

The Impact of a Multidimensional Intraoperative Pressure Injury Prevention Protocol on Postoperative Pressure Injuries Incidence in Elderly Patients Undergoing Internal Fixation for Hip Fracture

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AIM: To retrospectively analyze the comparative effectiveness of a multidimensional intraoperative pressure injury prevention protocol versus routine nursing care in elderly patients undergoing internal fixation for hip fracture, by comparing the incidence of postoperative pressure injuries, patient satisfaction, and clinical outcomes, to provide evidence-based reference for clinical nursing decision-making.

METHODS: A retrospective analysis was conducted by reviewing the medical records of elderly patients who underwent internal fixation for hip fracture during the same period. Based on the actual nursing protocol implemented clinically, patients were categorized into two groups: an observation group, which received the multidimensional intraoperative pressure injury prevention protocol ($n = 96$), and a conventional group, which received standard pressure injury care ($n = 104$). The pressure injury incidence on postoperative day 7, hospitalization duration, and medical expenses constituted the primary endpoints; the secondary measures included inflammatory factors (C-reactive protein [CRP], Interleukin-6 [IL-6]), oxidative stress indexes (Malondialdehyde [MDA], Superoxide dismutase [SOD]), and functional recovery parameters (hip joint mobility, muscle strength).

RESULTS: The 7-day incidence of postoperative pressure injuries was lower in the observation group than in the conventional group ($p < 0.05$). Shorter hospital stays, and lower medical expenses were observed in the observation group ($p < 0.05$), while patient satisfaction was also evaluated as a secondary clinical outcome. At 72 h post-operation, CRP, IL-6, and MDA were significantly reduced, while SOD activity was significantly elevated in the observation group compared with the conventional group ($p < 0.05$); no significant intergroup differences in these indicators were observed at 24 h post-operation ($p > 0.05$).

CONCLUSIONS: The multidimensional intraoperative pressure injury prevention protocol, which integrates preoperative accurate assessment and intraoperative dynamic mechanical intervention, is associated with a significantly lower incidence of postoperative pressure injuries, shorter length of hospital stay, and lower medical costs in elderly patients with hip fractures undergoing internal fixation.

Keywords: multidimensional intraoperative pressure injury prevention protocol; elderly; hip fracture patients; pressure ulcer; inflammation and oxidative stress

Introduction

Hip fractures in elderly patients are common orthopedic emergencies, with increasing prevalence as the population ages [1]. These patients often present with multiple underlying diseases (e.g., diabetes and malnutrition) and are exposed to local tissue compression and ischemia due to large surgical trauma, prolonged anesthesia, and sustained immobilization in the surgical position, placing them at high risk of postoperative pressure injury (PI) [2,3]. The incidence of pressure injuries after hip fracture surgery can reach 10%–25% among the elderly, which not only extends their hospital stays and increases medical expenses, but also seriously hinders their rehabilitation and compromises their quality of

life [4]. Therefore, exploring scientific and effective strategies for preventing intraoperative PI is critical.

In current clinical practice, intraoperative PI prevention relies on single measures (decompression pad employment, posture adjustment, skin care, etc.), resulting in limited effectiveness [5,6]. A previous study has attempted to combine risk assessment tools (e.g., the Braden Scale) for stratified interventions, but have overlooked the individual differences in elderly patients' physiological decline, intraoperative stress responses, and psychological states [7]. Furthermore, existing programmes pay insufficient attention to the multifactorial synergy of 'pressure-shear-moisture' and lack systematic integration of nursing processes, making it difficult to ensure the precision and continuity of preventive measures [8].

Based on this, a multidimensional intraoperative pressure injury prevention protocol was gradually implemented in our hospital's clinical practice. This study retrospectively compared the clinical effect of this programme with the traditional routine nursing. This programme not only overcomes the limitations of isolated measures by establishing

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an ‘assessment-intervention-monitoring’ closed-loop management model, but also incorporates psychological care into the intervention framework, thereby alleviating the adverse effect of patient anxiety on blood circulation. The findings are expected to help reduce the incidence of postoperative pressure injuries, lessen patient suffering and the medical burden, and provide a viable reference for refining clinical nursing services.

