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Construction and Empirical Study of a Standardized Nursing Protocol for CO_2 Angiography in Patients with Lower Extremity Arteriosclerosis Obliterans Complicated by Renal Insufficiency

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Abstract: *Objective*: To develop and empirically analyze a standardized nursing protocol for CO_2 angiography in patients with lower extremity arteriosclerosis obliterans (ASO) complicated by renal insufficiency. *Methods*: A standardized nursing protocol for CO_2 angiography was first established for patients with lower extremity ASO complicated by renal insufficiency. Subsequently, 30 patients who underwent interventional therapy for lower extremity ASO complicated by renal insufficiency in the interventional vascular surgery department of our hospital from October 2025 to December 2025, following the standardized protocol, were selected as the experimental group. Another 20 patients who received treatment without the standardized protocol from October 2024 to December 2024 were selected as the control group. Intraoperative cooperation time, hospital stay, cost-effectiveness indicators, complications, and patient satisfaction were analyzed. *Results*: Compared with the control group, the experimental group exhibited a reduction in intraoperative cooperation time and hospital stay ($p < 0.05$). Although the cost of surgical consumables in the experimental group decreased compared to the control group, this difference was not statistically significant ($p > 0.05$). However, the costs of medications and total hospitalization expenses significantly decreased in the experimental group ($p < 0.05$). The overall incidence of complications was lower in the experimental group than in the control group ($p < 0.05$), and patient satisfaction was higher in the experimental group. *Conclusion*: The development and application of a standardized nursing protocol for CO_2 angiography can effectively improve nursing quality, reduce the risk of complications, and enhance patient prognosis, demonstrating clinical value for widespread adoption.

Keywords: Lower extremity arteriosclerosis obliterans; Renal insufficiency; Carbon dioxide angiography; Standardized nursing

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1. Introduction

Arteriosclerosis obliterans (ASO) of the lower extremities is a common age-related disease, characterized pathologically by thickening of the arterial walls in the lower limbs, narrowing or even complete occlusion of the lumens, leading to the onset of limb ischemia symptoms. With the intensification of population aging and the rising prevalence of chronic diseases such as diabetes and hypertension, the incidence of ASO has been increasing year by year [1,2]. ASO not only severely affects patients' quality of life but may also lead to severe complications such as gangrene due to limb ischemia, posing a threat to life. However, when patients also suffer from renal insufficiency, the difficulty of treatment significantly increases. Patients with renal insufficiency, due to decreased glomerular filtration rate and impaired renal tubular function, are prone to contrast-induced acute kidney injury (PC-AKI) when undergoing traditional iodinated contrast agent angiography. PC-AKI is a common type of iatrogenic acute kidney injury that can further exacerbate renal impairment and prolong hospital stays [3,4]. Carbon dioxide (CO_2) angiography, as an alternative imaging technique, has gradually been applied in the diagnosis and treatment of lower extremity arterial diseases. Compared to traditional iodinated contrast agents, CO_2 angiography offers the advantage of having a lesser impact on renal function, making it particularly suitable for patients with renal insufficiency or iodine allergy. However, CO_2 angiography still faces numerous challenges in clinical practice, including high operational complexity and image quality interference from various factors [5,6]. Currently, there is a lack of standardized nursing protocols for CO_2 angiography in patients with lower extremity arteriosclerosis obliterans complicated by renal insufficiency. This not only limits the widespread application of this technique but may also affect patients' prognostic outcomes. Based on this, this study aims to construct a standardized nursing protocol for CO_2 angiography in patients with lower extremity arteriosclerosis obliterans complicated by renal insufficiency and conduct an empirical analysis to provide certain reference value for subsequent clinical research.

2. Subjects and methods

2.1. Subjects

Thirty patients with lower extremity arteriosclerosis obliterans (ASO) complicated by renal insufficiency who underwent interventional diagnosis and treatment using the standardized protocol in the Interventional Vascular Surgery Department of our hospital from October 2025 to December 2025 were selected as the experimental group. Twenty patients who received treatment without the standardized protocol in our hospital from October 2024 to December 2024 were selected as the control group. The general characteristics of the two groups were balanced and comparable ($p > 0.05$), as shown in **Table 1**.

