasizing marker maintenance, whereas lower-risk patients received sessions at the beginning, middle, and near the end of treatment. Interventions included personalized educational pamphlets, hypoallergenic adhesive patches, standardized marker pen replacements, and systematic tracking using the MOSAIQ® Radiation Oncology Management System (Elekta AB, Sweden). Data on marker detachment rates, repositioning times, and patient anxiety (Beck Anxiety Inventory) were collected before and after implementation. Statistical analyses, including paired *t*-tests, were conducted to assess the significance of observed changes. **Results:** After the implementation of interventions, marker repositioning incidents significantly decreased from 82 instances (average 102.5 min/month) to 7 instances (average 23.4 min/month) ( $P < 0.001$ ). The marker detachment rate was effectively reduced from approximately 15% to 3.5%, achieving the targeted goal. In addition, patient anxiety scores significantly decreased from an average of 5 points to 3 points ( $P < 0.001$ ), reflecting clinically meaningful improvement. **Conclusion:** The implementation of a structured nursing intervention program, featuring a red–green light marking system, personalized education, and systematic management, effectively decreased marker detachment rates, repositioning times, and patient anxiety. These improvements highlight the feasibility and effectiveness of integrating such interventions into routine radiation oncology practice, ultimately enhancing treatment accuracy, patient comfort, and resource efficiency.

**KEYWORDS:** *Anxiety, Marker detachment, Patient education, Quality improvement, Radiotherapy*


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## INTRODUCTION

Radiation therapy plays a critical role in modern cancer treatment, where precise patient positioning ensures accurate delivery of radiation doses to targeted tumor regions, while minimizing radiation exposure to surrounding healthy tissues [1,2]. Accurate positioning relies significantly on stable body surface markers established after computed tomography-based localization. These markers, typically drawn with skin markers or indicated by adhesive positioning tapes, serve as critical reference points throughout the radiotherapy course [3-5].

However, in clinical practice, these essential markers often fade or detach due to daily patient activities, bathing, sweating, friction from clothing, allergic reactions to adhesive tapes, and insufficient understanding of marker maintenance [6-8]. Marker detachment or fading negatively impacts treatment accuracy, extends treatment duration due to repositioning, and leads to increased medical costs and heightened patient anxiety [9,10]. The stability of these markers, therefore, directly affects the quality and efficiency of patient care in radiation oncology.

Internationally, methods to improve marker stability typically include permanent skin tattoos using India ink or semipermanent marking techniques. These methods have shown significant benefits in reducing marker detachment rates [11-14]. However, in Taiwan, cultural factors and patient preferences limit the widespread use of permanent tattoos, with oil-based pens and adhesive tapes remaining common practice. This local preference poses unique clinical challenges, as these temporary markers are inherently prone to fading and detachment, necessitating frequent replacements and remarking sessions [15,16].

Despite recognizing marker detachment as a clinical issue, existing literature predominantly focuses on marker types, materials, and tattooing methods, with limited research specifically addressing the problem of marker detachment through nursing interventions or patient education [17-19]. Furthermore, domestically, there is a lack of systematic research on the scale of marker detachment, related nursing interventions, and clearly defined goals for improving marker maintenance rates.

Accurate skin marker preservation is critical for reproducible patient setup in external beam radiotherapy, yet reported detachment rates vary from 3% to 17% worldwide, leading to treatment delays and workflow disruption. Although Taiwan lacks a nationwide registry, unpublished institutional quality-assurance (QA) data collected from four tertiary medical centers between January 2023 and March 2024 indicate an average detachment rate of 0.8%–10.7%. During the same period, our center documented a markedly higher baseline rate of 15%, highlighting a gap that prompted the tailored, theory-driven intervention evaluated in this study. To align our practice with national standards and improve patient outcomes, we established an internal target to reduce marker detachment to below 5%. This target was chosen based on a careful review of available peer data from regional centers,

representing a practical, achievable improvement within our clinical context.

Conceptual framework – self-efficacy theory guided by Bandura’s self-efficacy theory, which states that confidence in one’s ability to perform a behavior predicts both execution and persistence; our intervention was designed to strengthen patients’ belief in maintaining skin markers. Repeated demonstration, graded mastery experiences, and positive verbal persuasion have proven effective in enhancing self-care adherence among oncology patients. By stratifying patients with a red–green light system and providing tailored, iterative coaching, we operationalized all four self-efficacy sources – mastery experience, vicarious experience, verbal persuasion, and regulation of physiological state – thereby offering a theory-driven rationale for the anticipated reduction in marker detachment [20-22].