Methods

Research Participant Selection

This study was a retrospective cohort analysis based on clinical data from the electronic medical record system of Tianjin Hospital and was conducted to compare clinical outcomes across different nursing programmes. Patients with hip fractures admitted to Tianjin Hospital from April 2024 to June 2025 were retrospectively included in the study. All of them received internal fixation treatment for fractures in our hospital, among which 96 patients received a multidimensional intraoperative PI prevention protocol (observation group), and 104 patients received routine PI care (conventional group). The selection of nursing programmes for the two groups was based on the actual clinical work arrangement (such as the allocation of responsibilities among nursing units and the individualized assessment of patients’ conditions), and non-random grouping. This study, which retrospectively extracted only clinical data already available in the electronic medical record and did not involve additional interventions, was approved by the Ethics Committee of Tianjin Hospital (Ethics Approval No. 2025-229), with the requirement for individual informed consent waived.

Inclusion and Exclusion Criteria

Inclusion criteria included: ① Age ≥ 65 years; ② Imaging-based diagnosis of hip fractures (femoral neck fracture, intertrochanteric fracture, etc.) and treatment with reduction and internal fixation; ③ American Society of Anesthesiologists (ASA) grade I–III [9]; ④ Clear consciousness, enabling cooperation with the evaluation. Exclusion criteria included: ① Pre-existing pressure injuries; ② Inability to cooperate due to severe cognitive impairment (MMSE score < 10) [10] or mental illness; ③ Terminal malignant tumor, severe hepatic and renal insufficiency, or estimated survival < 3 months; ④ Hospital referral, withdrawal of care, or death; ⑤ Missing data.

Surgical Plan

All patients underwent open reduction and internal fixation of hip fractures by the orthopaedic team at our hospital, and the surgical procedure followed the clinical routine. The patient was placed in the supine position, with the affected hip elevated by approximately 15° – 20° , the lower limb maintained in an abducted neutral position, the hip slightly flexed at 15° – 20° , and a soft cushion placed un-

der the knee. The skin and subcutaneous tissue were sequentially cut, with particular care taken to protect the lateral femoral cutaneous nerve. The tensor fasciae latae was cut and separated to expose the greater trochanter of the femur and the fracture site. Under C-arm fluoroscopy assistance, traction was applied to the affected limb to correct shortening and rotational deformities, achieving anatomical alignment of the fracture ends, followed by temporary fixation with Kirschner wires. Finally, the fascia, subcutaneous tissue, and skin were sutured in sequence, and a sterile dressing was applied. When necessary, a negative pressure drainage tube was placed and removed 24–48 hours later.

Nursing Plan

Routine PI care: All included patients received the same standardized perioperative enhanced recovery after surgery (ERAS) management, including a unified multimodal analgesia protocol and early postoperative rehabilitation guidance (such as ankle pump exercise). The only difference between the two groups was the intraoperative pressure injury prevention protocol, as detailed below. The Braden Scale for Predicting Pressure Sore Risk was used to assess preoperative pressure injury risk [11]. The Braden Scale was used as an initial screening tool rather than as the sole basis for risk stratification, because its predictive performance may be limited in elderly surgical patients. Therefore, the final risk assessment in this study incorporated additional perioperative factors, including mobility limitation, skin humidity, operative positioning, and intraoperative tissue perfusion. The total score ranges from 6 to 23, with lower scores indicating higher risk; in this study, a score of ≤ 12 was defined as high risk. During surgery, the patient’s sacrococcygeal region, heels, hips, and other pressure-bearing areas were checked every 2 hours, and ordinary foam positioning pads were used for protection. At the same time, the sheets were kept dry to avoid dragging the patient. After surgery, routine turning was performed every two hours, and the skin condition was closely monitored.