Table 1. Comparison of general characteristics between the two groups

Group	Number of cases (n)	Gender (M/F)	Age (years)	Body mass (kg/m^2)
Control group	20	14/6	72.35 ± 6.82	24.31 ± 2.57
Experimental group	30	20/10	71.97 ± 7.14	24.58 ± 2.85
χ^2/t		0.061	0.187	0.341
p		0.804	0.851	0.735

2.1.1. Inclusion criteria

(1) Meeting the diagnostic criteria for lower extremity arteriosclerosis obliterans (ASO)

(2) Comorbid renal insufficiency (eGFR < 60 mL/min/1.73 m^2)
(3) Scheduled for CO_2 angiography-guided interventional therapy
(4) Voluntary participation in this study with signed informed consent

2.1.2. Exclusion criteria

(1) Comorbid severe cardiopulmonary dysfunction
(2) Presence of contraindications to CO_2 angiography
(3) Incomplete clinical data

2.2. Therapeutic approaches

This study constructed a comprehensive nursing protocol for CO_2 angiography in patients with lower extremity arteriosclerosis obliterans (ASO) complicated by renal insufficiency through multidisciplinary collaboration and systematic evidence-based methods. Initially, a dedicated research team was established, comprising the head nurse of the interventional operating room, the chief physician of interventional vascular surgery, the deputy chief technician of radiology, and two undergraduate nursing students, responsible for literature analysis, protocol development, expert coordination, and opinion integration.

During the literature analysis phase, databases including Medlive, CNKI, Wanfang, PubMed, and Web of Science were systematically searched using both Chinese and English keywords, covering the period from database inception to May 23, 2025. Two researchers employed content analysis to progressively refine items related to preoperative, intraoperative, and postoperative care, culminating in a preliminary draft of the nursing protocol after multiple rounds of group discussions.

To further refine the protocol, the research team conducted expert interviews, inviting 12 experts from two tertiary hospitals, including interventional vascular surgeons (5, with associate senior titles or above), radiologists (1), interventional vascular surgery nurses (2), renal care nurses (1), and interventional operating room nurses (3). All experts had over 10 years of work experience, with 7 holding senior titles and 5 possessing master's degrees, ensuring high authority.

Based on the interview feedback, the research team revised the protocol, ultimately forming a standardized, comprehensive nursing protocol covering preoperative assessment, intraoperative cooperation, complication prevention and management, and postoperative monitoring. This protocol emphasizes preoperative renal function assessment and mastery of CO_2 angiography indications; standardized intraoperative operations and close monitoring; and enhanced postoperative condition observation and complication alerts, providing systematic and feasible operational guidance for clinical nursing practice.

2.2.1. Control group treatment method

The conventional nursing model was adopted. Preoperative care included completing routine admission education, preoperative examinations, skin preparation, and establishing intravenous access, informing patients of surgical precautions, but without systematic respiratory training guidance or specific risk assessment for CO_2 angiography. Intraoperative care involved assisting patients in assuming a supine position, connecting electrocardiographic monitoring to monitor vital signs, and cooperating with physicians for CO_2 injection, with injection pressure, dosage, and frequency primarily based on the physician's personal experience, lacking standardized gas injection parameters (e.g., flow rate limit, total volume control). Intraoperative observation of patient discomfort was mostly empirically managed, without establishing a "respiration-injection" coordination mechanism, necessitating repeated image acquisition due to respiratory motion artifacts. Postoperative care included routine monitoring of vital signs after returning to the ward, compression hemostasis and bandaging at the puncture site, without implementing a standardized hydration protocol, with fluid volume administered according to routine medical orders. Blood creatinine was rechecked 24–48 hours postoperatively, but without setting alert thresholds or dynamic monitoring procedures. Lower extremity observation was primarily based on routine experience, without specified observation frequency or quantitative recording standards. Complication management adopted symptomatic treatment, lacking standardized emergency plans.

