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ORIGINAL RESEARCH

Intensive Care Nurses' Perceptions, Knowledge, and Attitudes Toward Pressure Injury Prevention in Prone Position Patients: A Multicenter Cross-Sectional Study in Shanghai, China

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Background: Pressure injury (PI) is a major concern in ICUs, where multiple risk factors contribute to its development. ICU nurses are vital in PI prevention, a key element of patient safety and care quality.

Aim: Explore ICU nurses' perceptions of PI prevention in prone-positioned patients across nine major hospitals in Shanghai, China, and to evaluate their knowledge and attitudes toward PI prevention.

Design: A multicenter cross-sectional study.

Methods: Convenience sampling recruited 252 ICU nurses from nine hospitals in Shanghai between July 31 and August 25, 2024. Participants completed a questionnaire assessing their perceptions of PI prevention in prone-positioned patients. Their knowledge and attitudes were evaluated using the Pressure Ulcer Knowledge Assessment Tool version 2.0 (PUKAT 2.0) and the Attitudes toward Pressure Ulcer Prevention instrument (APuP). Statistical analyses included Pearson correlation, *t*-tests, ANOVA, and multivariate regression.

Results: ICU nurses showed a positive perception of PI prevention in prone-positioned patients. The mean knowledge score was 8.45 ± 2.55 (40.24%, ≥60% satisfactory), while the mean attitude score was 39.39 ± 4.88 (75.75%, ≥75% satisfactory). Knowledge and attitudes were significantly positively correlated ($r = 0.215$; $p < 0.05$). Demographic factors such as gender, age, and ICU experience significantly influenced knowledge and attitudes (all $p < 0.05$). Nurses with a master's degree and those who had been primary nurses for prone-ventilated patients had higher knowledge scores. Additionally, nurses with 6–15 years of experience showed more favorable attitudes toward PI prevention.

Conclusion: Although ICU nurses had a positive perception of PI prevention in prone-positioned patients, their knowledge was insufficient, and their attitudes were moderate. To address these gaps, healthcare administrators should implement targeted strategies and update evidence-based protocols for PI prevention in prone-ventilated patients. Improving nurses' knowledge and fostering a proactive attitude can enhance clinical practices and patient outcomes.

Keywords: pressure injury, prone positioning, perception, knowledge, attitude, nurses

Introduction

Pressure injury (PI), defined as localized damage to the skin and underlying tissue due to sustained pressure or pressure in combination with shear, often occurs over bony prominences or beneath medical devices.[1] PI prevention is a global health priority, given its high prevalence, adverse clinical outcomes, and the significant economic burden it imposes on healthcare systems.[2] A systematic evaluation of 39 studies across 19 countries revealed that the overall prevalence of PI in hospitalized patients is 12.8%, with 8.4% being hospital-acquired.[3] The risk is particularly pronounced in intensive care unit (ICU) settings,[2] where patients often experience prolonged immobility,[4] advanced age, poor nutrition, and are

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frequently exposed to medical devices.[5–7] Based on a systematic review,[8] the 95% confidence intervals (CIs) for cumulative incidence and prevalence in adult ICU patients were 6.6–36.8% and 12.2%–24.5%, respectively. Additionally, a study revealed that the cumulative incidence of device-related PI ranged from 0.9% to 41.2% in the ICU, while the prevalence rates varied between 1.4% and 121%.[9]

Prone positioning, a risk factor for PI in ICU patients,[10] commonly used in ICU patients with moderate to severe acute respiratory distress syndrome (ARDS), has proven beneficial in improving ventilation/perfusion matching, reducing lung stress and strain,[11] decreasing ventilator-induced lung injury,[12] and potentially improving hemodynamics.[13] During the coronavirus disease 2019 (COVID-19) pandemic, it became a standard practice for ARDS management, even being used before intubation in spontaneously breathing patients.[14] However, despite its therapeutic benefits, prone positioning is associated with an increased risk of PI,[15] particularly in areas such as the face, cheekbones, thorax, and bony prominences.[16] A recent meta-analysis of 10 systematic reviews further highlights this concern, revealing that the cumulative incidence of PI in adult ICU patients undergoing prone positioning ventilation ranged from 25.7% to 48.5%.[2] PI contributes to pain, delayed recovery, increased infection risk, and psychological distress.[17] It compromises patient safety and quality of life,[18] prolongs ICU and hospital stays, and increases reliance on mechanical ventilation.[19] From a resource utilization perspective, the treatment of PI imposes substantial financial strain on healthcare systems, with estimated annual costs of USD 11 billion in the United States, GBP 750 million in the United Kingdom, and AUD 1.8 billion in Australia.[20,21] These challenges underscore the need for timely identification, targeted prevention strategies, and efficient resource allocation.[22]