Multidimensional intraoperative PI prevention protocol: Building on routine nursing, a closed-loop “assessment-intervention-monitoring” management model was adopted, encompassing six core modules:

(1) Preoperative multi-dimensional assessment: In addition to the Braden Scale, the Caprini thrombosis risk assessment (focusing on mobility), skin humidity testing, and the Zung Self-Rating Anxiety Scale (SAS) were integrated [12,13]. The SAS is a 20-item self-report instrument scored on a 4-point scale. The standard score is calculated by multiplying the raw total score by 1.25, with higher scores indicating greater anxiety severity; a standard score > 50 was used to identify clinically relevant anxiety requiring perioperative psychological support. Skin humidity was measured using a validated portable skin moisture tester (Corneometer CM 825, Courage + Khazaka Electronic, Cologne, Germany) on

the sacrococcygeal skin at admission, with stratum corneum hydration expressed as instrument readings. A threshold of <40 was used according to the predefined criterion applied in this study.

(2) Intraoperative dynamic decompression position management: Based on the standard supine surgical position required for the procedure, a clinical routine wedge-shaped turning pillow was used to maintain a 30° tilt of the healthy side trunk (modified supine position, not full lateral decubitus position), which did not affect the surgical area of the affected hip. Position adjustment and local decompression were performed hourly during the operation, only during non-critical surgical stages (preoperative disinfection and draping, incision suture period), and implemented by the circulating nurse after joint safety confirmation by the surgeon and anesthesiologist. The whole process strictly followed the sterile principle, did not damage the sterile barrier, and did not affect the stability of fracture fixation, to avoid continuous compression of the sacrococcyx, greater trochanter and other bony prominences.

(3) Modified decompression materials: Thickened ordinary foam pads (5–8 cm in thickness) were applied to bony prominences (sacrococcyx, heels, greater trochanters), cut to fit the contour of each site (e.g., “U” shape for heels). Non-bony areas (e.g., under the knees, lateral waist) were supported with standard medical soft pillows rather than specialized materials such as gel pads or memory foam. This approach ensured a flat, wrinkle-free support surface and prevented material displacement.

(4) Circulation and skin monitoring: Hourly intraoperative monitoring was conducted without relying on Doppler ultrasound or skin elasticity testers: ① Tactile monitoring: The patient’s dorsalis pedis artery was palpated to assess pulse strength (compared with the unaffected side to ensure no pulse weakening or absence); ② Visual observation: Skin color (redness, purplish discoloration) and temperature (coolness) of pressure points were checked. If redness persisted for >3 seconds after pressure was released, the position was adjusted immediately.

(5) Psychological support: Responsible nurses communicated with patients about their condition 1 day preoperatively and upon admission to the operating room. Soothing music (40–50 dB) was played during surgery, and a “handshake technique” was used to alleviate anxiety in patients with SAS scores >50. Psychological status was followed up within 24 hours postoperatively.

(6) Multidisciplinary collaboration: Anesthesiologists maintained intraoperative systolic blood pressure between 90–140 mmHg; scrub nurses minimized position exposure time to <5 minutes; and head nurses supervised the implementation of nursing measures daily.

Data Collection

Indicators were extracted from electronic medical records, nursing documentation, surgical nursing records, and labo-

ratory reports. Baseline confounders related to pressure injury risk were collected, including comorbidities (diabetes mellitus), preoperative Braden pressure ulcer risk score, fracture type (femoral neck fracture/intertrochanteric fracture), ASA classification, anesthesia type, operative duration and smoking history:

(1) Intraoperative safety indicators: Incidence of skin abrasions and intraoperative-related nerve injury, with standardized assessment protocols as follows: ① Skin abrasion: Assessed by the operating room circulating nurse immediately after surgery, with re-evaluation by the ward responsible nurse at 24 hours postoperatively (follow-up window: 24 hours after surgery). The diagnostic criterion was non-surgical site epidermal damage with or without punctate exudation, excluding skin injury related to surgical incisions, dressing fixation, or preoperative existing lesions. ② Intraoperative-related nerve injury: Assessed by the attending anesthesiologist immediately after surgery, with re-evaluation by the orthopedic attending physician at 72 hours postoperatively and before discharge (follow-up window: from the end of surgery to hospital discharge). The diagnostic criterion was new-onset lower limb sensory abnormality, motor dysfunction, or nerve irritation signs absent preoperatively, excluding pre-existing neurological lesions or fracture-related nerve injury;

