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Effectiveness of an Information-Based Graded Nursing Platform Based on the Donabedian Structure-Process-Outcome Model: A Historical Control Study

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Abstract: *Objective*: To explore the application effect of an information-based graded nursing platform for hospitalized patients, developed based on the Donabedian Structure-Process-Outcome (SPO) Framework. *Methods*: A historical control design was adopted. Hospitalized patients in a tertiary hospital in Shiyan City from January to March 2025 (control group, *n*=3,473) and from October to December 2025 (experimental group, *n*=2,586) were enrolled. The experimental group received the information-based graded nursing platform, while the control group received conventional graded nursing. Indicators related to structure, process, and outcome dimensions were compared between the two groups. *Results*: The total satisfaction score of nurses with information facilities in the experimental group increased significantly from 17.29±2.25 before the intervention to 21.37±2.29 after the intervention (P<0.001). The nursing round implementation rate (88.66% vs. 65.37%) and the nursing grading compliance rate (96.48%±3.62% vs. 90.23%±3.57%) were significantly higher in the experimental group than in the control group (P<0.01). The incidence of nursing adverse events (0.1‰ vs. 0.049‰) was significantly lower in the experimental group (P<0.01). Nurses' disease observation abilities (professional ability, critical thinking ability, and professional quality) in the experimental group were significantly improved compared with those before the intervention (P<0.05). *Conclusion*: The information-based graded nursing intervention program, constructed based on the Donabedian Structure-Process-Outcome Model, significantly improves the nursing round implementation rate and nursing grading compliance rate, reduces the incidence of adverse events, and enhances nurses' disease observation abilities. It provides a feasible solution for implementing the "Grading Standards for Nursing (WS/T 431-2023)" in tertiary hospitals.

Keywords: Graded nursing; Nursing quality improvement; Information-based nursing; Structure-Process-Outcome model

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1. Introduction

Graded nursing, which involves implementing differentiated nursing management based on patients' medical conditions and self-care abilities, is a core clinical practice. It is a key strategy for optimizing the allocation of nursing resources, improving nursing service efficiency, and ensuring patient safety [1–2]. In 2023, the official implementation of the "Grading Standards for Nursing (WS/T 431-2023)" introduced new requirements for dynamic assessment, multidisciplinary collaboration, and quantitative evaluation of self-care ability in graded nursing, serving as an important guideline for the standardized development of graded nursing practice in China [1, 3]. Concurrently, the rapid development of medical information technology provides critical technical support for implementing these new standards, promoting a shift in graded nursing from "experience-based execution" to "standardized and precise" practice [4].

Current research indicates that tertiary hospitals commonly face challenges in graded nursing practice, including inconsistent implementation of assessment standards, insufficient doctor-nurse collaboration, and weak information system support. These issues lead to a poor match between nursing measures and patient needs, increasing potential safety risks [5–6]. Moreover, existing studies often focus on a single aspect of grading standards or the effect evaluation of a particular intervention, lacking research grounded in classical theoretical frameworks that align with the new standards [7–8].

In 1966, the American scholar Donabedian proposed the "Structure-Process- Outcome" three-dimensional quality evaluation model, which has been widely used in healthcare service quality evaluation both domestically and internationally [9–12]. The core logic of this model, "structure determines process, and process affects outcome," aligns well with the research needs of graded nursing quality improvement [13–14]. Based on this, the hospital designed and constructed an information-based graded nursing platform guided by the Donabedian model. This platform, grounded in structural optimization, centered on process standardization, and oriented toward outcome improvement, aims to achieve closed-loop management of the entire graded nursing process, from physician order issuance and dynamic assessment to measure execution and quality evaluation.

2. Objects and methods

2.1. Study participants

The hospital has 3,206 operating beds. Using convenience sampling, hospitalized patients from January to March 2025 were selected as the control group (n=3,473, total occupied bed days: 298,003 days), receiving conventional graded nursing. Hospitalized patients from October to December 2025 were selected as the experimental group (n=2,586, total occupied bed days: 303,323 days), receiving the information-based graded nursing platform. The two groups were comparable in terms of total occupied bed days (P>0.05).

