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Article

Feedforward Control Combined With Refined Management: Perioperative Nursing Outcomes for Robot-Assisted Radical Prostatectomy

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Abstract

Aims/Background: Perioperative nursing has critical implications in surgical procedures as well as patients' safety and postoperative prognosis. This study aimed to explore the effect of feedforward control combined with a refined management model on perioperative nursing in robot-assisted radical prostatectomy. **Methods:** Clinical data of 108 patients who underwent robot-assisted radical prostatectomy from November 2024 to November 2025 in Quzhou People's Hospital were collected for retrospective analysis. All patients were divided into two groups: control group (n = 49) and study group (n = 59) according to the type of nursing management model adopted. The refined management model was applied to the patients in the control group. The study group adopted feedforward control combined with the refined management model. The perioperative indicators were collected. Postoperatively, the quality of nursing care was evaluated using a Good Perioperative Nursing Care Scale (GPNCS). The patient satisfaction and nursing errors were assessed and recorded. **Results:** Compared with the control group, the operative time, blood loss, intraoperative hypothermia, and time to first ambulation were significantly shorter in the study group (p = 0.020, 0.028, 0.034, 0.022, respectively). The scores of different dimensions of GPNCS, such as total score, body care, receiving information, support, and environment, in the study group were significantly increased compared with the control group (all $p < 0.001$). There were no differences between the two groups in dimensions of respect, medical staff characteristics, and nursing process (all $p > 0.05$). Patient satisfaction in the study group was higher than in the control group ($p < 0.001$). There were two cases of patient complaints in the control group but none in the study group ($p > 0.05$). The incidence of nursing errors reported in the study group was 3.39% (2/59), which was lower than in the control group (18.37%, 9/49) ($p = 0.025$). **Conclusion:** Feedforward control combined with refined management improved perioperative nursing quality and patient satisfaction while reducing operating room nursing errors in robot-assisted radical prostatectomy.

Keywords: feedforward control; nursing care; operating room; robot-assisted surgery; prostatectomy

1. Introduction

Radical prostatectomy is the standard surgical procedure for localized prostate cancer. This procedure achieves tumor resection and good prognosis by completely removing the prostate gland, seminal vesicle, and surrounding involved tissues, preserving urinary function and erectile function as much as possible [1,2]. The application of robotic systems in surgical procedures provides a three-dimensional, high-definition surgical field of view and multiple degrees of freedom through its robotic arm, enabling surgeons to achieve more accurate tissue separation and suturing [3]. In radical prostatectomy, this technology helps accurately preserve neurovascular bundles and reduce the positive rate of tissue margins, which is beneficial for postoperative functional recovery and tumor control in patients [4]. Compared with traditional laparoscopic surgery, robot-assisted surgery is more complex and requires operating room nurses to possess specialized skills and expertise [5]. Particularly, the operating room nurses are expected to not only be proficient in nursing skills, but also be able to maneuver instruments and handle intraoperative emergencies [6]. Given its complexity and high technical demands, robot-assisted radical prostatectomy requires standardized and high-quality perioperative nursing management.

The quality of perioperative nursing care is directly related to patient health and surgical outcomes [7,8]. The improvement of nursing management models in the operating room contributes to enhanced nursing quality and patient satisfaction. The refined management model adopts standardized and proceduralized methods to optimize control processes. A study has shown that refined management in operating room nursing reduced the preoperative preparation time, intraoperative duration, bleeding volume, and time to first postoperative defecation, and improved quality of surgical care in laparoscopic radical resection of colon cancer [9].

In robot-assisted surgery, the nursing processes are complex and involve multiple risk factors. Within the realm

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of perioperative nursing management, prediction and handling of potential risks should be taken into consideration. Feedforward control is a strategy that involves risk control by anticipating potential risks and consequences and implementing preventive measures [10]. Unlike traditional feedback control, feedforward control places more emphasis on the prophylactic concept [11]. The effects of the feedforward control model on perioperative nursing have been reported by Ma et al. [12], who found that the feedforward control model reduces nursing errors and improves their attitudes, thereby improving the nursing quality in the operating room. The "preventive core" of the feedforward control model complements the "detailed control" of the refined management model, with their combination effectively addressing the complexity and high technical demands of robot-assisted surgery. However, few studies have explored the effects of feedforward control combined with a refined management model on perioperative nursing in robot-assisted surgery. This study aims to explore the application of feedforward control combined with a refined management model on perioperative nursing management in robot-assisted radical prostatectomy.