(2) Postoperative indicators: Time to first ambulation after operation was extracted from postoperative rehabilitation records and defined as the interval between the end of surgery and the first assisted ambulation. ① Pressure injury incidence (assessed 7 days postoperatively based on medical record documentation of skin conditions); ② Hip joint range of motion (flexion and extension) and quadriceps femoris muscle strength were assessed on postoperative day 7 using the Medical Research Council (MRC) muscle strength grading scale (0 = no contraction, 1 = flicker or trace contraction, 2 = active movement with gravity eliminated, 3 = active movement against gravity, 4 = active movement against gravity and resistance, and 5 = normal power) [14].

(3) Laboratory indicators: Peripheral blood levels of C-reactive protein (CRP), Interleukin-6 (IL-6), Malondialdehyde (MDA), and Superoxide dismutase (SOD). at 24 and 72 hours postoperatively (laboratory-reported results);

(4) Clinical outcomes: Length of hospital stay, medical expenses, and patient satisfaction. Length of stay and medical expenses were extracted from the hospitalization settlement system. Patient satisfaction was obtained from routine discharge survey records and scored using a 5-point Likert scale: 1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, and 5 = very satisfied. Higher scores indicated greater patient satisfaction.

Statistical Analysis

Statistical analyses were performed using SPSS version 30.0 (IBM). Continuous variables were first assessed for

Table 1. Comparison of baseline data of the study subjects.

Groups		Observation group (n = 96)	Conventional group (n = 104)	Statistics (t/χ^2)	p-value
Age		69.63 ± 2.88	70.28 ± 3.35	1.476	0.142
Sex	Male	54 (56.25)	64 (61.54)	0.577	0.447
	Female	42 (43.75)	40 (38.46)		
BMI (kg/m ²)		22.44 ± 2.28	22.95 ± 2.26	1.589	0.113
Time from fracture to admission (h)		25.96 ± 7.17	24.49 ± 5.98	1.577	0.117
Causes of fracture	Fall	34 (35.42)	30 (28.85)	1.284	0.526
	Hit	54 (56.25)	62 (59.62)		
	Other	8 (8.33)	12 (11.54)		
Diabetes mellitus		22 (22.92)	28 (26.92)	0.427	0.513
Fracture type	Femoral neck fracture	42 (43.75)	49 (47.12)	0.228	0.633
	Intertrochanteric fracture	54 (56.25)	55 (52.88)		
ASA grade ≥II		61 (63.54)	71 (68.27)	0.497	0.481
General anesthesia		77 (80.21)	90 (86.54)	1.452	0.228
Smoking history		22 (22.92)	18 (17.31)	0.982	0.322
Preoperative Braden score		15.28 ± 3.31	14.98 ± 2.82	0.693	0.489

BMI, Body mass index; ASA, American Society of Anesthesiologists.

normality using the Shapiro-Wilk test. Normally distributed data are presented as mean ± standard deviation and were compared between groups using the independent-samples *t* test, while within-group comparisons across time points were performed using the paired *t* test. Repeated-measures data (CRP, IL-6, MDA, and SOD at 24 h and 72 h postoperatively) were analyzed using repeated-measures analysis of variance (ANOVA) to assess group effects, time effects, and interaction effects, followed by least significant difference (LSD) post hoc tests with Bonferroni correction for multiple comparisons. For repeated-measures ANOVA, *F* values, *p* values, and partial eta-squared (partial η^2) values were reported for the group effect, time effect, and group-by-time interaction effect. Categorical data are presented as n (%) and were compared using the chi-square test. The MRC muscle strength grade was treated as ordinal data and compared between groups using the Mann-Whitney U test. Patient satisfaction scores were assessed for normality using the Shapiro-Wilk test; normally distributed data were compared using the independent-samples *t*-test, whereas non-normally distributed data were analyzed using the Mann-Whitney U test. A two-sided *p* < 0.05 was considered statistically significant.

