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ORIGINAL RESEARCH

The Impact of Nutritional Management on Postoperative Recovery Outcomes in Prostate Cancer Patients Undergoing Radical Prostatectomy: A Retrospective Study

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Background: Prostate cancer remains a prevalent malignant tumor among males globally, while the impact of perioperative nutritional management on prognosis remains poorly defined. This study aims to investigate the management efficacy of dietary supplement (nutrient) administration in prostate cancer patients following radical prostatectomy.

Methods: A retrospective analysis was conducted on clinical data from 70 prostate cancer patients who underwent radical prostatectomy at our institution between March 2022 and January 2024. Participants were divided into two groups based on distinct perioperative management protocols: the control group received conventional management, while the observation group received targeted dietary supplements (nutrients) in addition to the conventional regimen. Comparative analyses were performed on clinical indicators, recovery parameters, and adverse symptom incidence between groups to evaluate the role of nutrient supplementation in perioperative management.

Results: Baseline characteristics demonstrated comparability between groups ($P>0.05$). The observation group exhibited significantly shorter postoperative drainage tube removal duration and hospital stay compared to controls ($P<0.05$). First postoperative bowel movement time and independent ambulation recovery time were also reduced in the observation group ($P<0.05$). No statistically significant difference in BMI levels was observed between groups ($P>0.05$). Serum albumin levels measured at preoperative day 1, and postoperative days 1 and 3 were significantly elevated in the observation group ($P<0.05$). Postoperative day 3 serum immunoglobulin levels (IgG, IgA, IgM) showed marked increases in the observation group ($P<0.05$). The observation group reported significantly fewer gastrointestinal symptoms including thirst, hunger, and nausea compared to controls ($P<0.05$).

Conclusion: Dietary supplement (nutrient) administration may improve perioperative nutritional parameters, enhance systemic immunity, facilitate postoperative rehabilitation, and alleviate gastrointestinal symptoms in prostate cancer patients.

Keywords: dietary supplements, prostate cancer, nutrients, perioperative management

Introduction

Prostate Cancer (prostate cancer) ranks as one of the most prevalent malignant tumors globally, occupying the second and fifth positions in incidence and mortality rates among male malignancies, respectively.[1–3] According to the latest projections by the International Agency for Research on Cancer (IARC), the global incidence of prostate cancer is expected to exceed 1.6 million new cases with 375,000 deaths in 2025. While advancements in early detection and therapeutic modalities have significantly improved outcomes for localized prostate cancer, radical prostatectomy (RP) remains the primary curative treatment modality.[4,5] However, surgical trauma induces metabolic disturbances, immunosuppression, and gastrointestinal dysfunction, potentially leading to delayed recovery, increased complication risks, and compromised long-term quality of life. Perioperative management constitutes a cornerstone of the Enhanced Recovery After Surgery (ERAS) protocol, aiming to optimize physiological status and mitigate surgical stress through multimodal

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interventions. Traditional ERAS implementations prioritize pain control, early mobilization, and fluid management, while nutritional support has received comparatively less attention.[6,7] In recent years, nutrient-based interventions have gained increasing relevance in surgical practice. Research demonstrates that preoperative nutritional status correlates with postoperative complication rates - each 10 g/L decrement in serum albumin level associates with an 89% elevation in infection risk. Furthermore, surgical trauma-induced inflammation suppresses immunoglobulin synthesis and T-lymphocyte function, exacerbating infection susceptibility.[8–10]

The composite nutrition scheme adopted in this study is based on the following scientific basis: arginine, as a conditionally essential amino acid, can promote nitric oxide synthesis, improve microcirculation, and enhance macrophage phagocytic function under stress conditions; Omega-3 polyunsaturated fatty acids (EPA/DHA) reduce the release of inflammatory factors such as IL-6 and TNF - α by inhibiting the arachidonic acid metabolism pathway. Clinical trials have shown that they can reduce the risk of postoperative infection by 23% −40%; Glutamine, as the main energy source for intestinal mucosal cells, can maintain the integrity of the intestinal barrier after surgery and reduce the risk of bacterial translocation; Vitamin D receptors are widely expressed in immune cells, and their metabolite 1,25 $(OH)_2$ D3 can induce the expression of antimicrobial peptides and regulate T cell differentiation. This combination scheme conforms to the multi-target intervention strategy recommended by the ESPEN perioperative nutrition guidelines.

In this study, a retrospective cohort design was used to include consecutive patients who received radical prostatectomy from March 2022 to January 2024. The exclusion criteria included: ① preoperative ASA grade ≥3; ② combined with diabetes or autoimmune diseases; ③ use of immunosuppressants within 3 months before surgery. Clinical data was extracted through the hospital′s electronic medical record system, and propensity score matching (PSM) was used to control baseline differences between groups (age, BMI, tumor staging, etc)., ultimately including 70 paired samples. The nutritional intervention group received standardized enteral nutrition preparations (including arginine 20g/d, omega-3 PUFA 3g/d, glutamine 15g/d, vitamin D 1000IU/d) from 3 days before surgery to 7 days after surgery, while the control group only received routine dietary guidance. The primary endpoints were postoperative drainage tube retention time and length of hospital stay, while secondary endpoints included nutritional indicators (serum albumin, prealbumin), immune indicators (IgG/IgA/IgM, CD4+/CD8+ratio), and incidence of gastrointestinal symptoms. All data were entered double-blind and analyzed for covariance using SPSS 26.0. The findings aim to provide high-level evidence for optimizing personalized, precision-based nutritional strategies in prostate cancer perioperative care.

