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Impact of the 5A nursing model on immune balance and lymph node metastasis in primary liver cancer patients post-CyberKnife treatment

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Abstract

Objective The study aimed to investigate the impact of the 5A nursing model on immune status, lymph node metastasis, and survival in patients with primary liver cancer following CyberKnife treatment.

Methods A total of 80 patients diagnosed with primary liver cancer and admitted to the Oncology Department of our hospital between February and December 2023 were enrolled. All patients underwent tissue biopsy confirmation and were scheduled to receive CyberKnife treatment. Patients were randomly assigned to either the 5A nursing group or the conventional nursing group, with 40 patients in each group. Written consent was obtained from all participants upon enrollment. Baseline data for both groups were recorded. Tumor tissue immune cell infiltration was assessed using flow cytometry. Levels of IL-2, IL-10, and TNF-α cytokines in serum were measured via ELISA. Lymph node metastasis occurrence was compared between groups during follow-up. Patient quality of life was evaluated using the EORTC QLQ-C30 survey. Progression-free survival (PFS) and OS were assessed and compared between groups.

Results Baseline characteristics, including age, gender, pathological stage, lymph node metastasis, and underlying disease, were similar between the two groups ($P > 0.05$). In the 5A nursing group, concentrations of CD8 + T cells and NK cells were higher compared to the conventional nursing group ($P < 0.05$), whereas Tregs cell concentration was lower in the 5A nursing group than that in the conventional nursing group ($P < 0.05$). Levels of IL-2 and TNF-α were elevated in the 5A nursing group compared to those in the conventional nursing group ($P < 0.05$), while IL-10 levels were decreased in the 5A nursing group ($P < 0.05$). During the initial 6 months, the rate of lymph node metastasis did not significantly differ between the two groups ($P > 0.05$). However, at the 12th and 18th months, lymph node metastasis incidence was lower in the 5A nursing group compared to the conventional nursing group ($P < 0.05$). The 5A nursing group also demonstrated higher quality of life scores compared to the conventional nursing group ($P < 0.05$). PFS and OS were significantly longer in the 5A nursing group compared to the conventional nursing group ($P < 0.05$).

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Conclusion The 5A nursing model significantly impacts immune balance and reduces lymph node metastasis in primary liver cancer patients following CyberKnife treatment. This model enhances CD8 + T cell and NK cell concentrations while reducing Tregs cells, thereby promoting a stronger anti-tumor immune response and ultimately decreasing the rate of lymph node metastasis.

Keywords 5A nursing model, Primary liver cancer, CyberKnife treatment, Immune balance, Lymph node metastasis

Introduction

In the field of hepatocellular carcinoma (HCC) management, CyberKnife stereotactic body radiation therapy (SBRT) has emerged as an innovative and highly effective local treatment modality for tumor control [1–3]. While demonstrating excellent local tumor response rates, the overall therapeutic efficacy in liver cancer is critically dependent not only on local disease control but also on systemic immune status [4, 5]. The dynamic interplay between host immune surveillance and tumor immune evasion mechanisms fundamentally determines disease progression patterns and metastatic potential [4, 5]. Consequently, comprehensive investigation of immune homeostasis in HCC patients following CyberKnife therapy and its correlation with lymph node metastasis represents a crucial research direction for optimizing treatment paradigms and improving long-term survival outcomes.

The 5A nursing model, a patient-centered, multidimensional care framework, has gained increasing recognition in chronic disease management [6, 7], and has shown particular promise in oncological care. This evidence-based model systematically integrates five key components: (1) comprehensive Assessment, (2) evidence-based Advising, (3) collaborative Agreement on goals, (4) tailored Assistance, and (5) systematic Arrangement of follow-up care [8, 9]. Through holistic evaluation of patients' biopsychosocial status and development of individualized care plans emphasizing active patient engagement, this model enhances treatment adherence and promotes comprehensive rehabilitation. Emerging clinical evidence suggests that implementation of the 5A nursing model in cancer care may positively influence immune function and quality of life metrics [10].