Results

Comparison of Baseline Data of Research Participants

A total of 96 patients in the observation group and 104 patients in the conventional group were retrospectively enrolled. There were no significant differences in age, gender, Body mass index (BMI) and other baseline data between the two groups (*p* > 0.05, Table 1), suggesting their clinical comparability.

Comparison of Intraoperative Complications

Compared with the conventional group, no significant differences were observed in the incidence of skin abrasion or nerve injury in the observation group (*p* > 0.05, Table 2).

Table 2. Comparison of intraoperative safety outcomes between the two groups.

Groups	n	Skin abrasion	Nerve injury
Observation group	96	5 (5.21)	6 (6.25)
Conventional group	104	9 (8.65)	11 (10.58)
χ^2		0.910	1.202
<i>p</i> -value		0.340	0.273

Comparison of Postoperative Rehabilitation

The observation group exhibited a shorter time to first postoperative ambulation than the conventional group (35.67 ± 8.17 h vs 41.37 ± 8.54 h, *p* < 0.001), greater hip flexion (99.45 ± 12.21° vs 91.92 ± 10.45°, *p* < 0.001) and extension (6.32 ± 1.71° vs 5.51 ± 0.99°, *p* < 0.001), and the postoperative day 7 MRC muscle strength grade was also higher in the observation group than in the conventional group [3.00 (2.00–4.00) vs 2.50 (1.00–3.00); *Z* = 2.751, *p* = 0.006] (Table 3).

Comparison of Pressure Injury Risk

According to medical record data, the total 7-day postoperative pressure injury incidence was 7.29% (7/96) in the observation group and 19.23% (20/104) in the conventional group (*p* = 0.014). The incidence of Stage II or higher pressure injuries was lower in the observation group compared with the conventional group (2.08% vs 8.65%, *p* = 0.042), whereas the difference in Stage I pressure injuries was not significant (*p* = 0.162). Operation time did not differ sig-

Table 3. Comparison of postoperative rehabilitation outcomes between the two groups.

Groups	N	Time to first ambulation after	Hip range of motion (°)		MRC muscle strength grade
		operation (h)	Flexion	Extension	
Observation group	96	35.67 ± 8.17	99.45 ± 12.21	6.32 ± 1.71	3.00 (2.00–4.00)
Conventional group	104	41.37 ± 8.54	91.92 ± 10.45	5.51 ± 0.99	2.50 (1.00–3.00)
Statistics (<i>t</i> or <i>Z</i>)		4.813	4.699	4.130	2.751
<i>p</i> -value		<0.001	<0.001	<0.001	0.006

MRC, Medical Research Council.

Table 4. Comparison of pressure injury risk between the two groups.

Groups	n	Pressure injuries			Operation time (min)
		None	Stage I	Stage II and above	
Observation group	96	89 (92.71)	5 (5.21)	2 (2.08)	89.00 ± 15.13
Conventional group	104	84 (80.77)	11 (10.58)	9 (8.65)	91.88 ± 17.17
Statistics (<i>t</i> / χ^2)		6.094	1.955	4.146	1.256
<i>p</i> -value		0.014	0.162	0.042	0.211

Table 5. Comparison of clinical outcomes between the two groups.

Groups	n	Length of stay (days)	Medical expenses (RMB)	Satisfaction rating
Observation group	96	12.63 ± 3.81	37,785.67 ± 4237.80	3.92 ± 0.84
Conventional group	104	15.10 ± 2.27	40,812.97 ± 5642.59	3.40 ± 1.23
Statistics (<i>t</i>)		5.547	4.263	3.463
<i>p</i> -value		<0.001	<0.001	<0.001

1 US (dollar) ≈ 6.6998 RMB (yuan).

nificantly between groups (89.00 ± 15.13 min vs 91.88 ± 17.17 min, *p* = 0.211) (Table 4).