Therefore, this study aimed to systematically investigate the effectiveness of a comprehensive nursing intervention strategy – including a novel red–green light patient classification and tailored educational approach – to significantly reduce marker detachment rates in radiation oncology patients. The findings are expected not only to enhance patient satisfaction and reduce anxiety and treatment delays but also to establish a replicable, evidence-based nursing protocol suitable for broader clinical implementation in radiation oncology practice.

## MATERIALS AND METHODS

### Study design

This study employed a single-center, pre–post comparative research design conducted at Chung Shan Medical University Hospital’s Radiation Oncology Department. We assessed the effectiveness of a structured nursing intervention strategy aimed at reducing marker detachment rates among cancer patients receiving radiotherapy. Data collection was conducted prospectively from January to June 2023, comparing outcomes before and after implementing the intervention measures.

### Study participants

Patients undergoing radiation therapy at Chung Shan Medical University Hospital were recruited consecutively based on the following inclusion and exclusion criteria:

#### *Inclusion criteria*

- Diagnosed cancer patients receiving radiation therapy
- Age  $\geq 18$  years
- Able to communicate clearly and comprehend instructions in Mandarin Chinese
- Provided written informed consent.

#### *Exclusion criteria*

- Patients with impaired consciousness or cognitive deficits preventing clear communication
- Patients not undergoing active radiotherapy treatment.

### Sampling method and sample size

Convenience sampling was used, enrolling consecutive eligible patients. Sample size estimation was based on detecting a reduction in marker detachment from 15% to 5%,

using a significance level (alpha) of 0.05, power of 80%, and an anticipated attrition rate of approximately 10%, leading to a final enrollment of 200 patients to ensure sufficient statistical power [23].

### Ethics approval and consent to participate

This study was conducted according to a protocol approved by the Institutional Review Board of Chung Shan Medical University Hospital and in accordance with the standards of good clinical practice. The approval number was CS2-22203. This study was conducted in accordance with the Declaration of Helsinki. All enrolled participants received oral and written information about the study and provided written informed consent. No deviation from the plan was carried out. After quality control review, the uploaded study files are posted on the ClinicalTrials.gov public website. File NCT Identification Number was NCT00806117, first registered on February 07, 2023, and last published on February 13, 2023.

### Intervention and implementation protocol

#### *Patient classification: Red–green light system*

An innovative patient classification system using a “red–green light” method was developed based on clinical experience and published literature regarding risk factors for marker detachment:

- High risk (red group): Patients who met one or more of the following criteria:
  - Body mass index (BMI) >25
  - Education level of high school or below
  - No specific caregiver available.
- Low risk (green group): Patients meeting all the following criteria:
  - BMI ≤25
  - Education level above high school
  - Specific caregiver consistently available.

Patients were clearly identified using colored stickers (red or green) on their medical records and individual patient happiness cards.

#### *Nursing intervention and educational approach*

Customized education interventions were provided according to patient risk levels:

- Red group (high risk):
  - Received weekly one-on-one educational counseling sessions emphasizing marker care and maintenance
  - Education included verbal instructions, hands-on demonstration, visual aids (educational leaflets), and audiovisual materials (short video clips)
  - Emphasized critical factors such as appropriate bathing techniques, clothing choices, avoidance of marker friction, and hypoallergenic tape application.
- Green group (low risk):
  - Received educational interventions on day 1, day 10, and day 25 of treatment
  - Educational materials included printed leaflets clearly illustrating marker maintenance techniques, supported by concise verbal explanations.

#### *Additional intervention measures*

Several measures were implemented systematically for all patients:

- Consistent Replacement Schedule for Marker Pens: Marker pens used for positioning lines were systematically replaced after every 50 uses to maintain consistency and reduce skin discomfort
- Hypoallergenic Adhesive Patches: Patients with sensitivity to standard adhesive tapes were provided hypoallergenic alternatives, individually selected based on their skin type and reactions
- Patient Education Leaflets: Developed and provided in-house, these leaflets detailed essential marker maintenance techniques and highlighted common pitfalls leading to marker detachment.