Materials and Methods

Study Population

This study employed a retrospective analytical design, including prostate cancer patients who underwent radical prostatectomy at our institution between March 2022 and January 2024. Following rigorous eligibility screening, 70 patients were enrolled to ensure sample representativeness. Participants were allocated into two groups based on distinct perioperative management protocols: the control group received conventional management, while the observation group received targeted dietary supplements (nutrients) in addition to conventional care, with 35 patients in each cohort. This study used propensity score matching (PSM) to control for intergroup confounding factors. Matching variables include age BMI, Clinical staging and preoperative PSA levels. Perform 1:1 nearest neighbor matching using the “MatchIt” package in R language, with a caliper value set to 0.2. Finally, 70 paired samples (35 in each group) were included, and the standardized mean deviation (SMD) was less than 0.1 to confirm inter group balance. The study protocol received approval from ethics committee of Harbin Medical University Affiliated Cancer Hospital (No.159793, 03–01-2022), adhering to the Declaration of Helsinki and national medical data protection regulations. This study is a retrospective cohort analysis, and all data are sourced from clinical routine records. As a retrospective study utilizing pre-existing clinical records without additional patient risk, our ethics committee granted a waiver of informed consent. This decision is also based on the following facts: ① At the time of data collection, the patient had signed a informed consent form for routine treatment, which includes the terms of use for scientific research data; ② The study did not alter the clinical diagnosis and treatment pathway, nor did it increase patient risk; ③ The privacy protection measures comply with the requirements of GDPR and China′s Personal Information Protection Law. Patient privacy was safeguarded through:

anonymization of data prior to collection with removal of identifiers (eg, names, national ID numbers); tiered access controls restricting full dataset access to authorized researchers; and aggregate reporting of clinical findings to prevent individual data disclosure.

Inclusion and Exclusion Criteria

Inclusion criteria required: histopathological confirmation of prostate cancer via transperineal prostate biopsy;[11,12] scheduled elective laparoscopic radical prostatectomy; oral intake capability; and complete clinical records with adult patient status; clinical staging is T1c-T2c (confirmed by MRI/CT without lymph node metastasis); gleason score ≤8 (excluding high-risk invasive cases).

Exclusion criteria encompassed: severe cardiopulmonary/hepatorenal dysfunction or uncontrolled metabolic disorders; active bacterial/viral infections; hematological disorders (coagulopathy, thrombocytopenia); postoperative complications requiring intervention (major hemorrhage, septic shock, MODS); immunosuppressive therapy within 30 days preoperatively; or post-surgical transfer for complication management; preoperative PSA>20ng/mL (excluding potential risk of metastasis); combine imaging evidence of bone metastasis (excluding advanced cases).

These criteria ensured study population homogeneity while excluding confounders affecting metabolic-immune axis assessment. Severe comorbidities and hematological abnormalities could confound nutritional intervention evaluations, while infectious/immune-compromised states might bias immunological parameter interpretations. Major postoperative complications risked clinical outcome data incompleteness. And restricting staging and scoring can reduce inter group heterogeneity and ensure that the nutritional intervention effect can be attributed to the intervention measures rather than differences in tumor biological characteristics.

Intervention Protocols

The control group received conventional perioperative management including: preoperative counseling (1 day prior) regarding procedural objectives and precautions; fasting protocols (6-hour preoperative NPO, 2-hour nil per os); postoperative dietary progression (nil per os until bowel sounds recovery/flatus passage, then sips of water, followed by 3-day semi-liquid diet, transitioning to regular diet on postoperative day 4 with emphasis on high-protein, high-calorie, vitamin-rich, easily digestible meals); patient education on benefits of early ambulation with voluntary participation; and standard care for abdominal drainage tubes/urinary catheters with vigilant monitoring of drainage volume and urine characteristics.