Comparison of Inflammation and Oxidative Stress

CRP, IL-6, MDA, and SOD showed no significant inter-group differences at 24 h postoperatively (*p* > 0.05). At 72 h postoperatively, CRP, IL-6, and MDA were significantly lower in the observation group than in the conventional group, whereas SOD was significantly higher in the observation group (*p* < 0.05, Fig. 1). Repeated-measures ANOVA showed significant time effects for CRP, IL-6, MDA, and SOD, indicating postoperative changes in these indicators over time. Significant group-by-time interaction effects were also observed for CRP, IL-6, MDA, and SOD, suggesting that the temporal changes differed between the two groups. The detailed *F* values, *p* values, and partial η^2 values are presented in **Supplementary Table 1**.

Comparison of Clinical Outcomes

Statistical analysis showed that hospital stays were shorter and medical expenses were lower in the observation group than in the conventional group (*p* < 0.05). The satisfaction survey results further indicated higher satisfaction ratings in the observation group than in the conventional group (*p* < 0.05, Table 5).

Discussion

This retrospective analysis suggests that a multidimensional intraoperative pressure injury prevention protocol was associated with a reduced incidence of postoperative pressure injuries. Its advantage lies in the integration of preoperative multi-dimensional assessment, intraoperative dynamic position management and postoperative system monitoring, forming a targeted nursing system.

The benefits of multi-dimensional intraoperative PI prevention nursing may be explained from the following four aspects: (1) Preoperative precise assessment breaks the limitations of traditional screening. Traditional PI risk assessment tools, such as the Braden Scale, remain useful for preliminary screening; however, their predictive accuracy may be reduced in elderly surgical patients when used alone, particularly because intraoperative factors such as anesthesia-related hypotension, muscle relaxation, shear force, and prolonged immobilization are not fully captured [15]. This study achieved comprehensive coverage of multidimensional risks related to “stress-shear-humidity-psychology” by combining Caprini thromboembolism risk assessment (focusing on mobility), skin moisture detection (predefined threshold <40) and the SAS anxiety scale (intervention for those with scores >50). Evidence indicates that anxiety can lead to peripheral vasoconstriction through sympathetic nervous excitation, increasing the risk of local ischaemia during surgery [16].