#### *Data collection tools and measurements*

The following validated and reliable measurement tools and methods were employed:

- Marker detachment rate and repositioning incidence: Data on instances of marker fading or detachment requiring repositioning were systematically recorded in the MOSAIQ® Radiation Oncology Management System (Elekta AB, Sweden), providing accurate longitudinal data for comparison before and after intervention [24]
- Beck Anxiety Inventory (BAI): We explicitly described its established high reliability (Cronbach’s alpha = 0.92) and provided supporting validation studies from previous literature [25,26]. The scoring method (total scores from 0 to 63) was clearly presented
- Patient Satisfaction Questionnaire: It has elaborated on its development process involving expert consensus and pilot testing. Reliability (Cronbach’s alpha = 0.88), validity, and scoring methods (1–5 Likert scale) are now clearly indicated, supported by references [27,28]
- Supply and Cost Tracking: Data regarding the consumption of medical supplies (e.g., hypoallergenic adhesive patches and marker pens) and staff overtime were systematically tracked by the hospital’s administrative department, enabling detailed cost analysis.

#### *Data collection procedures*

- Preintervention data (marker detachment incidents, repositioning times, anxiety levels, patient satisfaction, and cost data) were collected for 3 months before implementation (January to March 2023)
- Postintervention data collection was conducted for 3 months following the implementation period (April to June 2023)
- Consistent monthly meetings were held among research team members to ensure adherence to intervention protocols and consistent data collection practices
- Local Benchmark Data: Annual QA reports from tertiary radiation-oncology centers in Taiwan were reviewed to establish a contemporary local benchmark for marker detachment rates. Each center prospectively logs weekly incidences of marker fading or detachment as part of its ISO-certified QA program. Deidentified aggregated data covering January 2023 to March 2024 were shared with the present authors upon request. Because these figures have not been formally published, they are cited herein as unpublished institutional data and were used solely for contextual comparison rather than hypothesis testing.

## Statistical analysis

Data analysis was conducted using IBM SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means, standard deviations (SDs), frequencies, and percentages, were calculated for demographic variables and outcomes. Paired-sample *t*-tests were employed to compare pre- and postintervention differences for continuous variables such as anxiety levels, repositioning time, and marker detachment rates. Statistical significance was defined as  $P < 0.05$ . Subgroup analyses comparing pre- and postintervention outcomes in the high-risk (red) versus low-risk (green) cohorts were performed using paired *t*-tests; *P* values were adjusted with the Bonferroni correction to account for multiple comparisons (adjusted  $\alpha = 0.025$ ).

## RESULTS

### Patient demographics

The study included 200 participants (110 male and 90 female), with an average age of 56.4 years (SD  $\pm$  10.2 years). Among them, 78 patients (39%) were classified into the high-risk (red) group and 122 patients (61%) into the low-risk (green) group. The average BMI was 24.9 ( $\pm$ 3.8), with 52% having education levels of high school or below.

### Marker detachment and repositioning rates

Before implementing the intervention, there were a total of 82 marker repositioning incidents over 3 months, averaging 27.3 per month, equivalent to a marker detachment rate of approximately 15%. After the intervention, incidents decreased dramatically to a total of 7 occurrences, averaging 2.3 per month, resulting in a significantly lower marker detachment rate of 3.5%. Statistical analysis confirmed that this reduction was highly significant [ $t = 14.85$ ,  $df = 199$ , paired *t*-test,  $P < 0.001$ ; Table 1].

### Treatment table repositioning time

The cumulative repositioning time before intervention totaled 1,230 min, averaging 410 min per month. After intervention implementation, cumulative repositioning time decreased significantly to 70 min, averaging only 23.4 min per month. Statistical tests revealed this reduction to be statistically significant [ $t = 18.22$ ,  $df = 199$ , paired *t*-test,  $P < 0.001$ ; Table 2].

**Table 1: Marker detachment and repositioning incidents (before vs. after intervention)**

Period	Total incidents	Average per month	Detachment rate (%)	<i>t</i> (df=199)	<i>P</i>
Preintervention	82	27.3	15.0	14.85	<0.001
Postintervention	7	2.3	3.5		<0.001

**Table 2: Total repositioning time on treatment table (before vs. after intervention)**

Period	Total time (min)	Average per month (min)	<i>t</i> (df=199)	<i>P</i>
Preintervention	1230	410.0	18.22	<0.001
Postintervention	70	23.4		

### Patient anxiety levels (Beck Anxiety Inventory)

Patient anxiety levels, measured by the BAI, showed significant improvement postintervention. Mean anxiety scores decreased from 5.0 (SD  $\pm$  1.2) preintervention to 3.0 (SD  $\pm$  0.9) postintervention, representing a statistically significant improvement ( $t = 12.60$ ,  $df = 199$ , paired *t*-test,  $P < 0.001$ ). This reduction indicated clinically meaningful improvements in patient anxiety related to treatment positioning, as shown in Table 3.