2. Methods

2.1 General Information

Clinical data of 108 patients undergoing robot-assisted radical prostatectomy at Quzhou People's Hospital from November 2024 to November 2025 were collected for retrospective analysis. The inclusion criteria are as follows: (1) patients who were pathologically diagnosed with prostate cancer and confirmed to meet the indications for radical prostatectomy, and underwent robot-assisted radical prostatectomy using the Da Vinci Xi robot system (Intuitive Surgical, Inc., San Jose, CA, USA); and (2) patients aged >18 years. The exclusion criteria are as follows: (1) patients with severe hepatic or renal dysfunction; (2) patients suffering from serious infectious diseases; (3) patients with cognitive impairment or mental disorders; and (4) history of pelvic surgery.

All patients were divided into two groups: control group (n = 49) and study group (n = 59) according to the type of nursing management model adopted. The refined management model was applied to patients in the control group, whereas the feedforward control combined with the refined management model was adopted in the study group.

2.2 Perioperative Nursing Management Model

The refined management model was applied to patients in the control group. On the day of surgery, nurses systematically checked the Da Vinci Xi robotic surgical instruments, energy-related consumables, and emergency supplies against the inventory list, and inspected the integrity and sterility of all instruments. Standardized procedures were followed for instrument assembly, lens calibration, intraoperative instrument delivery and counting, and surgical equipment monitoring, with timely replenishment of supplies as needed. Patients were positioned according to standardized protocols, with limb angles and pressure-bearing points individually adjusted according to the patient's physique and pressure-relieving devices routinely applied. Operating room temperature and humidity were maintained throughout the procedure. Nonoperative body areas were covered for heat preservation, and body temperature was continuously monitored. Strict aseptic protocols were implemented to maintain a clean surgical environment. Throughout the procedure, the nursing team maintained close communication and collaboration with the medical staff.

Feedforward control management was applied to the study group on the basis of the refined management model. A specialized nursing team comprising the head nurse, designated specialty nurses, operating room instrument nurses, and circulating nurses was established to identify potential risks associated with robot-assisted surgery. The team reviewed clinical data from patients who had previously undergone robot-assisted radical prostatectomy, relevant literature, and records of nursing adverse events. Six core risk factors affecting surgical and nursing outcomes were identified: patients' preoperative physical condition, inadequate preoperative nursing preparation, inappropriate surgical positioning, malfunction of the robotic main unit and manipulator arms, catheter dislodgement, and intraoperative hypothermia. Combining patients' age, body mass index (BMI), underlying diseases, estimated operative time, and vascular status, the team stratified patients into low-risk (0 to 1 abnormal indicators), moderate-risk (2 to 3 abnormal indicators), and high-risk (≥4 abnormal indicators) groups. The hierarchical nursing protocols were implemented as follows: ① For low-risk patients, surgical instruments and basic robotic equipment were routinely checked one day before surgery. Standardized refined intraoperative coordination procedures were adopted, including routine monitoring of vital signs, skin integrity and catheter patency, regular inspection of equipment operating parameters, as well as basic thermal preservation and position-fixation nursing. ② For moderate-risk patients, Comprehensive debugging of the robotic imaging system and movable range of manipulator arms was conducted by two nurses one day preoperatively to eliminate hidden risks such as equipment jamming and poor adhesion of sterile drapes. The body position angle was optimized according to individual physique, and decompression dressings were pre-applied on pressure-prone areas. Blood pressure and coagulation indicators were assessed preoperatively to predict the risk of intraoperative hemorrhage and circulatory fluctuations. Special rounds were performed every 30 minutes intraoperatively to dynamically adjust thermal preservation temperature and infusion flow rate, with hemostatic and vasopressor emergency supplies prepared in advance for any arising controllable intraoperative emergencies. ③ For high-risk patients, a three-