2.2. Intervention methods

2.2.1. Control group

The control group followed the hospital's existing graded nursing management system. Nursing grades were determined by the attending physician based on clinical experience upon admission and remained static during hospitalization. Self-care ability assessments were recorded manually on paper. Bedside nursing rounds were documented using paper records. Nursing records used traditional electronic medical record templates. The Nursing Department conducted routine monthly quality checks.

2.2.2. Experimental group

(1) Research Team: The research team consisted of 10 members, including 2 nursing professors, 2 information engineers, 3 nursing quality management personnel, and 3 master's degree nursing students. The team was responsible for literature retrieval and organization, questionnaire development, organizing expert discussions, distributing questionnaires, data extraction, data organization, and statistical analysis.

(2) Intervention: In addition to routine nursing care, the intervention strictly adhered to the core requirements of WS/T 431-2023, including "quantitative assessment of self-care ability, dynamic adjustment of nursing grades, and multidisciplinary collaborative decision-making." The hospital information system (HIS) and mobile nursing information system (MNIS) were interconnected to implement four core interventions:

(1) Standardized Assessment and Dynamic Decision-Making: Upon admission, the responsible nurse dynamically assessed self-care ability, and the attending physician dynamically assessed the patient's condition. The HIS automatically captured the results to generate an electronic "Nursing Grading Assessment Summary Form," and the system automatically matched the appropriate nursing grade.

(2) Information-Based Nursing Round Execution and Traceability: Data were collected using PDA barcode recognition and digital positioning technology. Based on preset rules (symbols, fields, time periods, data coverage) in the system backend, personalized rounding tasks were automatically generated according to the assigned nursing grade. Nurses used PDAs to perform and document rounds, with data automatically recorded in the backend. Abnormal patient conditions triggered a "one-key alert" synchronously sent to the physician's workstation for rapid response.

(3) Closed-Loop Management for Patient Absence and Discharge: The system clarified the risks, precautions, and contact information for patients of different nursing grades who left the ward temporarily [15–16]. Nurses marked "temporary leave" in the system for patients planning to leave, which triggered a "three-level alert." All information regarding the leave, contact attempts, and return to the ward was recorded in a standardized format in the nursing notes, forming a complete clinical evidence chain and strengthening process risk control [5].

(4) Predictive Nursing Training: Using high-fidelity simulators and VR technology, combined with the requirements of WS/T 431-2023 for nurses' disease observation and risk assessment abilities, immersive training and assessments were conducted [17]. Regular "Nursing Safety Case Workshops" and "Disease Observation Key Points Challenge" skills competitions were held to enhance nurses' clinical judgment and emergency response abilities, providing personnel competency support for the effective implementation of WS/T 431-2023 [18].

2.3. Outcome measures

2.3.1. Structure dimension: Satisfaction with information facilities

A self-developed scale, referencing the Hospital Informationization Survey Form from the National Health Commission Statistical Information Center, was used to survey 56 registered nurses before and after the implementation of the platform [19]. The scale included five dimensions (hardware operation convenience, system function integrity, interface friendliness, response speed and stability, and support for clinical work), with one item per dimension. Each item was rated on a 5-point Likert scale (1=very dissatisfied to 5=very satisfied), with total scores ranging from 5 to 25. Higher scores indicated greater satisfaction with

information facilities. The Cronbach's α coefficient was 0.87.

2.3.2. Process dimension: Nursing round implementation rate

Nursing round records of patients in both groups were reviewed. The information-based rounding implementation rate was calculated as (number of person-times using information-based rounding / total number of rounding inspections required) × 100%.

2.3.3. Process dimension: Nursing grading compliance rate

An assessment scale based on WS/T 431-2023 was used, with a total score of 100. The matching degree between the assigned nursing grade and the actual patient needs in both groups was assessed. A score ≥80 was considered compliant. The nursing grading compliance rate was calculated as (number of patients with compliant nursing grades during the period / total number of patients surveyed during the period) × 100%.