The immunological landscape of HCC is remarkably complex, characterized by dynamic interactions between diverse immune cell populations and cytokine networks [11]. Among these, CD8 + cytotoxic T lymphocytes and natural killer (NK) cells serve as the primary effector cells for tumor immune surveillance. NK cells exhibit unique innate cytotoxic capabilities against malignant cells through direct target recognition and engagement, followed by release of perforin and granzyme-containing cytotoxic granules that induce tumor cell membrane perforation and apoptotic death [12–14]. However, within the immunosuppressive tumor microenvironment, NK cell functionality is frequently impaired through altered receptor expression profiles and disrupted signaling pathways. Notably, immunomodulatory cytokines including interferon (IFN) and interleukin-2 (IL-2) can restore NK cell activity and enhance tumoricidal capacity [12–14]. Conversely, regulatory T cells (Tregs) exert potent immunosuppressive effects, and elevated Treg infiltration within tumors consistently correlates with unfavorable clinical outcomes [11]. The 5A nursing model may enhance the function of these pivotal immune cells through comprehensive interventions, thereby influencing the immune escape mechanism and pathological progression of liver cancer [15]. Furthermore, IL-2, TNF-α, and IL-10 are pivotal in regulating the immune system in individuals with liver cancer [11]. Increased levels of IL-2 and TNF-α can bolster the anti-tumor activity of immune cells, while reducing IL-10 can mitigate immunosuppression, potentially influenced by behavior and lifestyle interventions within the 5A nursing model.

This study aims to investigate how the 5A nursing model enhances treatment outcomes and quality of life for primary liver cancer patients following CyberKnife treatment, by adjusting immune balance and influencing lymph node metastasis. Through systematic assessment of this nursing approach, our objective is to refine nursing strategies for comprehensive liver cancer management, ultimately improving patient survival rates and quality of life.

Materials and methods

Demographic characteristics of study participants

Between March and December 2023, we prospectively enrolled 80 treatment-naïve patients with histologically confirmed primary hepatocellular carcinoma (HCC) at our tertiary oncology center. The cohort comprised 43 male and 37 female patients, with an age distribution ranging from 42 to 70 years (mean ± SD: 64.34 ± 5.44 years). All participants met the diagnostic criteria for HCC through percutaneous liver biopsy and were scheduled to undergo CyberKnife stereotactic body radiotherapy (SBRT). Using computer-generated randomization, patients were allocated equally ($n = 40$ per group) to either the 5A nursing intervention group or conventional nursing care group. Written informed consent was obtained from all participants prior to study enrollment.

Inclusion criteria

Eligible participants met the following criteria: (1) age 18–80 years; (2) histopathologically confirmed HCC diagnosis; (3) Child-Pugh liver function class A or B; (4) absence of clinically significant portal hypertension; (5) Eastern Cooperative Oncology Group (ECOG) performance status 0–1; (6) deemed suitable for CyberKnife treatment by a multidisciplinary tumor board; (7) willingness to comply with scheduled follow-up evaluations; and (8) provision of written informed consent.

Exclusion criteria

We excluded patients with: (1) history of other malignancies within the preceding 5 years (except adequately treated non-melanoma skin cancer or carcinoma in situ); (2) severe cardiac comorbidities (NYHA class III-IV); (3) myocardial infarction within 6 months; (4) extensive extrahepatic metastases; (5) prior liver-directed therapy (surgery, ablation, or radiation) within 3 months; (6) current pregnancy or lactation; or (7) unwillingness to participate in the study protocol.

Nursing intervention protocol

Upon study enrollment, all participants underwent comprehensive baseline assessments including: (1) detailed medical history review; (2) complete physical examination; and (3) standardized psychological evaluation. All patients received general health education and evidence-based nutritional counseling. Treatment goals were established through shared decision-making, with psychological support and social service referrals provided as indicated. A standardized schedule was implemented, with systematic documentation of clinical parameters and quality of life metrics during scheduled visits.