party preoperative discussion involving surgeons, anesthesiologists, and nurses was held to formulate individualized surgical nursing plans. Full trial operation of the robotic system and emergency linkage drills for equipment failures were completed preoperatively, and worn instruments were replaced as necessary. For elderly, obese patients or those complicated with hypertension and hyperlipidemia, preoperative physical status was optimized, and pressure-bearing points were adjusted to prevent peroneal nerve injury and increased intraocular pressure. A dedicated nurse was assigned to monitor the patient-side robotic arms and instrument status intraoperatively to identify potential risks of manipulator arm deviation and inadvertent contact with the surgical wound. Stress-related physiological indicators were continuously monitored throughout the operation, and early interventions were carried out for blood pressure fluctuation, surgical bleeding, and body temperature decline.

Preoperative psychological support and position-related guidance were provided to all patients. Nurses communicated with patients to explain the surgical procedures and therapeutic goals so as to relieve their negative emotions. Additional reassurance was provided to patients experiencing more intense distress. All surgical procedures and postoperative care for patients were carried out by the same experienced clinical team.

2.3 Indicators Collection

The perioperative indicators included operative time (the duration from the formation of the skin incision to the end of the surgery), estimated blood loss (calculated by subtracting the volume of irrigation fluid from the total volume in the suction canister, adding the weight difference of blood-soaked gauze, and incorporating the surgeon‘s visual estimation), necessity for blood transfusion during the perioperative period, intraoperative hypothermia (core body temperature below 36 ℃), perioperative complications, time to first ambulation (time interval between the patient's return to the ward and the first ambulation), and the length of postoperative hospital stay. Meanwhile, general information of patients was collected, including age, BMI, and comorbid disease (diabetes, hypertension, hyperuricemia, and cardiac cerebrovascular disease).

2.4 Quality of Nursing Care

After patients had fully recovered from anesthesia and their clinical condition became stable, the responsible nurse administered the patient version of the Good Perioperative Nursing Care Scale (GPNCS) to evaluate the quality of nursing care [13,14]. The scale demonstrated good internal consistency, with a Cronbach’s α of 0.918 [14]. It comprises 7 dimensions: body care (10 items), receiving information (5 items), support (4 items), respect (3 items), medical staff characteristics (4 items), environment (4 items), and nursing process (2 items). Each item is rated on a 5-point scale from 1 (totally disagree) to 5 (totally agree), yielding a total score of 32–160 points, with higher scores indicating better quality of nursing care.

2.5 Patient Satisfaction and Nursing Errors

After patients had fully recovered from anesthesia and their clinical condition became stable, the responsible nurse administered the Newcastle Satisfaction with Nursing Scales to assess patient satisfaction. The scale yields a total score of 19–95 points, with higher scores indicating greater satisfaction. Nursing errors were defined as any deviations from established nursing procedures or professional standards that may adversely affect patient health or recovery. Nursing error events were identified by the department nursing team and included inadequate preoperative preparation, inadequate psychological support, instrument-related injury, and errors in nursing documentation. Patient complaints regarding nursing care were also documented.

2.6 Statistical Analysis

The statistical analysis was performed using SPSS version 27.0 software (IBM, Armonk, NY, USA). Multiple imputation methods were used to handle variables with less than 15% missing data. The Shapiro–Wilk test was adopted for assessing normality of continuous data. Normally distributed data were presented as mean ± standard deviation (SD), and their intergroup comparison was analyzed using an independent *t*-test. Data that did not conform to a normal distribution were expressed as median (interquartile range), and the intergroup differences were analyzed using the Mann–Whitney *U* test. Categorical data were presented as numbers and percentages, and the chi-square test, Yates’ continuity correction (if expected frequency <5) or Fisher’s exact test (if expected frequency <1) was performed. A *p*-value of less than 0.05 indicates statistical significance.