2.3.4. Outcome dimension: Incidence of nursing adverse events

Adverse events, including falls, pressure injuries, unplanned extubation, drug extravasation, suicide, and elopement, were collected through the hospital's adverse event reporting system. The incidence rates of various nursing adverse events were calculated according to the formulas in the "Nursing Professional Medical Quality Control Indicators (2020 Edition)."

2.3.5. Outcome dimension: Nurses' disease observation ability

A self-developed scale, based on the "Clinical Nurse Disease Observation Ability Evaluation Scale", was used to assess the disease observation ability of clinical nurses [20]. The scale included 20 items across three dimensions: professional ability, critical thinking ability, and professional quality. Each item was rated on a 5-point Likert scale (1=very poor to 5=very good), with total scores ranging from 20 to 100. Higher scores indicated better disease observation ability. The Cronbach's α coefficient was 0.89.

2.4. Statistical analysis

SPSS 26.0 software was used. Continuous data were first tested for normality and homogeneity of variance. Data meeting the assumptions were expressed as mean ± standard deviation (Mean ± SD), and intergroup comparisons were performed using independent samples t-tests. Categorical data were expressed as frequencies and percentages, and intergroup comparisons were performed using the chi-square (x^2) test. A *P*-value <0.05 was considered statistically significant.

3. Results

3.1. Comparison of satisfaction with information facilities

The difference in total satisfaction scores of nurses with information facilities between pre- and post-implementation was statistically significant ($P<0.01$). Further item analysis showed no significant difference in satisfaction with interface friendliness ($P>0.01$), as detailed in **Table 1**.

Table 1. Comparison of nurse satisfaction with information facilities

Group	Hardware Operation Convenience	System Function Integrity	Interface Friendliness	Response Speed & Stability	Support for Clinical Work	Total Satisfaction Score
Pre-implementation (n=56)	3.21±0.44	2.27±0.56	2.65±0.75	3.59±0.35	3.06±0.77	17.29±2.25
Post-implementation (n=56)	4.28±0.35	4.33±0.46	2.59±0.48	4.37±0.41	4.32±0.58	21.37±2.29
x^2	14.242	21.272	-0.504	10.828	9.781	9.510
P	<0.001	<0.001	0.615	<0.001	<0.001	<0.001

3.2. Comparison of nursing round implementation rate

The nursing round implementation rate in the experimental group was significantly higher than that in the control group (P<0.01), as shown in **Table 2**.

Table 2. Comparison of nursing round implementation rate

Group	Number of Patients (Grades I, II, III)	Required Rounding Times	Actual Rounding Times	Missed Rounding Times	Implementation Rate(%)
Control	3373	54816	35829	18987	65.37%
Experimental	2518	40504	35912	4592	88.66%
x^2					6797
P					<0.01

3.3. Comparison of nursing grading compliance rate

The nursing grading compliance rate in the experimental group was significantly higher than that in the control group (P<0.05), as shown in **Table 3**.

Table 3. Comparison of nursing grading compliance rate

Group	Number of Hospitalized Patients	Number Compliant with Nursing Grade	Compliance Rate (%)
Control	3473	3210	92.44%
Experimental	2586	2500	96.68%
x^2			49.31
P			<0.001

3.4. Comparison of nursing adverse event incidence

The incidence of nursing adverse events in the experimental group was significantly lower than that in the control group (P<0.05), as shown in **Table 4**.

Table 4. Comparison of nursing adverse event incidence

Group	Number of Hospitalized Patients	Total Patient Bed Days	Total Days of Urinary Catheter Use	Adverse Event Incidence (‰)	
				Falls	Unplanned Extubation
Control	3473	298003	19835	0.020‰	0.1‰
Experimental	2586	303323	20205	0.007‰	0.049‰
u				4.41	7.24
P				<0.01	<0.01

3.5. Comparison of nurses' disease observation ability

Nurses' disease observation abilities in the experimental group were significantly improved after the intervention ($P<0.05$), as shown in **Table 5**.