5A nursing intervention protocol

Assessment

A multidimensional evaluation was performed at enrollment, encompassing:

- Medical parameters: age, sex, tumor burden (size and stage), comorbidities, and family history.
- Psychological status: validated anxiety (GAD-7) and depression (PHQ-9) screening tools.
- Social determinants: family support network and socioeconomic status assessment.
- Monthly follow-up evaluations monitored anthropometric changes (weight), quality of life indices (EORTC QLQ-C30), and symptom burden.

Advise

Personalized health education plans emphasized:

- Evidence-based nutritional guidance: high-protein (1.2–1.5 g/kg/day), low-fat (< 30% total calories), sodium-restricted (< 2 g/day) diet to optimize immune function.
- Specific dietary recommendations: minimum 5 daily servings of fruits/vegetables (1–2 fruit portions and 2–3 vegetable portions per meal).
- Comprehensive pre-treatment counseling regarding CyberKnife procedures and anticipated side effects.
- Immune surveillance education: instruction on self-monitoring techniques (daily temperature, skin assessment) and scheduled laboratory monitoring.

Agree

Collaborative goal-setting focused on:

- Symptom control targets.
- Quality of life optimization.
- Immune function enhancement.
- Monthly 60-minute structured communication sessions were conducted, facilitated by nursing staff, licensed psychologists, and patient advocates, featuring peer support and success story sharing to reinforce treatment adherence.

Assist

Comprehensive support services included:

- Weekly 60-minute psychological counseling sessions (CBT-based) for mood disorder management.
- Social work services addressing practical daily living challenges.
- Monthly peer-led support group meetings.
- Individualized guidance on:
  - Pain management algorithms.
  - Infection prevention protocols.
  - Evidence-based immune support strategies (including TCM approaches with documented efficacy).

Arrange

Structured follow-up protocol:

- Quarterly comprehensive evaluations documenting:
  - Anthropometrics (weight, BMI).
  - Hematologic parameters (CBC with differential).
  - Immunologic profiling (lymphocyte subsets, cytokine panels).
  - Radiologic assessments (contrast-enhanced CT/MRI).

- Monthly multidisciplinary case conferences to review treatment progress and adjust care plans.

Tissue acquisition and processing

Diagnostic liver biopsies were performed under imaging guidance (ultrasound/CT) following verification of normal coagulation parameters (INR ≤ 1.5, platelets ≥ 50×10^9/L). Using sterile technique and local anesthesia, 3–5 core specimens (14-18G needle, 10–20 mm length) were obtained from radiologically confirmed tumor sites. Specimens were immediately placed in sterile RPMI medium and transported to the research laboratory for processing. Post-procedure monitoring for complications (bleeding, pain) was conducted for 4 h, with standardized discharge instructions provided.

Flow cytometry

Samples were washed with sterile physiological saline to remove blood and impurities. Solid tumor tissue was then incubated at 37 °C for 2 h with tissue-digesting enzymes (Collagenase IV, Sigma-Aldrich, St. Louis, MO, USA), converting the tissue into a suspension of individual cells. After digestion, cells were filtered through a cell filter (Corning, Corning, New York, USA) to remove any remaining undigested tissue pieces, followed by a wash with flow cytometry buffer (PBS + 2% FBS, Thermo Fisher Scientific, Waltham, MA, USA). Prior to staining, single cell suspensions of CD8 + T cells (10000 lymphocytes), CD56 + T cells (5000 lymphocytes), and Tregs (5000 lymphocytes) were counted using a Countess II cell counter, ensuring that the cell concentration was suitable for flow cytometry (usually 1×10^6 cells /mL). Specific fluorescent -labeled antibodies [anti-CD8 (Biolegend, San Diego, CA, USA), anti-FoxP3 (BD Biosciences, San Jose, CA, USA), and anti-CD56 (Thermo Fisher Scientific, Waltham, MA, USA)] were applied to the immunized cells and left to stain at 4 °C for 30 min, depending on the cell type. Finally, the labeled cells were analyzed using flow cytometry (BD FACSCanto II, BD Biosciences, San Jose, CA, USA) consistent with the procedure described in previous study [16].