2.2.2. Experimental group treatment method

Preoperative care included stratified assessment using a renal function grading assessment form, excluding contraindications with a screening form, guiding patients in "inhalation-breath-hold-exhalation" respiratory training twice daily, and formulating individualized hydration protocols based on renal function grading, starting intravenous infusion of 0.9% sodium chloride solution 3 hours before surgery. Intraoperative care involved establishing a "nurse-technician-physician" tripartite coordination mechanism with clear division of labor, setting standardized injection parameters (flow rate ≤ 20 mL/s, single dose ≤ 50 mL, total volume ≤ 200 mL), using a dedicated CO_2 injection system to ensure gas purity, implementing a "respiration-injection" coordination mechanism with nurses instructing patients to hold their breath before injection to reduce respiratory motion artifacts, continuously monitoring vital signs with set abnormal alert thresholds, and establishing standardized emergency management procedures for complications such as gas embolism and vasospasm. Postoperative care included continuing the standardized hydration protocol for 6–12 hours, dynamically monitoring renal function with set AKI alert thresholds (initiation of alert when blood creatinine increases > 26.5 μmol/L or > 50%), adopting quantitative recording for lower extremity observation (every 30 minutes within 2 hours postoperatively, every 2 hours from 2–24 hours), recording puncture site observations according to specified frequencies, initiating multidisciplinary collaborative care for patients requiring combined use of iodinated contrast agents, and conducting patient satisfaction surveys using the MSQ scale 24–48 hours postoperatively.

2.3. Indicator detection

2.3.1. Intraoperative cooperation time and hospital stay

The circulating nurse in the interventional operating room used a stopwatch for real-time timing, simultaneously extracting the start and end times of surgery from the surgical nursing record in the hospital's nursing management information system for verification. The timing started when the physician began the puncture operation and ended when hemostasis at the puncture site was completed and the physician declared the end of surgery.

2.3.2. Cost-effectiveness indicators

(1) Surgical consumable costs

Charging records for surgical-related consumables were extracted from the hospital's material management system and patient hospitalization expense details, independently verified by two researchers, and then entered into the database.

(2) Medication costs

Charging records for medications were extracted from the hospital's pharmacy management system and patient hospitalization expense details, independently verified by two researchers.

(3) Total hospitalization costs

Summary sheets of patient hospitalization expenses were extracted from the hospital's hospitalization charging system, independently verified by two researchers, and then entered.

2.3.3. Adverse reactions

Adverse reactions, including acute kidney injury, lower extremity burning sensation, nausea, and vomiting, were recorded by healthcare personnel.

2.3.4. Patient satisfaction

Patient satisfaction was evaluated using the short form of the Minnesota Satisfaction Questionnaire (MSQ) [7]. This scale includes three dimensions: intrinsic satisfaction, extrinsic satisfaction, and general satisfaction, with a total of 20 items. Each item employs a Likert 3-point scoring method (1 = dissatisfied, 2 = moderately satisfied, 3 = satisfied). The total scale score ranges from 20–100, with higher scores indicating higher satisfaction.

3. Results

3.1. Comparison of intraoperative cooperation time and hospital stay between groups

As shown in **Table 2**, compared with the control group, the experimental group exhibited a reduction in both intraoperative cooperation time and hospital stay, with statistically significant differences ($p < 0.05$).

Table 2. Comparison of intraoperative cooperation time and hospital stay between groups ($\bar{x} \pm s$)

Group	Number of cases (n)	Intraoperative cooperation time (min)	Hospital stays (d)
Control group	20	58.65 ± 8.23	9.55 ± 2.08
Experimental group	30	45.26 ± 6.18	7.23 ± 1.31
t value		6.567	4.847
p value		0.001	0.001

3.2. Comparison of cost-effectiveness indicators between groups

As shown in **Table 3**, compared with the control group, the experimental group demonstrated a decrease in surgical consumable costs, with no statistically significant difference ($p > 0.05$), while showing a reduction in medication costs and total hospitalization expenses, with statistically significant differences ($p < 0.05$).

Table 3. Comparison of cost-effectiveness indicators between groups ($\bar{x} \pm s$)

Group	Number of cases (n)	Surgical supplies cost (yuan)	Medication cost (yuan)	Total hospitalization cost (yuan)
Control group	20	3512.32 ± 402.58	1123.40 ± 187.54	22348.85 ± 2678.35
Experimental group	30	3245.69 ± 358.82	876.56 ± 124.30	18765.41 ± 2154.62
t value		2.452	5.607	5.225
p value		0.112	0.001	0.001

3.3. Comparison of adverse reactions between groups

As shown in **Table 4**, the overall incidence of adverse reactions in the experimental group was lower than that in the control group, with a statistically significant difference ($p < 0.05$).