Table 5. Comparison of nurses' disease observation ability

Group	Professional Ability	Critical Thinking Ability	Professional Quality
Pre-implementation (n=56)	16.54±2.11	42.33±2.25	48.62±2.39
Post-implementation (n=56)	18.01±1.98	46.22±2.37	52.45±2.28
t	3.802	8.908	8.677
P	<0.001	<0.001	<0.001

4. Discussion

4.1. Content analysis of the information-based graded nursing platform based on the SPO model

4.1.1. Structure dimension

The structure dimension serves as the fundamental guarantee for nursing service implementation, and its completeness directly determines the execution effectiveness of the process dimension [13]. This study showed that the experimental group addressed shortcomings in both information facilities and personnel competency by deploying mobile nursing terminals (PDAs), integrating HIS and MNIS data, developing an electronic nursing grading assessment summary form, and implementing predictive nursing training using VR/high-fidelity simulators. Results demonstrated a significant increase in nurses' overall satisfaction with information facilities from 17.29±2.25 to 21.37±2.29 ($P<0.001$), with significant improvements in four sub-dimensions: hardware operation convenience, system function integrity, response speed and stability, and support for clinical work. However, no significant difference was found in "interface friendliness" before and after implementation (2.65±0.75 vs. 2.59±0.48, $P=0.615$). This finding suggests that the current system's interface design may still follow traditional HIS interaction logic without ergonomic optimization for nurses' mobile work scenarios. It also reflects that nurses' expectations for interface friendliness increase with system use, reminding future research to prioritize user experience design in nursing information systems, not just functional implementation. Hou et al. also indicated that information facilities and nurses' professional competency are important structural factors influencing graded nursing quality [5]. However, this study further suggests that the adaptability of structure is more critical than its advancement. The structural improvement in the experimental group did not pursue high-precision technology but precisely targeted the three core

requirements of WS/T 431-2023: electronic assessment tools designed according to the new standards and personnel training focused on the new standard's competency requirements. This high adaptability of the structure to the new standards provides structural support for the localized implementation of WS/T 431-2023 [5, 17].

4.1.2. Process dimension

The process dimension, acting as a bridge between structure and outcome, relies on standardized execution to fully leverage structural advantages [14]. The results of this study show that all process dimension indicators in the experimental group were significantly higher than those in the control group (P<0.001), indicating that the information-based intervention significantly improved process standardization and execution. First, the information system enhances structural standardization and precision by embedding best practices, clinical pathways, and operating specifications into solidified digital workflows, decision support systems, or automated scripts, thereby mandating or guiding practitioners to follow established optimal steps [21]. For example, in stroke emergency care, 5G-based mobile stroke units integrate CT image transmission, AI-assisted diagnosis, and electronic medical record synchronization, ensuring seamless and standardized connection between pre-hospital and in-hospital emergency processes, reducing process deviations caused by information gaps or human error, and greatly improving the standardization of emergency procedures [22]. In this study, this was specifically manifested in standardized assessment and decision-making: a collaborative model using nurse self-care ability assessment, physician condition assessment, and system-automated grade matching reduced experiential decision-making bias. Second, it promoted closed-loop rounding execution: the system automatically generated personalized rounding tasks according to nursing grade, with PDA confirmation and backend tracking, enabling full supervision and traceability. Third, it enabled proactive risk management: establishing a three-level alert and standardized recording for patient absence or leave, addressing process management gaps.