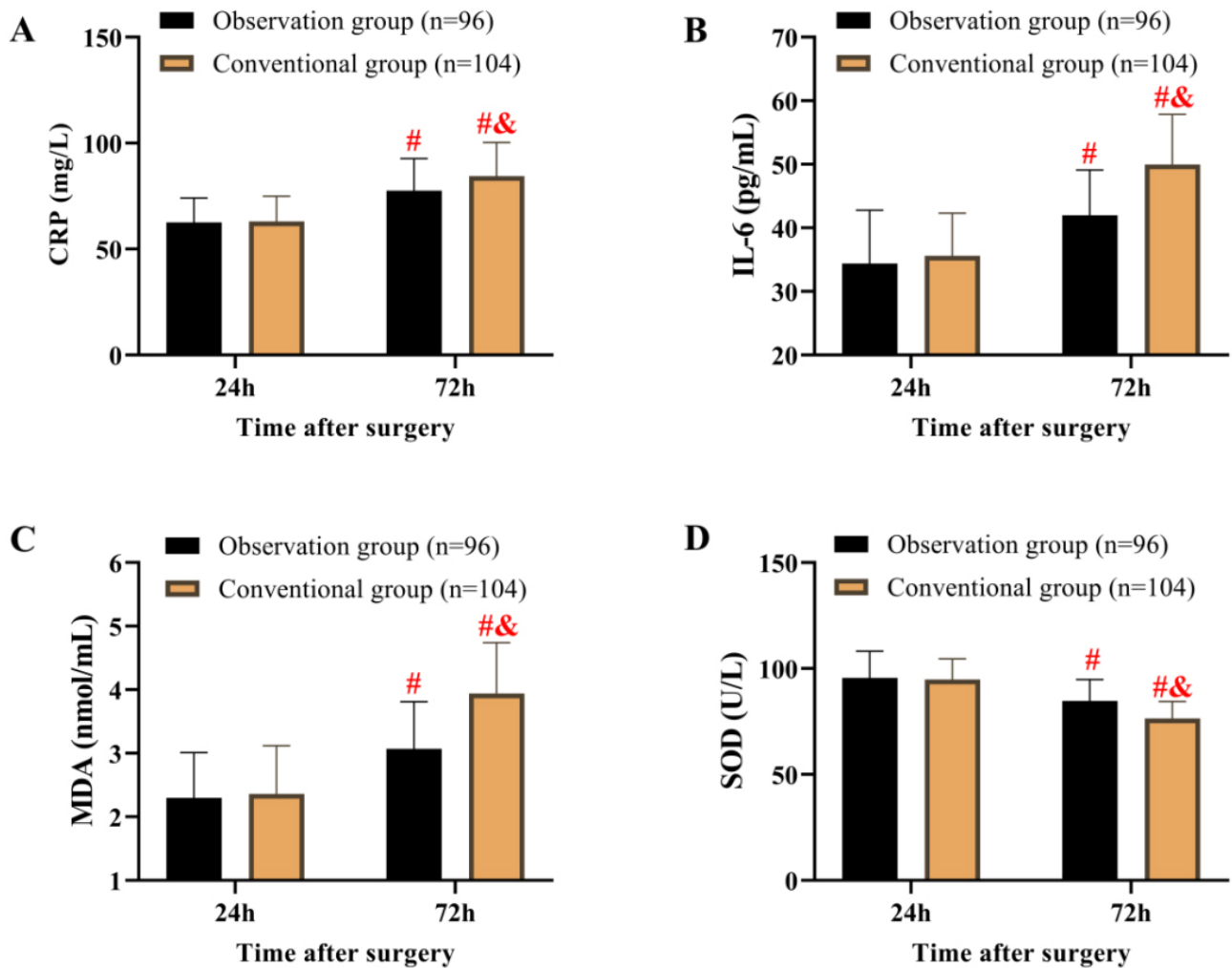


Fig. 1. Comparison of inflammatory and oxidative stress responses between the two groups. (A) Changes and comparison of CRP. (B) Changes and comparison of IL-6. (C) Changes and comparison of MDA. (D) Changes and comparison of SOD. “&” indicates a significant difference between the observation group and the conventional group at the same time point ($p < 0.05$); “#” indicates a significant within-group difference between 24 h and 72 h postoperatively ($p < 0.05$). CRP, C-reactive protein; IL-6, Interleukin-6; MDA, Malondialdehyde; SOD, Superoxide dismutase.

(2) Dynamic posture management and the use of pressure-injury prevention materials. At the tissue level, the core mechanism of intraoperative pressure injuries involves tissue ischemia and hypoxia caused by continuous pressure and shear forces [17]. Traditional nursing relies on a passive intervention mode of repositioning (2 hours/time), which is difficult to adapt to the mechanical sensitivity of bony prominences (e.g., the sacrococcygeal region) in elderly patients [18]. Hourly routine position adjustments were performed in this study, with a turning pillow used to maintain a 30° lateral position. This approach avoided local tissue damage caused by prolonged pressure exceeding the injury threshold (pressure >32 mmHg for 60 minutes can induce deep tissue injury) without requiring smart pressure-sensing mattresses. Turning pillows are standard clinical consumables and are easy to use without specialized training. In addition, limiting documentation to position-

adjustment times reduces nursing paperwork, making this approach compatible with busy clinical workflows. Also, an animal study has confirmed that sustained pressure >32 mmHg for 60 minutes leads to deep tissue damage [19]. While gel pads and memory foam offer viscoelastic properties that absorb 30–50% of pressure energy [20] and reduce shear force accumulation via nonlinear rebound, the modified thickened foam pads and standard soft pillows in this study effectively distributed local pressure by increasing contact area and contour fitting. These materials are readily available, cost-effective, and free from the procurement constraints or financial burdens associated with specialized decompression products—making them more suitable for promotion in primary hospitals or resource-limited departments.