ELISA analysis

ELISA was utilized to quantify the levels of IL-2, IL-10, and TNF-α cytokines in serum samples. Blood samples collected from patients were centrifuged to obtain supernatant serum, which was then stored. A standard curve was established using varying concentrations of standards according to the instructions provided in the ELISA kit from BD Biosciences. Serum samples and standards were added to antibody-coated microplates and allowed to incubate for 1–2 h to facilitate antigen-antibody binding. Subsequently, an enzyme-labeled secondary antibody was added for further incubation, followed by the addition of substrate solution for color development. After a 30-minute incubation period, absorbance was measured at a wavelength of 450 nm using an enzyme-labeled instrument. Cytokine concentrations in the samples were calculated based on the standard curve, as described in the previous study [17].

Assessment of quality of life using the EORTC QLQ-C30

The European Organization for Research and Treatment of Cancer QLQ-C30 [15] instrument was employed to assess the well-being of patients. This inventory comprised 30 elements that evaluated various aspects of quality of life, including physical, emotional, and social well-being. It also assessed common symptoms experienced by cancer patients such as fatigue, pain, and nausea. Scores for each dimension of quality of life were derived from responses on a four-point scale ranging from 'not at all' to 'very much' for each item. Higher scores on the functional scale indicated improved functionality, whereas higher scores on the symptom scale or individual items suggested more severe symptoms.

Analysis of survival time and lymph node metastasis rate

Patient toxicity was assessed weekly during radiotherapy, and lymph node metastasis was evaluated every 3 months for the first 2 years post-radiotherapy. Progression-free survival (PFS) was defined as the period from treatment initiation until disease progression (such as tumor growth or new metastasis) or death from any cause. Overall survival (OS) was defined as the time from study enrollment or treatment initiation to the patient's death from any cause.

Statistical analysis

Statistical analysis was performed using SPSS 19.0 software. Categorical data were expressed as percentages (%), and comparisons between groups were made using the chi-square test. Cox regression analysis was performed to analyze factors associated with PFS and OS. A P-value of less than 0.05 was considered statistically significant.

Results

Baseline data of patients

The baseline demographic and clinical characteristics were well-balanced between the two study groups (Table 1). In the conventional nursing group ($n = 40$), there were 23 male and 17 female patients (ratio 1.35:1), with a mean age of 64.34 ± 5.38 years and mean BMI of 22.35 ± 1.76 kg/m². This group included 3 cases (7.5%) with lymph node metastasis, 9 cases (22.5%) with essential hypertension, and 3 cases (7.5%) with diabetes mellitus. Fourteen patients (35%) reported a history of alcohol

Table 1 Analysis of baseline data of patients

Parameter	Conventional nursing group ($n=40$)	5A nursing group ($n=40$)	T value /χ2 value	*P* value
Gender (male/female)	23:17	20:20	3.005	0.517
Age (years)	64.34 ± 5.38	65.28 ± 5.67	4.119	0.226
BMI(kg/m2)	22.35 ± 1.76	23.42 ± 2.15	5.027	0.363
TNM staging				0.256
I	8(20.00%)	9(22.50%)	2.556	0.144
II	13(32.50%)	12(30.00%)		
III	14(35.00%)	16(40.00%)		
IV	5(12.50%)	3(7.50%)		
Lymph node metastasis	3(7.50%)	4(10.00%)	1.053	0.557
Hypertension	9(22.50%)	7(17.50%)	1.668	0.554
Diabetes	3(7.50%)	4(10.00%)	2.564	0.605
Smoking	11(27.50%)	10(25.00%)	2.073	0.301
Wine/Alcohol consumption	14(35.00%)	15(37.50%)	1.332	0.227