### Patient satisfaction

The overall patient satisfaction rate improved substantially after the intervention, increasing to 96% postintervention compared to 74% preintervention. Statistical analysis confirmed significant improvement in patient satisfaction ( $t = 10.45$ ,  $df = 199$ , paired *t*-test,  $P < 0.001$ ), as shown in Table 3.

### Cost and resource utilization

Monthly overtime costs associated with patient repositioning decreased significantly from an average of 6888 NTD per month preintervention to 1378 NTD postintervention, amounting to an annual saving of 66,120 NTD. In addition, the use of hypoallergenic adhesive patches decreased from 228 applications (13,680 NTD) preintervention to 35 applications (2100 NTD) postintervention, representing substantial savings in material resources ( $t = 13.30$ ,  $df = 199$ ,  $P < 0.001$ ). Detailed results are shown in Table 4.

### Subgroup analysis

Marker detachment reduction was greater in the high-risk (red) group compared to the low-risk (green) group (red: 17.8% to 4.2%, green: 12.3% to 3.1%,  $t = 3.42$ ,  $df = 198$ ,  $P = 0.001$ ). Anxiety scores improved significantly more in the high-risk group (red: 5.7–3.1, green: 4.5–2.9,  $t = 2.75$ ,  $df = 198$ ,  $P = 0.006$ ). Detailed results are shown in Table 5.

## DISCUSSION

This study systematically evaluated the effectiveness of an innovative nursing intervention combining patient classification, targeted educational strategies, and standardized marker management protocols to reduce marker detachment rates among radiotherapy patients. Our results demonstrated significant improvements across multiple clinically relevant outcomes, including marker detachment rates, patient anxiety, patient satisfaction, and resource utilization.

### Comparison with previous literature

The marker detachment rate in the present study fell from 15.0% to 3.5% (absolute reduction 11.5%). This endpoint is better than the 7.2% residual rate reported in the United Kingdom for tattoo-free surface-guided setup [11] and modestly lower than the 4.8% achieved with organic tattoo seals in a Japanese cohort [29] or the 5.1% observed in the Portuguese COMFORTATTOO trial that employed electric marking pens [30]. The larger effect size in our setting may stem from our theory-based, risk-stratified education for high-risk patients and the relatively high baseline detachment rate associated with oil-based pen markings that are culturally preferred in Taiwan.

Our absolute reduction of 11.5% in marker detachment rate exceeds the 8% pooled improvement reported by

Naidoo and Leech [31] in their systematic review of surface-guided radiotherapy and is marginally larger than the 10% reduction observed in a recent Japanese cohort that used temporary organic tattoo seals [29]. These results suggest that a theory-driven, risk-stratified educational model can achieve at least comparable, if not superior, effectiveness relative to technological alternatives.

**Theoretical implications and contributions**

The greater decline in detachment among high-risk (red) patients (-13.6%) compared with low-risk (green) patients (-9.2%) supports the self-efficacy hypothesis that targeted mastery experiences and verbal persuasion disproportionately benefit individuals with initially low confidence. The parallel improvement in anxiety scores likewise suggests that enhanced self-efficacy moderates psychological distress during radiotherapy positioning, echoing findings from skin-care self-management programs in chemotherapy populations [20-22].

**Clinical relevance and practical implications**

The marked improvement observed in marker detachment rates – from approximately 15% to 3.5% – reflects substantial clinical value. Notably, reduced repositioning frequency significantly shortened treatment durations and improved patient experiences. The accompanying reduction in anxiety scores (BAI from 5.0 to 3.0) suggests clinically meaningful alleviation of psychological distress associated with radiotherapy treatment positioning. Clinicians and nursing staff should consider integrating structured education protocols and individualized risk assessments into standard radiation oncology care routines to optimize treatment accuracy, enhance patient compliance, and reduce anxiety.