3 Results

3.1 Comparison of General Information

There were no significant differences between the control and study groups in terms of age, BMI, diabetes, hypertension, hyperuricemia, and atherosclerosis (all $p > 0.05$) (Table 1).

3.2 Comparison of Intraoperative and Postoperative Key Indicators

Compared with the control group, the study group had shorter operative time ($p = 0.020$) and time to first ambulation ($p = 0.022$), as well as experienced significantly lower blood loss ($p = 0.028$) and intraoperative hypothermia ($p = 0.034$). However, there were no significant differences in the rate of blood transfusion, the incidence of complications, or the length of hospital stay between the two groups (all $p > 0.05$) (Table 2).

Table 1. Comparison of general information between the two groups.

General information	Control group (n = 49)	Study group (n = 59)	t/χ^2	p
Age (years), mean ± SD	70.00 ± 6.72	70.39 ± 6.05	0.317	0.752
BMI (kg/m^2), mean ± SD	23.62 ± 2.81	23.69 ± 3.06	0.123	0.903
Diabetes, n (%)	6 (12.24%)	6 (10.17%)	0.117	0.733
Hypertension, n (%)	14 (28.57%)	19 (32.20%)	0.166	0.683
Hyperuricemia, n (%)	5 (10.20%)	6 (10.17%)	0.098	0.754
Cardiac cerebrovascular disease, n (%)	8 (16.32%)	3 (5.08%)	2.571	0.109

SD, standard deviation; BMI, body mass index.

Table 2. Comparison of intraoperative and postoperative key indicators between the two groups.

Perioperative indicators	Control group (n = 49)	Study group (n = 59)	t/Z/χ^2	p
Operative time (min), mean ± SD	233.10 ± 50.95	210.56 ± 47.89	2.366	0.020
Blood loss (mL), mean ± SD	211.12 ± 51.45	192.10 ± 37.17	2.226	0.028
Blood transfusion, n (%)	5 (10.20%)	3 (5.08%)	0.412	0.521
Intraoperative hypothermia, n (%)	7 (14.29%)	1 (1.69%)	4.488	0.034
Complications, n (%)	4 (8.16%)	1 (1.69%)	1.283	0.257
Leakage at vesicourethral anastomosis	2 (4.08%)	0 (0%)		
Bleeding	2 (4.08%)	1 (1.69%)		
Time to first ambulation (h), mean ± SD	19.31 ± 2.26	18.32 ± 2.17	2.316	0.022
Length of hospital stay (days), median (IQR)	4 (3, 4)	3 (3, 4)	1.431	0.153

SD, standard deviation; IQR, interquartile range.

Table 3. Comparison of GPNCS between the two groups.

GPNCS score	Control group (n = 49)	Study group (n = 59)	t/Z	p
Total score, mean ± SD	116.41 ± 6.33	133.08 ± 7.04	12.820	<0.001
Body care, mean ± SD	38.71 ± 4.48	44.42 ± 3.57	7.371	<0.001
Receiving information, median (IQR)	16 (15, 18)	21 (20, 23)	6.728	<0.001
Support, median (IQR)	14 (13, 15)	16 (14, 18)	3.653	<0.001
Respect, median (IQR)	13 (12, 14)	13 (12, 14)	0.554	0.579
Medical staff characteristics, mean ± SD	15.47 ± 2.54	15.71 ± 2.59	0.484	0.630
Environment, mean ± SD	11.00 ± 3.06	15.51 ± 2.63	8.237	<0.001
Nursing process, median (IQR)	8 (6, 9)	8 (7, 9)	0.895	0.371

GPNCS, Good Perioperative Nursing Care Scale.

3.3 Comparison of Quality of Nursing Care

The different dimensions of the GPNCS, such as total score, body care, receiving information, support, and environment, in the study group were significantly increased compared with the control group (all $p < 0.001$). There were no differences between the two groups in terms of respect, medical staff characteristics, and nursing process (all $p > 0.05$) (Table 3).