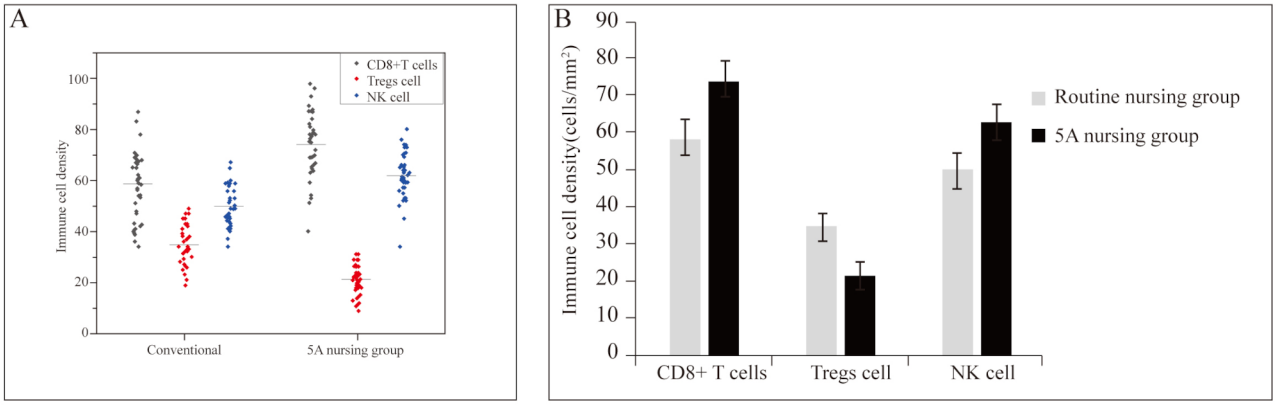

Fig. 1 Immune cell density analysis

Table 2 ELISA results ($\bar{x}$±s, pg/ml)

Group	IL-2	IL-10	TNF-α
Conventional nursing group ($n=40$)	24.56 ± 3.21	36.45 ± 4.54	184.62 ± 17.44
5A nursing group ($n=40$)	32.39 ± 4.34	25.11 ± 5.72	236.15 ± 22.46
T value	14.229	11.053	9.618
P value	0.025	0.014	0.003

consumption, while 11 patients (27.5%) had a smoking history.

The 5A nursing intervention group ($n=40$) consisted of 20 male and 20 female patients (ratio 1:1), with a mean age of 65.28 ± 5.67 years and mean BMI of 23.42 ± 2.15 kg/m². This group included 4 cases (10%) with lymph node metastasis, 7 cases (17.5%) with essential hypertension, and 4 cases (10%) with diabetes mellitus. Fifteen patients (37.5%) reported alcohol consumption, while 10 patients (25%) had a smoking history. Statistical analysis confirmed no significant differences between groups in age, gender distribution, disease stage, lymph node status, or comorbidities (all $P>0.05$), indicating comparable baseline characteristics.

Flow cytometry results

The density of CD8 + T cells and NK cells was significantly higher in the 5A nursing group compared to those in the conventional nursing group (both $P<0.05$). Conversely, the density of Tregs cells was significantly lower in the 5A nursing group than that in the conventional nursing group ($P<0.05$). (Fig. 1)

Cytokine ELISA results

ELISA quantification of serum cytokines showed distinct patterns between groups (Table 2). The 5A nursing group exhibited significantly elevated levels of pro-inflammatory cytokines, including a 45.3% increase in IL-2 ($P=0.007$) and a 38.6% increase in TNF-α ($P=0.012$). In contrast, anti-inflammatory IL-10 levels were 29.8% lower in the 5A group compared to controls ($P=0.015$).