**Table 3: Patient-reported outcomes before versus after intervention (anxiety and satisfaction)**

Outcomes	Preintervention	Postintervention	t (df=199)	P
BAI anxiety, mean±SD	5.0±1.2	3.0±0.9	12.60	<0.001
Satisfaction (%)	74	96	10.45	<0.001

SD: Standard deviation, BAI: Beck anxiety inventory

**Table 4: Resource utilization and cost savings (before vs. after intervention)**

Items	Preintervention	Postintervention	t (df=199)	P
Overtime (NTD/month)	6888	1378	13.30	<0.001
Hypoallergenic patches (n)	228	35	11.56	<0.001
Marker pens (n)	200	20	12.90	<0.001

All differences presented were statistically significant at  $P<0.001$ , paired *t*-test. NTD: New Taiwan dollar

**Table 5: Subgroup analysis of marker detachment rates and anxiety scores**

Outcome measures	Red group (high-risk)	Green group (low-risk)	t (df=198)	P
Marker detachment (%)	17.8 → 4.2 (Δ=13.6)	12.3 → 3.1 (Δ=9.2)	3.42	0.001
Patient anxiety (BAI score)	5.7 → 3.1 (Δ=2.6)	4.5 → 2.9 (Δ=1.6)	2.75	0.006

Δ represents the difference between before and after intervention. BAI: Beck Anxiety Inventory

Furthermore, the program generated an annual saving of 83 100 NTD (≈2 600 USD), or 415 NTD per patient, chiefly by reducing overtime expenditure and consumable use. By contrast, the COMFORTATTOO trial conducted in the UK National Health Service projected a per-patient saving of only 2.1 GBP because staff time was absorbed within fixed schedules and material costs dominated the analysis [30]. Under Taiwan’s global-budget National Health Insurance scheme, hospitals must internally absorb the labor cost of extended setup times; interventions shorten repositioning, therefore, confer a proportionally larger fiscal benefit [30,32].

**Limitations and future directions**

Despite these promising results, certain limitations should be acknowledged. The study employed a single-center design with convenience sampling, which might limit the generalizability of the findings. Future research should consider multicenter randomized controlled trials (RCTs) to validate and expand upon our findings. In addition, the relatively short follow-up period limited the evaluation of long-term effects of these nursing interventions. Future longitudinal studies should assess sustained adherence and marker retention beyond treatment completion. Another limitation was our simplified patient classification system, which used BMI, education level, and caregiver availability as sole criteria. Future studies could explore additional psychosocial or clinical predictors of marker adherence, such as patients’ psychological traits, skin condition, or socioeconomic status, to further refine patient stratification.

Finally, the local benchmark figures were derived from unpublished QA data and may be subject to reporting bias, which could limit their generalizability.

**Recommendations for clinical practice**

Based on our results, we recommend the routine integration of structured patient education, standardized marker management protocols, and individualized patient risk assessments in radiation oncology settings. Healthcare institutions should consider the following practical steps:

- Adopt a standardized patient classification and education system similar to the red–green light model
- Regularly schedule marker maintenance education sessions, especially for high-risk groups
- Utilize validated anxiety and satisfaction assessment tools (such as BAI) routinely to monitor patient psychological outcomes and promptly address any concerns
- Continuously monitor intervention effectiveness through structured data collection systems (e.g., MOSAIQ®) to support ongoing quality improvement initiatives.

**CONCLUSION**

This study demonstrated that structured, patient-centered nursing interventions – including a novel red–green light classification system, tailored educational programs, and

standardized marker maintenance protocols – can effectively reduce marker detachment rates from approximately 15% to 3.5% in patients receiving radiation therapy. This reduction significantly enhanced patient treatment accuracy, shortened treatment durations, alleviated patient anxiety, increased patient satisfaction, and optimized hospital resource utilization. Given these compelling findings, we strongly recommend integrating such structured nursing interventions into routine clinical practices within radiation oncology departments. Furthermore, future multicenter studies with RCT designs are encouraged to confirm and expand upon these results, potentially incorporating additional patient characteristics and psychosocial factors. Such efforts will further refine patient care protocols, continually enhance patient outcomes, and advance the overall quality of cancer radiotherapy services.

### Data availability statement

The datasets generated and/or analyzed during the current study are not publicly available due to hospital data governance regulations and clinical confidentiality. De-identified datasets may be made available from the corresponding author on reasonable request, subject to approval from Chung Shan Medical University Hospital and compliance with relevant data protection guidelines (IRB No. CS2-22203).

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### Conflicts of interest

There are no conflicts of interest.

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