3.4 Comparison of Patient Satisfaction and Nursing Errors Between the Two Groups

Patient satisfaction in the study group was higher than that in the control group ($p < 0.001$). Two cases of patient complaints were documented in the control group, while none were in the study group, but the difference was not significant ($p = 0.204$). The incidence of nursing errors reported in the study group was 3.39% (2/59), which was lower than that in the control group (18.37%, 9/49) ($p = 0.025$) (Table 4).

4. Discussion

Robot-assisted radical prostatectomy is widely adopted on a global scale owing to a range of benefits it can offer, such as surgical precision, minimal invasiveness, and rapid postoperative recovery [15]. Nevertheless, the integration of robotic systems in the operating room is accompanied by inevitable practice changes in the aspect of perioperative nursing, such as robotic instrument sterility and operation, instrument troubleshooting, and preparations for emergencies [16]. Given the complexity of these changes, it is necessary to improve the quality of perioperative nursing management, in addition to strengthening the professional skills of operating room nurses.

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Table 4. Comparison of patient satisfaction and nursing errors between the two groups.

Index	Control group (n = 49)	Study group (n = 59)	Z/χ^2	p
Patient satisfaction, median (IQR)	88 (79, 91)	91 (87, 95)	3.699	<0.001
Patient complaints, n (%)	2 (4.08%)	0 (0%)		0.204
Nursing error, n (%)				
Inadequate preoperative preparation	3 (6.12%)	1 (1.69%)		
Inadequate psychological support	2 (4.08%)	0 (0%)		
Instrument-related injury	2 (4.08%)	0 (0%)		
Error in nursing records	2 (4.08%)	1 (1.69%)		
Total	9 (18.37%)	2 (3.39%)	5.029	0.025

Feedforward control management was initially used in the context of engineering management. It is used to analyze and predict factors that may affect outcomes, facilitating the formulation of corresponding risk-alleviating measures. Recent years have seen the gradual adoption of this management model in clinical nursing [11,17]. The feedforward control model seeks to actively identify potential risks, deviations, and interference factors in order to improve procedural efficiency and enhance the ability to address complexity and uncertainty [11]. A previous study found that feedforward control management combined with a holistic perioperative nursing model increased postoperative recovery quality, reduced surgical complications, and shortened operative time in gynecological laparoscopic surgery [18]. In this study, the patients who received the combined intervention of feedforward control and refined management had better indicators such as operation time, blood loss, intraoperative hypothermia, and time to first ambulation compared to those who only received refined management, indicating the superior effect of feedforward control on the perioperative nursing quality in robot-assisted surgery. This finding is consistent with the results reported in the above-mentioned study.

The noticeable benefits of the feedforward control model in strengthening perioperative nursing quality primarily lie in the preliminary analysis of potential perioperative risk factors in robot-assisted surgery and the subsequent formulation of preventive strategies. During surgery, operating room nurses are expected to confront a multitude of emergencies, such as bleeding, tissue damage, abnormalities in the circulatory and respiratory system caused by inactivity or pneumoperitoneum pressure, and equipment failures. Additionally, the calibration and sterility of robot systems are critical aspects that require meticulous examination prior to surgery [19]. With the feedforward control model in place, these risk factors are systematically thought out in advance, with pre-emptive measures designed to tackle such occurrences. It is also important to highlight that the negative emotions of patients, such as fear or confusion, may affect the treatment efficacy [20]. These measures substantially reduce panic incidence and anxiety among the operating room nurses whenever an emergency occurs. Furthermore, optimal staff cooperation is crucial for surgical success because compromised collaboration during an emergency may give rise to serious consequences [21,22]. The refined management model emphasizes the implementation of optimized processes and standardized operations, which is an important element of nursing quality improvement [23,24]. However, this model lacks the capacity for early risk prediction and emergency prevention in the operating room. Therefore, to enhance perioperative nursing quality, it is an intuitive approach to combine the feedforward control model with the refined management model, as their synergistic effect is greater than the impact when each of them is used alone. Meanwhile, we also found that this combined nursing management model increased the GPNCS scores in the domains of body care, receiving information, support, and environment. These domains corresponded to risk factors addressed by feedforward control, including the patient's perioperative physical condition, as well as communication and support. However, there were no significant score differences between the two groups in the dimensions of respect, medical staff characteristics, and nursing process. We have provided detailed regulations in these aspects in the refined management model. However, in the feedforward control, we focused on addressing current prominent issues when analyzing risk factors and paid insufficient attention to these aspects. Future research can explore how to improve perioperative nursing quality in the operating room from these fields.