4.1.3. Outcome dimension

The outcome dimension reflects the ultimate effectiveness of nursing quality improvement. This study showed that the experimental group achieved a 23.29 percentage point increase in the nursing round implementation rate and a 6.25 percentage point increase in the nursing grading compliance rate. Compared with the control group, the incidence of falls decreased by 65.0% and unplanned extubation decreased by 51.0% in the experimental group. Pressure injuries and unplanned extubation of tracheal tubes had zero incidence. Consistent with related research findings, the information system embeds risk alerts, rounding requirements, and grading standards into clinical work, driving nursing management from post-hoc remediation to pre-event prevention and in-process monitoring, effectively reducing the risk of adverse events such as falls, pressure injuries, unplanned extubation, and elopement [23–25]. Simultaneously, the intelligent system enables synergistic effects between standardized processes and competency training, reducing human error while strengthening nurses' clinical judgment and emergency response abilities, making nursing services more aligned with patients' actual needs and further improving nursing quality. Therefore, the closed-loop management of "structure-process- outcome" aligns highly with the continuous quality improvement philosophy emphasized by the SPO model [13–14].

4.2. Scientific analysis of the information-based graded nursing platform based on the SPO model

In 1969, scholar Donabedian proposed the Structure-Process-Outcome theoretical model for evaluating healthcare system quality. Since then, it has been introduced into the nursing field and widely applied [9–12]. This study used the Donabedian Structure-Process-Outcome theoretical model as a framework, centered around the core requirements of the "Grading Standards for Nursing (WS/T 431-2023)", and constructed a preliminary information-based graded nursing intervention plan through literature review, clinical status survey, and expert discussion [1]. Subsequently, a quasi-experimental research design was adopted, selecting departments from the same hospital as a control, to empirically evaluate the platform's application effect. Hierarchical regression analysis was used to clarify the transmission pathway of "structure-process-outcome." Furthermore, this study strictly followed the quality evaluation logic of the SPO model, with indicators covering the three dimensions of structure facilities, process execution, and outcome results [9]. All dimensional indicators were validated by clinical experts, aligning with the principles of nursing quality management. The quasi-experimental design ensured comparable baseline data, and the data were objectively measurable with reliable sources, effectively controlling for selection and implementation biases. The above design ensures that this study has a scientifically sound theoretical framework, standard-based specifications, and rigorous methodology, conferring high scientific validity.

4.3. Feasibility analysis of the information-based graded nursing platform based on the SPO model

The information-based graded nursing platform constructed in this study demonstrates good clinical feasibility and potential for widespread adoption. Regarding process adaptability, the plan is based on the existing HIS and mobile nursing system, requiring only functional optimization and data interoperability to achieve core functions such as standardized assessment, automatic rounding, and closed-loop recording. It can be seamlessly integrated into daily workflows without significantly increasing the burden on nurses. In terms of resource investment, the focus is on information system upgrades and process optimization, utilizing existing PDA equipment. Training is primarily conducted within the hospital, resulting in low investment costs and high cost-effectiveness, making it suitable for large-scale application in tertiary hospitals. Regarding clinical acceptance, the information tools simplify documentation, enhance reminders, and reduce double-checking, leading to significantly improved nurse satisfaction and strong implementation willingness, thus minimal resistance to adoption. In terms of management sustainability, the closed-loop model of "structure improvement-process control-outcome monitoring" can be directly translated into routine nursing quality control work, facilitating long-term implementation and continuous improvement.

4.4. Limitations

This study has several limitations. First, the single-center, historical control design limits the representativeness of the sample. Second, the observation period was relatively short, and no long-term longitudinal follow-up was conducted, making it impossible to determine the sustainability of the intervention effects. Future research plans include conducting multicenter randomized controlled trials involving 3–5 hospitals at different levels within Hubei Province, performing a 12-month longitudinal follow-up study using structural equation modeling to explore causal pathways, and incorporating artificial

intelligence technology to achieve intelligent prediction of patient risks and personalized recommendations for nursing measures.

5. Conclusion

The information-based graded nursing intervention plan constructed based on the SPO model, through structural improvement and process standardization, significantly increases the nursing round implementation rate and nursing grading compliance rate, reduces the incidence of nursing adverse events, and enhances nurses' disease observation abilities. The "structure-process-outcome" closed-loop system for graded nursing quality constructed in this study achieves the localized and information-based implementation of WS/T 431-2023, serving as an effective solution for quality improvement in graded nursing under the new standards in tertiary hospitals.

Disclosure statement

The authors declare no conflict of interest.

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