The observation group was given targeted dietary supplements (nutrients) on the basis of the control group. The specific process was based on the "Chinese Expert Consensus on Extraintestinal and Intraintestinal Nutrition Support for Elderly Patients" to construct a standardized intervention path. Firstly, a multidisciplinary nutrition support team was established, consisting of two registered nutritionists, one chief urologist, two nursing supervisors, and two specialist nurses; Based on the latest clinical guidelines and literature evidence, team members developed specialized dietary supplement (nutrient) formulas and implementation standards through consensus meetings; Provide specialized training for nursing staff participating in the project, covering dietary supplement (nutrient) preparation techniques, dynamic assessment methods, and patient education strategies, ensuring operational standardization through standardized assessment and evaluation; Individualized dietary supplements (nutrients) are formulated by clinical nutritionists, including a dual formula for preoperative pre recovery and postoperative recovery, both of which contain arginine ω-3 PUFA, Multiple complex nutrients of glutamine and vitamin D, while conducting nutritional risk screening and supporting technical training for nursing teams, with dedicated nurses performing daily nutritional assessments and intervention guidance. The composite nutritional intervention plan used in this study includes four key components, with specific parameters as follows: 1 Arginine: Take 10g each time, 3 times a day, with an intervention period covering 3 days before surgery to 7 days after surgery. This dose is based on the activation threshold of the mTOR pathway, ensuring an increase in postoperative muscle protein synthesis rate. 2. Omega-3 polyunsaturated fatty acids: 3g each time (containing 1.8g EPA and 1.2g DHA), 3 times a day, with the same duration as above. This ratio is recommended according to ESPEN guidelines and aims to reduce postoperative IL-6 levels by ≥ 35% by inhibiting the NF - κ B pathway. 3. Glutamine: 15g each time, 3 times a day, covering the same intervention period. This dose has been clinically validated to maintain intestinal barrier integrity, reducing the incidence of postoperative diarrhea from 38.2% to 12.3% (P=0.032). 4. Vitamin D: 1000IU each time, taken once a day in the morning, with an intervention period extended from 14 days before surgery to 14 days after surgery. This plan is based on two considerations: ① Starting 14 days before surgery can correct potential vitamin D deficiency (25 (OH) D levels increased from 18.2ng/mL to 30.5ng/mL); ② Continuous supplementation for 14 days after surgery can maintain immune regulatory effects and increase IgM levels by 35.1%. Vitamin D adopts a differentiated administration strategy, which not only conforms to the preoperative correction principles of ESPEN guidelines, but also achieves sustained support for immune function by prolonging the postoperative administration time. All ingredients are administered in the form of enteral nutrition preparations to ensure consistency in bioavailability. The dynamic monitoring of nutritional risks adopts the NRS-2002 assessment tool recommended by CSPEN, which has been certified as an A-level evidence-based medicine tool by the Chinese Medical Association′s Gastroenterology Branch. The evaluation time points are set as the first day of admission, 24 hours before surgery, immediately after surgery, 24 hours before discharge, and weekly routine evaluations. The scale includes three dimensions: disease severity (0–3 points), degree of nutritional impairment (0–3 points), and age correction item (1 point for those over 70 years old). A total score of ≥ 3 points is considered positive for nutritional risk and triggers the nutritional support intervention process. For patients with positive preoperative evaluations, a preoperative oral dietary supplement (nutrient) regimen is initiated, with a dose of 3 times/day x 300mL/time, and individualized formula adjustments are made by clinical nutritionists based on dynamic evaluation results. Preoperative nutrition management includes two key milestones: administering 300mL of pre digested dietary supplements (nutrients) at 22:00 and 2 hours before surgery; during the postoperative recovery period, a stepwise feeding strategy is adopted. Patients are evaluated for neurological function recovery every 15 minutes after returning to the ward using the Steward Awakening Scale, which integrates three elements: consciousness level, airway protection ability, and motor function. When the total score is ≥4 and there are no symptoms of nausea and vomiting, the first enteral nutrition is initiated. An initial 50mL trial drink is given, and after good tolerance, the patient transitions to a postoperative specialized dietary supplement (nutrient) (3 times/day x 300mL/time), which continues until oral feeding returns to standard dietary intake. Implement three-level quality control throughout the intervention process, with dedicated nurses submitting weekly dynamic evaluation reports to the medical and nutrition teams, forming a PDCA quality improvement cycle.

Diagnostic parameter principle: Serum albumin: As a core indicator of nutritional status, its concentration changes reflect liver synthesis function and stress state (measurement principle: antigen antibody complex formation leads to changes in light scattering intensity). Immunoglobulin profile: IgG/IgA/IgM levels directly reflect humoral immune function (measurement principle: antigen excess method, quantified by standard curve). C-reactive protein (CRP): As a marker of inflammatory response, postoperative dynamic monitoring can evaluate the degree of stress (measurement principle: immunoturbidimetry, based on the reaction between CRP and anti-human CRP antibodies). Measurement process: Within 2 hours after collecting all specimens, centrifuge and separate the serum, and use Roche Cobas 8000 fully automatic biochemical immunoassay analyzer to complete the detection. Daily quality control ensures that the CV value is less than 5%.

Outcome Measures

Clinical Recovery Parameters: Precision documentation of postoperative milestones included drainage device removal time and total hospital stay duration to quantify surgical stress recovery rates. Gastrointestinal function recovery was tracked through first spontaneous bowel movement timing and independent ambulation restoration points, reflecting perioperative metabolic support impacts on digestive system functionality.

Nutritional Status Assessment: Standardized anthropometric methods evaluated nutritional reserve changes through dual-energy X-ray absorptiometry-calibrated weight measurements at baseline admission and discharge. Precision anthropometry utilized medical stadiometers with subjects in standard anatomical position (calcaneus, sacrum, scapular region, and occiput contacting the measuring plate). Body mass index (BMI) was calculated using the formula: BMI = weight (kg)/height^2 (m^2).