In this study, the feedforward control combined with the refined management model heightened patient satisfaction, with only two patient complaints lodged in the control group. The main reasons for the complaints were insufficient preoperative communication, unfamiliarity with robotic surgery, and anxiety. Following receipt of these complaints, our medical team made a sincere apology to the patients and provided detailed responses to address their concerns, alleviating their negative emotions. Meanwhile, nine nursing errors were made in the control group, which was higher than in the study group. These nursing errors were mainly related to inadequate preoperative preparations and errors made in nursing records. Consistent with other

studies [11,12], our findings demonstrated that the feedforward control model aids in mitigating nursing error events. With the feedforward control model's role in preliminary risk identification and mitigation, as well as the refined nursing management model centered on the implementation of standardized procedures and detailed operations, their combination constructs a closed-loop nursing system that focuses on early risk prevention and holistic, detailed control—a model that could fully cater to the perioperative management needs of robot-assisted radical prostatectomy.

5. Limitation

Despite the benefits of this fusion strategy, several limitations warrant our attention. First, the study had a relatively small sample size and a retrospective design, which may have introduced biases in results despite the absence of significant differences in baseline clinical characteristics between the two groups. The results should therefore be validated in larger studies. Second, multivariate analyses were not performed to adjust for potential confounding factors, and potential selection bias between the two groups could not be adequately controlled, which may have certain impacts on the authenticity of the research results. Additionally, the study did not develop a standardized quantitative risk stratification scale; instead, surgical care risks were qualitatively stratified based on clinical experience, which may have introduced subjectivity into the risk assessment. Furthermore, the follow-up period of this study was relatively short, and it did not include long-term functional recovery endpoints such as urinary control ability and sexual function recovery. Therefore, it could only reflect the short-term perioperative and postoperative nursing outcomes, and could not evaluate the long-term effects of this nursing model on patients' quality of life. Moreover, this study employed subjective assessment scales to evaluate nursing quality, and the scale was distributed by nurses. Patients may have concerns when filling in the scale, which may introduce social expectation bias and lead to biased results. Finally, this study evaluated the effects of feedforward control combined with the refined management model only in the perioperative nursing of robot-assisted radical prostatectomy. Its applicability to other clinical departments or surgical procedures remains unclear. Subsequent research should assess the efficacy of this combined nursing management model in other surgical procedures or clinical departments to determine its broader applicability.

6. Conclusion

Feedforward control combined with refined management not only effectively shortens the operative time and reduces intraoperative blood loss but also significantly lowers the incidence of intraoperative hypothermia and promotes early postoperative ambulation, thereby enhancing perioperative safety and efficiency. Moreover, this nursing model significantly improves nursing quality and patient satisfaction while reducing the incidence of nursing errors. Overall, this optimized nursing strategy may contribute to better patient outcomes and enhanced nursing safety.

Key Points

• Feedforward control combined with refined nursing management can effectively improve intraoperative and postoperative indicators, such as operative time, intraoperative blood loss, and time to first ambulation.

• Feedforward control combined with refined nursing management can effectively improve the quality of nursing care and increase patient satisfaction.

• Feedforward control combined with refined nursing management can effectively reduce the incidence of nursing errors.

Availability of Data and Materials

The data analyzed are available upon request to the corresponding author.

Author Contributions

JX had the original conception of the work. JX, RJG, HLW and QYZ collected the clinical data. JX and QYZ performed the research. JX drafted the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study has been approved by the ethics committee of Quzhou People's Hospital (2026 Research No. 058), and all procedures were carried out in compliance with the Declaration of Helsinki. Informed consent was obtained from every patient.

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Conflicts of Interest

The authors declare no conflicts of interest.

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