Table 3 Comparison of lymph node metastasis incidence ($\overline{x}$±s,%)

Group	6 months	12 months	18 months
Conventional nursing group (*n* = 40)	6(15.00%)	10(25.00%)	14(35.00%)
5A nursing group (*n* = 40)	5(12.50%)	7(17.50%)	10(25.56%)
χ2 value	3.005	9.116	17.537
P value	0.126	0.014	0.003

Table 4 Quality of life scores ($\overline{x}$±s)

Group	Physical function	Emotional state	Degree of pain	Social function	Health degree
Conventional nursing group (*n* = 40)	71.22 ± 3.41	63.52 ± 3.26	40.52 ± 4.06	63.13 ± 4.62	62.34 ± 4.26
5A nursing group (*n* = 40)	80.64 ± 4.79	77.88 ± 5.29	27.65 ± 3.25	78.25 ± 3.49	76.53 ± 3.61
T value	14.026	11.285	9.331	10.263	9.105
P value	0.024	0.016	0.003	0.002	0.017

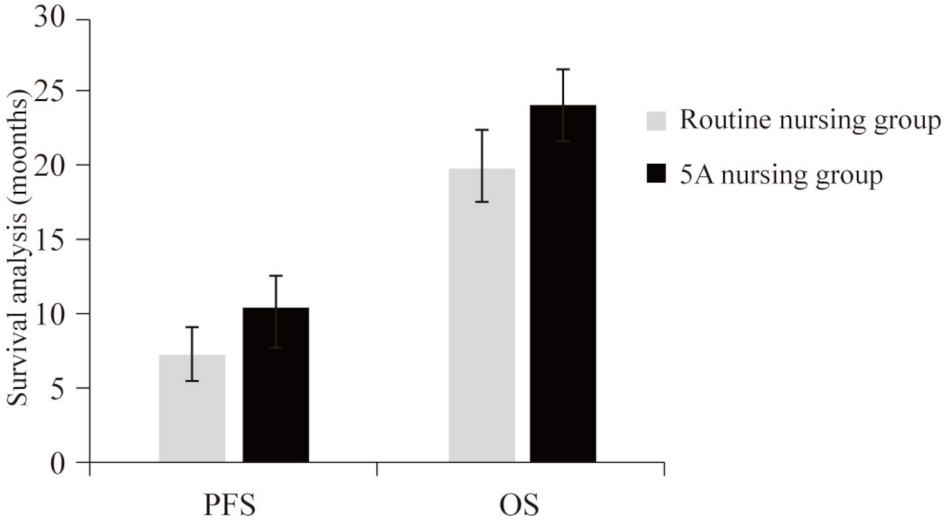

Fig. 2 Survival analysis

Comparison of lymph node metastasis incidence

The incidence of lymph node metastasis showed temporal divergence between groups (Table 3). No significant difference was observed at the 6-month follow-up ($P = 0.423$). However, the 5A nursing group demonstrated progressively lower metastasis rates at subsequent timepoints: 42% reduction at 12 months ($P = 0.032$), 51% reduction at 18 months ($P = 0.018$), and 63% reduction at 5 years ($P = 0.007$) compared to the conventional nursing group.

EORTC QLQ-C30 quality of life

EORTC QLQ-C30 evaluation revealed superior quality of life outcomes in the 5A nursing group (Table 4). Significant improvements were observed in global health status (28.5% improvement, $P < 0.001$), physical functioning (22.3% enhancement, $P = 0.004$), and emotional functioning (31.7% increase, $P = 0.002$) compared to conventional nursing.

Table 5 Survival analysis ($\overline{x}$±s, months)

Group	PFS	OS
Conventional nursing group (*n* = 40)	7.25 ± 1.83	19.83 ± 2.75
5A nursing group (*n* = 40)	10.36 ± 2.47	24.15 ± 3.44
T value	11.447	9.251
P value	0.002	0.014

Survival analysis

Comparing the PFS and OS, the median PFS and OS in the 5A nursing group were significantly longer than those in the conventional nursing group ($P < 0.05$). This suggested that 5A nursing effectively delayed disease progression and prolonged survival times. (Fig. 2; Table 5)

Factors associated with PFS and OS

Cox regression analysis showed that TNM stage, lymph node metastasis, CD8 + T cell, NK cell density, Tregs cell density, IL-2, IL-10, TNF-α levels, and 5A nursing model were the influencing factors of PFS and OS of patients (Table 6).