(3) With support from a multidisciplinary team, the fast-track recovery concept is implemented. Pressure in-

jury prevention and control is not merely a single aspect of nursing care but requires the full involvement of the surgical team. This study established a ‘preoperative-intraoperative-postoperative’ closed-loop management system in which anaesthetists controlled blood pressure fluctuations (systolic 90–140 mmHg), surgical nurses shortened the positioning exposure time (<5 minutes), and the head nurse supervised the implementation rate of interventions daily. Our research data showed that precise operations prevented secondary damage to the wound caused by ineffective turning. In addition, the multidimensional pressure injury prevention protocol reduced tissue damage and pain at the compressed sites, alleviated patients’ concerns about postoperative activity, and combined with the standardized perioperative ERAS management, allowed the observation group to get out of bed for the first time sooner than the conventional group, consistent with the ERAS principle of “reducing immobilisation time to improve prognosis” [21].

(4) Analysis of relevant biomarkers provided preliminary support for the underlying mechanisms of the intervention programme. Inflammation and oxidative stress response are the key pathological pathways for the occurrence and progression of pressure injuries [22]. In the observation group, CRP, IL-6, and MDA were lower at 72 hours after surgery, while SOD was higher. These results suggest that multidimensional interventions may be associated with reduced systemic inflammatory and oxidative stress responses after surgery and was associated with reduced systemic inflammatory and oxidative stress responses, consistent with a previous study indicating that pressure relief is associated with reduced oxidative stress [23].

Based on these findings, the multidimensional approach used in this study could be further refined to clarify the frequency of intraoperative position adjustments, the selection of decompression materials, and the multidisciplinary collaboration process, thereby promoting the standardization of nursing care. The retrospective design has the advantage of using existing clinical data, thereby avoiding the ethical risks and resource consumption associated with prospective intervention. The results are also closer to real clinical practice and have reference value for implementation in primary hospitals. However, despite the positive results of this study, the following limitations exist: (1) The non-randomized group allocation may have introduced selection bias, as the choice of nursing programme was based on actual clinical work arrangements and patient conditions. (2) The data depend on the completeness of medical records. Intraoperative peak pressure was not included in the final analysis because of incomplete and inconsistent recording in the retrospective data, with no standardized measurement protocol across the study period. (3) Only the pressure injury outcomes at 7 days postoperatively were observed, and long-term complications (such as chronic wound formation) and functional recovery were not tracked. (4) Although reduced medical expenses were observed in the ob-

servation group, the investment costs of the the implementation costs of the intervention protocol were not quantified; therefore, further health economic evaluations are required.

Conclusions

A multidimensional intraoperative PI prevention protocol is associated with a significantly lower incidence of pressure injuries, shorter length of hospital stay, and higher patient satisfaction. Its key advantage lies in integrating precise preoperative assessment, intraoperative dynamic mechanical intervention, and postoperative biomarker monitoring, thereby forming a systematic protective network encompassing physical protection, tissue repair, and psychological support.

Availability of Data and Materials

The data used and analyzed during the current study are available from the corresponding author.

Author Contributions

JSL: Conceptualization, Methodology, Supervision, Project administration, Writing – review & editing. YLH: Data curation, Investigation, Software, Visualization, Writing – original draft. KXY: Validation, Formal analysis, Resources, Writing – review & editing. All authors contributed to the critical revision of the manuscript for important intellectual content. 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 retrospective study was approved by the Ethics Committee of Tianjin Hospital (Ethics Approval No. 2025-229). The requirement for individual informed consent was waived, given that all patient-level data utilized in this retrospective analysis had been completely anonymized, with no identifiable personal information retained and no possibility of re-identification of individual subjects. The study was conducted in accordance with relevant national regulations and the approved protocol. The study conformed to the provisions of the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at <https://doi.org/10.62713/aic.4561>.

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