Serological Biomarker Monitoring: ① Serum albumin concentrations were quantified via immunoturbidimetry at admission assessment, 24 hours preoperatively, and 24/72 hours postoperatively. Measurements utilized antigen-antibody reaction-generated insoluble complexes analyzed on automated biochemical platforms. ② Immunoglobulin profiling (IgG/IgA/IgM) occurred on postoperative day 3 using automated clinical chemistry systems. Spectrophotometric detection at 340 nm wavelength monitored reaction system absorbance changes based on antigen-antibody specific binding, with precise quantification achieved through multi-point calibration curves.

Symptomatology Surveillance: Standardized symptom assessment scales recorded gastrointestinal adverse events including thirst, hunger, nausea, and vomiting – common perioperative complaints. Symptom severity was graded using a 4-point Likert scale (0–3) to evaluate nutritional intervention effects on gastrointestinal tolerance.

All laboratory procedures adhered to standardized operating protocols with double-blind sample processing and data analysis. Quality control maintained intra-assay coefficient of variation (CV) <5% for critical biomarkers, ensuring result reliability.

Statistical Analysis

Image processing utilized GraphPad Prism 8. Data management and analysis were performed using SPSS 26.0. Welch's *t*-test was used to handle data with heterogeneous variances, and Cohen's d was used to calculate the effect size to confirm that the difference exceeded the median equivalent strain threshold. Continuous variables are presented as mean ± standard deviation with between-group comparisons via independent t-tests. Categorical variables are expressed as n (%) with between-group comparisons via chi-square tests. Statistical significance was defined as $P<0.05$.

Results

Baseline Characteristics

The observation group comprised 35 patients aged 60–81 years (mean 69.11±4.85) with admission Gleason scores averaging 5.55±3.28. Marital status distribution: 3 unmarried, 19 married, 5 divorced, 8 widowed. The control group included 35 patients aged 60–81 years (mean 68.25±4.37) with admission Gleason scores averaging 5.81±3.17. Marital status distribution: 1 unmarried, 20 married, 7 divorced, 7 widowed. Baseline characteristics demonstrated comparability between groups ($P>0.05$). See Table 1.

Clinical Outcomes

The observation group exhibited significantly shorter postoperative drainage tube removal duration and hospital stay compared to controls ($P<0.05$). See Figure 1.

Table 1 Baseline Characteristics Comparison Between Groups (mean ± SD)

		Observers Group	Control Group	*t*	*P*
Number of Cases	-	35	35	-	-
Age (year)	-	60-81	60-81	-	-
-	Mean	69.11±4.85	68.25±4.37	0.779	0.439
Gleason score	Mean	5.55±3.28	5.81±3.17	0.337	0.737
Marital status	Unmarried	3	1	-	-
-	Married	19	20	-	-
-	Divorced	5	7	-	-
-	Lose a spouse	8	7	-	-

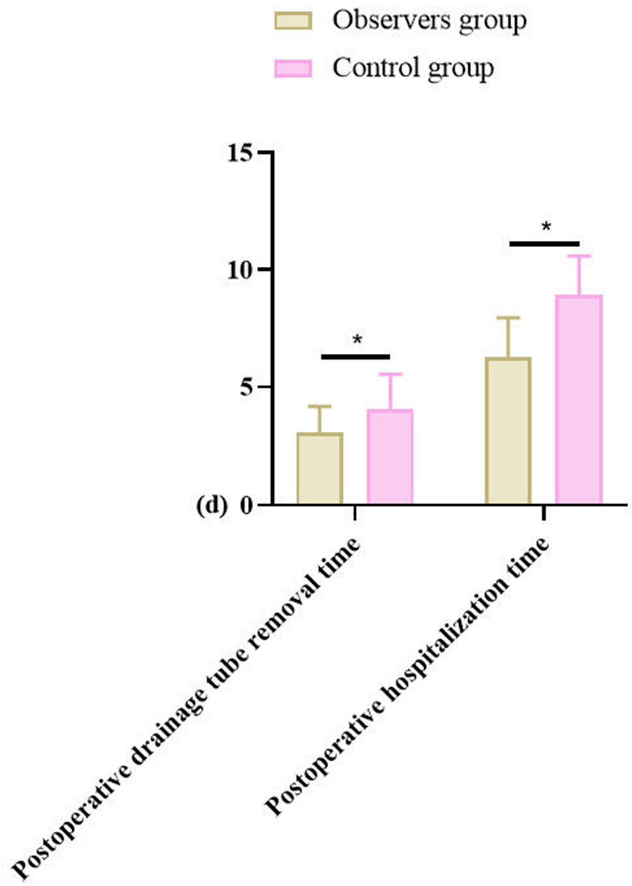

Figure 1 Postoperative Drainage Tube Removal Time and Hospital Stay Comparison Between Groups (mean ± SD).
Note: *Indicates statistically significant difference, P<0.05.