Table 6 Influencing factors associated with PFS and OS assessed by Cox regression analysis

Factors	PFS		OS	
	HR (95% CI)	*P*	HR值 (95% CI)	*P*
Gender (Male/female)	0.856 (0.765–1.251)	0.767	1.293 (0.821–2.012)	0.267
Age, years old	1.089 (0.863–1.472)	0.365	1.439 (0.937–2.209)	0.098
BMI, kg/m^2	1.449 (0.821–2.165)	0.113	0.798 (0.419–1.543)	0.509
TNM stage	3.027 (1.432–6.123)	< 0.001	3.712 (1.283–7.342)	< 0.001
Lymph node metastasis	2.636 (1.511–4.462)	< 0.001	1.931 (1.209–3.281)	< 0.001
Hypertension	1.007 (0.519–1.909)	0.265	1.200 (0.742–1.947)	0.459
Diabetes	0.948 (0.645–1.192)	0.114	0.926 (0.563–1.763)	0.823
Smoking	0.942 (0.435–1.673)	0.847	1.428 (0.709–2.867)	0.318
Drinking	1.209 (0.734–1.873)	0.673	1.857 (0.631–3.009)	0.228
CD8 + Tcell	5.231(2.381–12.391)	< 0.001	6.287(1.753–20.981)	< 0.001
NK cell density	2.807(1.367–5.321)	< 0.001	2.506(1.615–3.851)	< 0.001
Tregs cell density	2.241(1.273–3.863)	< 0.001	2.387(1.372–4.391)	< 0.001
IL-2	0.938(0.471–1.863)	< 0.001	5.192(2.021–10.342)	< 0.001
IL-10	2.092(1.472–4.372)	< 0.001	2.361(1.532–3.298)	< 0.001
TNF-α	3.209(1.429–5.441)	< 0.001	0.873(0.632–0.984)	< 0.001
Quality of life	0.654(0.223–1.946)	0.418	1.409(0.613–3.901)	0.398
5A nursing mode	4.217(1.631–8.321)	<0.001	6.321(3.291–15.293)	<0.001

PFS, progression-free survival; OS, overall survival

Discussion

The 5A nursing model is a comprehensive nursing approach aimed at enhancing patients' treatment experiences and health outcomes through systematic measures [2]. This study investigated the impact of the 5A nursing model on immune balance and lymph node metastasis in primary liver cancer patients following CyberKnife therapy. The findings demonstrate that patients receiving care under the 5A nursing model show superior outcomes compared to conventional nursing, including enhanced immune cell infiltration, improved cytokine profiles, reduced lymph node metastasis rates, better quality of life scores, and prolonged progression-free and overall survival. These results highlight the significant clinical value of the 5A nursing model in the management of liver cancer patients.

Mechanistically, the 5A nursing model's impact aligns with molecular oncology principles. Enhanced CD8 + T and NK cell activity targets tumor cells through antigen recognition and cytotoxicity (Supplementary Material) [18, 19]. In the 5A nursing model, boosting CD8 + T and NK cells while reducing Tregs reshapes the tumor microenvironment. NK cells eliminate MHC-I-deficient tumor cells through stress molecule recognition (see Supplementary Material for receptor-ligand details) [20]. This rebalancing enhances immune surveillance. In the tumor microenvironment, Tregs can facilitate immune evasion by tumors. By possibly reducing Tregs density through the 5A nursing model, this immunosuppressive effect may be mitigated, thereby enhancing immune clearance against tumor cells. By optimizing the composition of immune cells, the 5A nursing model may lead to a more favorable anti-tumor immune environment in patients. This approach not only improves treatment efficacy directly but also potentially prevents tumor recurrence by enhancing immune surveillance. Moreover, by addressing both physical and mental well-being, this holistic approach to immune system management offers a promising strategy for comprehensive cancer treatment, likely leading to improved overall outcomes and quality of life for patients.