Table 4. Comparison of adverse reactions between groups [n (%)]

Group	Number of cases (n)	Acute kidney injury	Burning sensation in lower limbs	Nausea and vomiting	Total incidence rate
Control group	20	3 (15.00)	2 (10.00)	1 (5.00)	6 (30.00)
Experimental group	30	1 (3.33)	1 (3.33)	0 (0.00)	2 (6.67)
χ^2 value					4.861
p value					0.027

3.4. Comparison of patient satisfaction between groups

As shown in **Table 5**, the satisfaction level in the experimental group was higher than that in the control group, with the difference being statistically significant ($p < 0.05$).

Table 5. Comparison of patient satisfaction between groups [n (%)]

Group	Number of cases (n)	Satisfied	Moderately satisfied	Dissatisfied	Overall satisfaction
Control group	20	6 (30.00)	8 (40.00)	6 (30.00)	14 (70.00)
Experimental group	30	15 (50.00)	14 (46.67)	1 (3.33)	29 (96.67)
χ^2 value					7.087
p value					0.008

4. Discussion

During the interventional diagnosis and treatment of patients with lower extremity arteriosclerosis obliterans (ASO) complicated by renal insufficiency, ensuring image quality while minimizing renal damage is a key and challenging aspect of clinical nursing management [8]. CO_2 angiography has gradually become an ideal choice for such patients due to its advantages of being non-nephrotoxic and free from allergic reactions. However, its complex operation and susceptibility to image interference necessitate a highly standardized and collaborative nursing process [9].

The results of this study indicate that, compared to the control group, the experimental group experienced reductions in intraoperative cooperation time and hospital stay. While surgical consumable costs in the experimental group decreased compared to the control group, this difference was not statistically significant ($p > 0.05$). However, medication costs and total hospitalization expenses significantly decreased. Analysis of the reasons reveals that the standardized nursing protocol contributes to enhancing surgical efficiency and postoperative recovery. This may be closely related to preoperative systematic respiratory training and the establishment of an intraoperative "breathing-injection" coordination mechanism. By standardizing operational procedures and clarifying division of responsibilities, repetitive operations due to improper handling or poor image quality are reduced, improving surgical fluency and thus shortening intraoperative cooperation time [10,11]. The implementation of a postoperative standardized hydration protocol and dynamic renal function monitoring aids in early identification and intervention of potential complications, promoting early patient recovery and shortening hospital stays. In terms of cost-effectiveness, although surgical consumable costs in the experimental group decreased, the lack of statistical significance may be related to the small sample size or consumable pricing mechanisms. However, the significant reduction in medication costs and total hospitalization expenses is closely associated with factors such as decreased postoperative complications, shortened hospital stays, and individualized medication regimens [12,13]. The standardized protocol emphasizes preoperative assessment and individualized hydration, reducing unnecessary medication use and additional treatment costs incurred due to complications, demonstrating favorable health economic benefits.

The study also found that the overall incidence of adverse reactions in the experimental group was lower than that in the control group. Analysis of the reasons reveals that this is closely related to the strict setting of CO_2 injection parameters during surgery and the establishment of emergency procedures for gas embolism. Standardized operations reduce vascular stimulation and discomfort caused by rapid or excessive gas injection, enhancing surgical safety.

Furthermore, the study results indicate that patient satisfaction in the experimental group was higher than that in the control group. Analysis of the reasons reveals that the standardized nursing protocol not only improves medical quality but also enhances the patient's healthcare experience. Preoperative thorough communication, intraoperative coordinated cooperation, and postoperative meticulous observation and humanistic care strengthen patients' trust and recognition of nursing work.

5. Conclusion

In summary, the application of a standardized CO_2 angiography nursing protocol in patients with ASO complicated by renal insufficiency effectively improves nursing quality, reduces the risk of complications, shortens hospital stays, alleviates economic burdens, and enhances patient satisfaction, demonstrating high clinical promotion value. However, due to the limited sample size and short follow-up period in this study, future research should expand the sample size and prolong the observation period to further validate the long-term effects and feasibility of promoting this protocol.

Disclosure statement

The authors declare no conflict of interest.

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