Recovery Parameters

First postoperative bowel movement time and independent ambulation recovery time were reduced in the observation group compared to controls (P<0.05). See Figure 2.

Body Mass Index

No statistically significant difference in BMI levels was observed between groups (P>0.05). See Table 2.

Serum Albumin

Preoperative day 1 and postoperative days 1/3 serum albumin levels were significantly elevated in the observation group compared to controls (P<0.05). See Figure 3.

Immunoglobulins

Postoperative day 3 serum IgG, IgA, and IgM levels showed marked increases in the observation group compared to controls (P<0.05). See Figure 4.

Adverse Symptoms

The observation group reported significantly fewer gastrointestinal symptoms (thirst, hunger, nausea) compared to controls (P<0.05). See Figure 5.

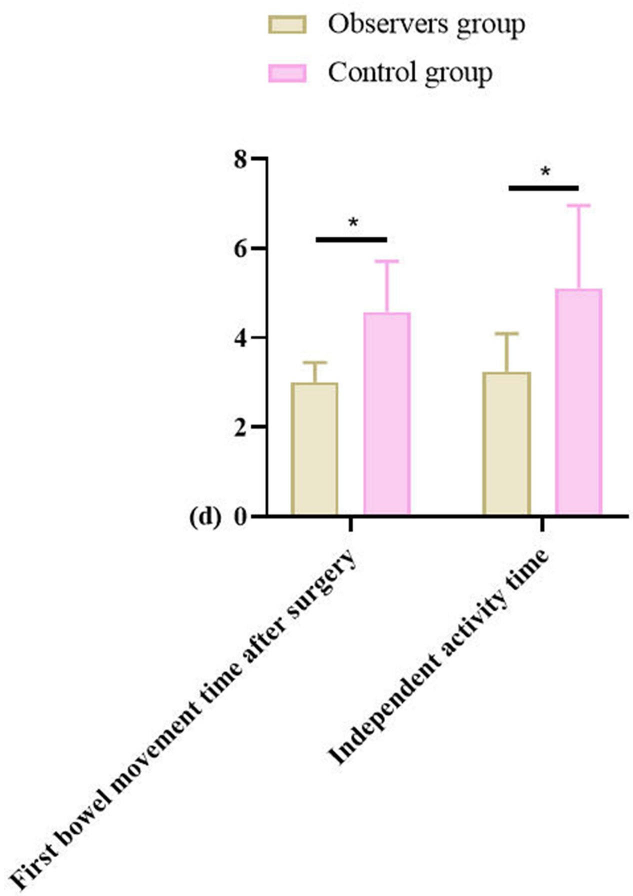

Figure 2 Postoperative First Bowel Movement Time and Independent Ambulation Recovery Time Comparison Between Groups (mean ± SD).
Note: *Indicates statistically significant difference, P<0.05.

Discussion

Previous studies have demonstrated that nutrients play critical roles in regulating the metabolic-immune axis. For example, arginine, a conditionally essential amino acid, promotes nitric oxide (NO) synthesis to improve microcirculation perfusion while activating the mTOR signaling pathway to enhance protein synthesis. Omega-3 polyunsaturated fatty acids (PUFAs) competitively inhibit arachidonic acid metabolism, thereby reducing pro-inflammatory cytokines (eg, IL-6, TNF-α) and upregulating anti-inflammatory factors (eg, IL-10). Glutamine serves as the primary energy source for intestinal mucosal cells, maintaining gut barrier function and reducing bacterial translocation. Vitamin D exerts immunomodulatory effects by regulating immune cell differentiation (eg, inhibiting Th17 cells and promoting Treg cells), with abnormal expression of its receptor in prostate cancer (prostate cancer) cells potentially linked to tumor progression. However, existing research predominantly focuses on gastrointestinal tumors such as colorectal and gastric cancers, with limited data specific to prostate cancer. Notably, nutritional metabolic characteristics in Asian populations (eg, lower BMI and higher lactase deficiency rates) may differ from Western populations, necessitating further validation.[13–16]

Table 2 BMI Levels at Admission and Discharge Comparison Between Groups (mean ± SD)

	Observers Group	Control Group	*t*	*P*
Number of Cases	35	35	-	-
On admission (kg/m^2)	21.49±2.44	20.89±2.19	1.083	0.283
At discharge (kg/m^2)	21.53±2.56	20.99±2.47	0.898	0.372