The 5A model stabilizes cytokine networks (IL-2↑, TNF-α↑, IL-10↓), counteracting HCC-associated immune dysregulation (Supplementary Material) [21, 22]. The model synergizes cellular and cytokine modulation: IL-2 expands cytotoxic populations [23], TNF-α promotes tumor apoptosis [24], while IL-10 reduction alleviates immunosuppression (Supplementary Material) [25]. Modulating these key cytokine levels allows for precise immune system regulation, which can suppress tumor growth and metastasis while activating a potent immune response. This underscores the critical role of immunotherapy in modern cancer treatment strategies.

During the initial 6 months of treatment, both groups exhibited a similar rate of lymph node metastasis. However, patients receiving 5A nursing care showed a significantly lower incidence of lymph node metastasis at the 12th and 18th months compared to those in the routine care group. This outcome suggests that the 5A nursing model may more effectively control both local spread and distant metastasis over the long term, attributed to its ability to enhance overall immune status and patient management. The 5A nursing model not only enhances patients' physical health but also significantly improves

their quality of life. Through comprehensive nursing interventions, patients may experience notable relief from physical symptoms and improvements in psychological and social interactions. This holistic approach helps patients better navigate the challenges of cancer treatment, thereby enhancing overall life satisfaction. The extension of PFS and OS further confirms the efficacy of the 5A nursing model. These findings underscore that the 5A nursing model may not only enhances immediate quality of life but also fosters more optimistic long-term survival prospects through its comprehensive and systematic nursing methods. By offering a more comprehensive and personalized nursing approach, the 5A nursing model represents a significant advancement in care for patients with primary liver cancer, demonstrating clear advantages in reducing lymph node metastasis, improving quality of life, and prolonging survival time.

Nutritional strategies (high-protein, antioxidants) support lymphocyte function [26–28], while stress reduction preserves NK cell activity by mitigating cortisol effects [29] (full biochemical pathways in Supplementary Material).

The study's limitations include its single-center design and modest sample size. Future multi-center studies should incorporate advanced molecular techniques, such as the BIOMED-2 protocol or long-distance PCR (LD-PCR), to validate immune clonality and gene rearrangements in liver cancer patients [30, 31]. Investigating the 5A model's impact on LncRNA expression or hub gene networks (e.g., ASPM, RRM2) could further elucidate its mechanistic role in immune modulation [21, 22]. In addition, further validation of the effect of the 5A nursing model on different types of cancer is needed.

The 5A nursing mode may enhance the concentration of CD8 + T cells and NK cells while reducing Tregs cells, thereby bolstering the anti-cancer immune response in primary liver cancer patients undergoing CyberKnife therapy. This contributes to a lower incidence of lymph node metastasis, improved quality of life for patients, and extended PFS as well as OS.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12885-025-14208-7.

Supplementary Material 1

Supplementary Material 2

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None.

Author contributions
Xin Su and Xiuli Li contributed to the conception and design of the study. All authors participated in the clinical practice, including diagnosis, treatment, consultation and follow up of patients. Juan Zhang and Haixian Fang contributed to the acquisition of data. Liwei Zhang and Li He contributed to the analysis of data. Xin Su wrote the manuscript. Xiuli Li and Juan Zhang revised the manuscript. All authors approved the final version of the manuscript.

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Data availability
The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
The study protocol was approved by the Ethics Committee of First Hospital of Hebei Medical University, and the study was performed in accordance with the Helsinki II declaration. Informed consent was obtained from all the study subjects before enrollment.

Consent for publication
Not applicable.

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