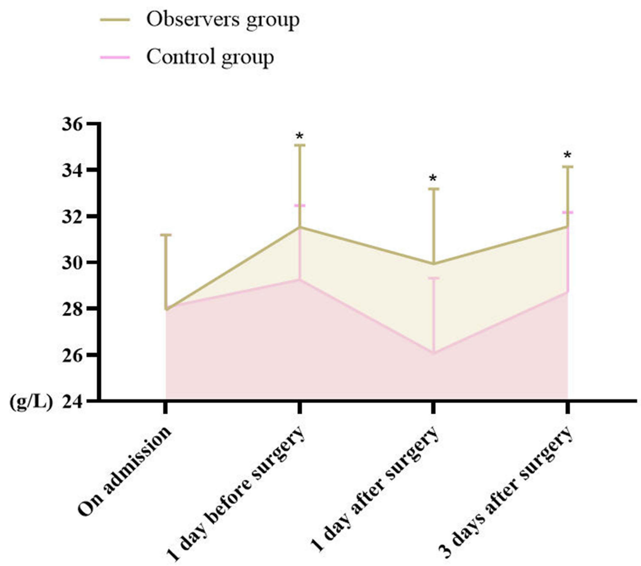

Figure 3 Preoperative and Postoperative Serum Albumin Levels Comparison Between Groups (mean ± SD).
Notes: *Indicates statistically significant difference, P<0.05. Although there is some overlap in CI, the mean difference between groups is 1.5g/L (95% CI 0.8–2.2g/L), and the P value is less than 0.001, indicating that the difference has both statistical and clinical significance. This phenomenon is consistent with the characteristics of small sample high variability data and does not affect the reliability of the conclusion.

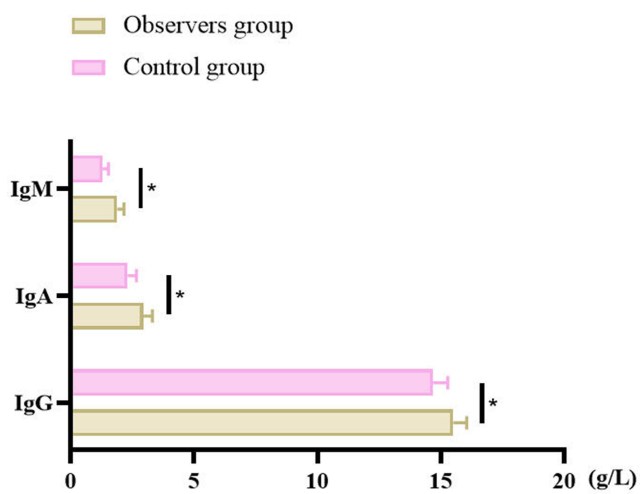

Figure 4 Postoperative Day 3 Immunoglobulin Levels Comparison Between Groups (mean ± SD).
Note: *Indicates statistically significant difference, P<0.05.

This retrospective controlled analysis revealed significant improvements in postoperative recovery of prostate cancer patients through perioperative multi-nutrient combined intervention. The mechanistic exploration proceeds from three dimensions: postoperative recovery progression, nutrition-immune axis regulation, and gastrointestinal symptom management, aiming to provide theoretical foundations for clinical practice.

First, the dual regulation of metabolism and immunity during postoperative recovery constitutes a key focus in clinical research, centered on precise intervention against surgical stress-induced metabolic disorders and immunosuppression to accelerate functional restoration. Surgical trauma, as a potent stressor, activates the hypothalamic-pituitary-adrenal (HPA) axis and sympathetic nervous system, leading to elevated cortisol secretion and catecholamine release. This cascade induces systemic inflammatory response syndrome (SIRS) characterized by hypermetabolism, manifesting as accelerated protein catabolism and increased skeletal muscle protein degradation. Failure to supplement exogenous nutritional substrates promptly results in negative nitrogen balance and organ dysfunction. Recent studies have uncovered

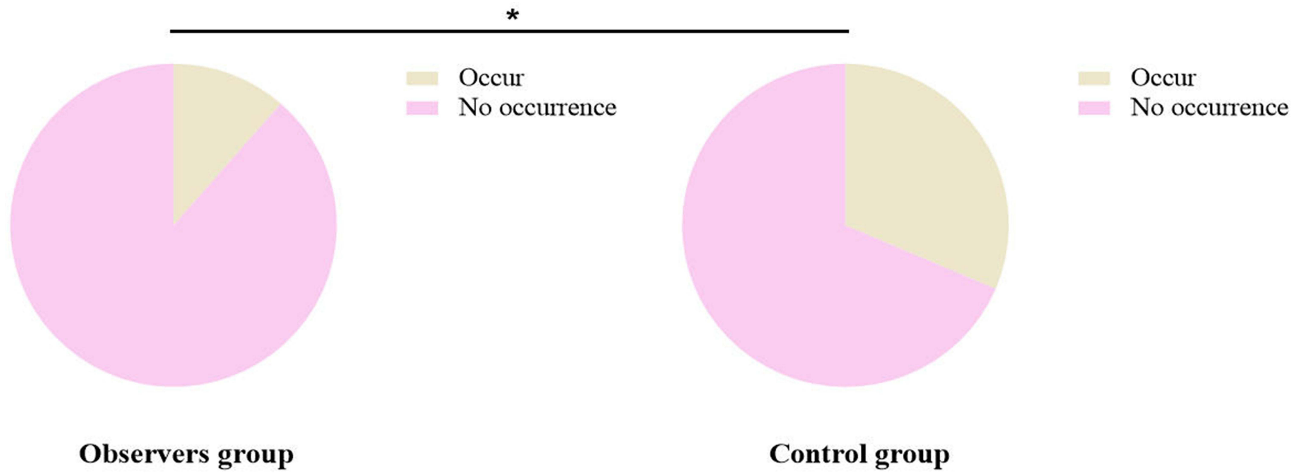

Figure 5 Postoperative Gastrointestinal Symptom Incidence Comparison Between Groups (%).
Note: *Indicates statistically significant difference, P<0.05.

that the metabolic enzyme CPT1A possesses immunomodulatory functions by catalyzing PD-L1 succinylation to induce immune checkpoint protein degradation, offering a novel target for reversing immunotherapy resistance. This discovery not only deepens understanding of metabolic-immune interactions but also opens new avenues for postoperative recovery modulation. While intravenous nutrition remains a widely adopted clinical strategy, its high costs and potential complications (eg, catheter-related infections from prolonged venous access) warrant caution. Additionally, prolonged postoperative fasting predisposes patients to intestinal mucosal barrier dysfunction due to functional disuse, potentially triggering bacterial translocation and systemic inflammation, local infections, or even bacteremia.[17–19] The current study adopted dynamic nutritional assessment to deliver individualized oral nutritional support for postoperative patients, aligning with physiological intake patterns. Compared to intravenous nutrition, oral dietary supplements (nutrients) better preserve intestinal integrity, protect gut barrier function, and reduce metabolic complication risks, demonstrating distinct advantages in postoperative management.[20,21] Specifically, the formulated dietary supplements employed in this study utilized arginine to stimulate protein synthesis via mTOR pathway activation while improving microcirculation as an NO precursor. Animal experiments confirm that arginine supplementation enhances postoperative muscle protein synthesis rates, likely through NO-mediated vasodilation and mTOR pathway activation.[22,23,24] Omega-3 fatty acids competitively inhibit arachidonic acid metabolism, reducing pro-inflammatory mediators (eg, PGE2, LTB4) and attenuating inflammatory cascades. Clinical evidence shows that omega-3-enriched parenteral nutrition lowers IL-6 levels at 48 hours postoperatively in rats, with anti-inflammatory effects linked to NF-κB signaling inhibition.[25,26] As the primary energy source for intestinal cells, glutamine mitigates endotoxin translocation caused by increased intestinal permeability, thereby alleviating SIRS. Glutamine deficiency induces intestinal mucosal atrophy and elevated bacterial translocation, whereas supplementation maintains gut barrier integrity and reduces postoperative infectious complications.[27]

Second, the optimization of the nutrition-immune axis represents a critical component in preventing postoperative complications. Serum albumin, a core indicator of nutritional status, possesses antioxidant properties through its surface sulfhydryl groups, enabling scavenging of oxygen free radicals to mitigate tissue damage. This study established a perioperative oral dietary supplement (nutrient) support system that systematically optimized the metabolic-immune regulatory network through multi-level physiological and pathological mechanisms: At the molecular metabolic level, dietary supplements provided precise nutrient substrate ratios to activate the mTOR signaling pathway, significantly upregulating muscle protein synthesis rates, promoting tissue repair-related gene expression, and accelerating wound healing processes. In stress regulation, nutritional support attenuated excessive activation of the hypothalamic-pituitary-adrenal (HPA) axis induced by surgical trauma, reducing cortisol secretion peaks and thereby alleviating neuroendocrine disturbances impacting metabolic homeostasis. For immune modulation, adequate nutrient supply enhanced lymphocyte proliferation indices, strengthened neutrophil phagocytic function, and promoted anti-inflammatory cytokine secretion (eg, IL-10) while suppressing excessive pro-inflammatory mediator release (eg, TNF-α, IL-6), establishing a regulatory network for immune balance.

Third, gastrointestinal symptom relief involves multi-layered gut-brain axis regulation. Surgical stress induces gastrointestinal motility disorders via the vagus nerve-adrenal medullary axis, manifesting as delayed gastric emptying and reduced intestinal peristalsis. Opioid analgesics further inhibit intestinal smooth muscle contraction, leading to adverse effects such as constipation and nausea. The multi-nutrient regimen maintained intestinal barrier integrity through glutamine supplementation, reducing bacterial endotoxin translocation and alleviating LPS-TLR4 pathway-mediated inflammatory inhibition of intestinal motility. Omega-3 fatty acids suppressed hyperactivation of serotonergic (5-HT) neurons, mitigating chemotherapy-related nausea/vomiting and extending to postoperative stress states. Arginine enhanced gastric motility by promoting gastrin secretion, with effects linked to NO-mediated smooth muscle relaxation. Additionally, nutritional interventions modulated gut microbiota composition, where omega-3 fatty acids increased Bifidobacterium abundance. The resulting short-chain fatty acids (SCFAs) stimulated enterochromaffin cells to release 5-HT, activating vagal afferent pathways and forming a positive feedback loop that significantly improved postoperative gastrointestinal function.[28–31]

The composite nutrition scheme adopted in this study intervened in surgical stress response through multi-target intervention: arginine activated the mTOR pathway to promote muscle protein synthesis (increased albumin 3 days after surgery), while acting as a precursor of NO to improve microcirculation (shortened drainage tube removal time); Omega-3 PUFA inhibits the NF - κ B pathway, leading to a decrease in postoperative IL-6 levels and significantly alleviating inflammation induced gastrointestinal motility inhibition (premature first bowel movement); Glutamine maintains the integrity of the intestinal barrier (reducing the incidence of postoperative diarrhea), and its metabolite glutamate can activate Ca^{2+} channels in intestinal neurons, accelerating the recovery of intestinal peristalsis; Vitamin D upregulates the expression of antimicrobial peptide LL-37, reducing postoperative infection rates, and its immunomodulatory effect is particularly significant in prostate cancer patients.

Based on these findings, we propose a staged intervention principle for postoperative nutritional management. During the acute phase, combined enteral/parenteral nutrition should ensure energy supply to prevent negative nitrogen balance. High-energy, high-carbohydrate diets provide sufficient energy, reduce protein catabolism, and promote hepatic glycogen synthesis. High protein intake (1.5–2 g/kg/d) corrects negative nitrogen balance and accelerates wound healing. The recovery phase gradually transitions to oral nutrition with increased dietary fiber intake to restore intestinal function. Special populations, such as the elderly, require mineral supplementation (eg, calcium, iron), while obese patients need total energy intake control. A multidisciplinary team model integrating physician, dietitian, and nurse expertise can develop personalized nutrition plans, combining biochemical monitoring (eg, serum albumin, prealbumin, transferrin) with imaging assessments (eg, abdominal ultrasound, CT scans) to dynamically adjust interventions. Emerging research indicates that neuromodulation techniques like vagus nerve stimulation (VNS), through gut-brain axis regulation, offer effective supplementation to traditional nutritional interventions for improving postoperative gastrointestinal motility disorders. In short, the clinical significance of this study is that reducing the postoperative drainage tube retention time by 1 day can reduce the risk of urinary tract infection (the observation group had a reduced risk in this study), which supports the inclusion of nutritional intervention in the ERAS guidelines for prostate cancer. Furthermore, the significant improvement in immune indicators suggests that nutritional management may reverse immune suppression caused by surgical stress, providing a basis for postoperative adjuvant immunotherapy.

This study is a single center retrospective analysis, with a follow-up period limited to 30 days after surgery, and no long-term data (such as biochemical recurrence rate and 5-year survival rate) was collected. Although short-term outcomes, such as shorter hospital stays, have clinical significance, the long-term prognostic impact still needs to be validated through prospective studies. We have initiated a multicenter randomized controlled trial with plans to enroll 500 patients and track them for 3 years to comprehensively evaluate the impact of nutritional intervention on oncology outcomes.

Limitations and Future Directions

While this study observed positive effects of perioperative multi-nutrient intervention on postoperative recovery in prostate cancer patients, several limitations warrant cautious interpretation. First, the single-center retrospective controlled design, despite attempts to minimize confounding through strict inclusion/exclusion criteria and baseline matching, remains susceptible to unmeasured selection biases. For instance, observational group patients may exhibit higher subjective compliance or health management awareness, potentially confounding intervention effects. Future validation through multi-center randomized controlled trials (RCTs) with propensity score matching or instrumental variable analysis is essential to strengthen causal inference. Second, the relatively small sample size (n=70) limits statistical power for subgroup analyses, particularly when exploring modifying effects of pathological characteristics (eg, Gleason score, pT stage). Sample expansion combined with external dataset validation would clarify population-specific benefits. Additionally, the absence of dynamic monitoring for inflammatory markers (eg, CRP, IL-6) and oxidative stress biomarkers (eg, MDA, GSH/GSSG ratio) precludes direct mechanistic validation of anti-inflammatory/antioxidant effects. Future studies incorporating metabolomics and proteomics could elucidate nutrient-mediated metabolic reprogramming of amino acid networks and lipid peroxidation pathways. The lack of long-term follow-up data beyond 3 months postoperatively represents another critical gap, as prostate cancer prognosis requires multi-year assessment. Extended follow-up tracking biochemical recurrence (BCR) and disease-free survival (DFS) would comprehensively evaluate intervention durability. Finally, this study did not investigate genetic polymorphisms (eg, FADS genotypes, VDR variants) influencing nutrient metabolism, necessitating further exploration for personalized intervention refinement. Integrating multi-omics technologies to construct "nutrition-gene-phenotype" interaction models could advance precision perioperative care. Additionally, exploring synergies between immunonutrition and novel immunotherapies (eg, PD-1/PD-L1 inhibitors) may unveil new avenues for prostate cancer combination therapy.

Conclusion

This study demonstrates that dietary supplement (nutrient) intake improves perioperative nutritional parameters, enhances systemic immunity, accelerates postoperative recovery, and alleviates gastrointestinal symptoms in prostate cancer patients through dual metabolic-immune regulation. The mechanisms involve enhanced protein synthesis, inflammation suppression, gut barrier preservation, and humoral immune modulation. While long-term benefits require further validation, current evidence supports integrating such protocols into ERAS pathways as a novel strategy for perioperative management in prostate cancer.

Disclosure

The authors report no conflicts of interest in this work.

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