Nurses play a pivotal role in the multidisciplinary approach required for PI prevention and early intervention.[23] For patients undergoing prone position ventilation, evidence-based strategies—such as systematic risk assessment, frequent skin inspection, off-loading techniques, use of pressure redistribution surfaces, and prophylactic dressings[24,25]—are critical for effective PI prevention.[26] The Theory of Planned Behavior (TPB) emphasizes that an individual's actions are shaped by their attitude toward a behavior, which is, in turn, influenced by their knowledge, behavioral intention, and interest in the subject.[27] A positive attitude toward PI prevention is associated with better implementation of PI prevention practices.[28] Grimshaw et al[29] also identified that barriers such as lack of knowledge, negative attitudes, and underdeveloped skills hinder the implementation of evidence-based practices. Guided by the TPB framework, this study seeks to explore how modifiable factors influence nurses' perceptions of PI prevention. Understanding these determinants can inform targeted interventions and policies. Ensuring nurses have adequate knowledge and a positive attitude may enhance the implementation of preventive strategies and support informed clinical decisions.[26,30]

While previous research[31–33] has explored ICU nurses' knowledge and attitudes toward PI prevention, there is limited evidence specifically addressing their perceptions in the context of prone positioning—a high-risk intervention with growing clinical adoption, particularly in Chinese ICUs. Given the increasing reliance on prone ventilation, particularly in pandemics or respiratory crises, understanding frontline nurses' preparedness and perspectives is critical for policy formulation and clinical risk mitigation.[34] Therefore, this study aims to explore ICU nurses' perceptions of PI prevention in prone positioning patients in key hospitals in China, with a focus on their understanding of evidence-based practices, including risk assessment, skin assessments, nursing care, and the use of preventive dressings. Nurses' knowledge and attitudes will be assessed using the validated Chinese versions of the Pressure Ulcer Knowledge Assessment Tool (PUKAT 2.0) and the Attitude toward Pressure Ulcer Prevention Instrument (APuP), respectively. Furthermore, the study seeks to examine whether perceptions, knowledge, and attitudes vary across demographic characteristics such as educational level, years of clinical experience, and prior training. Identifying such differences may help inform the design of targeted interventions and evidence-based policy recommendations.

Materials and Methods

Study Design

From July 31 to August 25, 2024, we conducted a web-based cross-sectional study to investigate ICU nurses' perceptions of PI prevention in prone positioning patients across nine key hospitals in Shanghai, China, and to evaluate their knowledge and attitudes toward PI prevention.

Sample and Setting

This study was conducted in the ICUs of nine tertiary general hospitals in Shanghai, China. All participating hospitals are affiliated with four major universities that integrate medical care, teaching, and research, and serve as clinical teaching bases for medical colleges. Given the higher frequency of prone position ventilation in tertiary hospitals, a convenience sampling method was used to select hospitals and nursing staff based on the number of ICU beds and available personnel.

Eligible participants were registered nurses who met the following inclusion criteria: (1) currently working in adult ICUs with at least one year of clinical experience, and (2) voluntarily provided informed consent to participate. Nurses were excluded if they were (1) undergoing clinical rotations or (2) in training at the time of the survey. A total of 252 ICU nurses were recruited.

Data Collection Instrument

The survey was collected using a four-part questionnaire. Before data collection, we obtained the rights to use the PUKAT2.0 and APuP.

Part One: Demographic and professional characteristics, including age, gender, education level, ICU work experience, professional title, job position, previous PI prevention training, and experience as a primary nurse for patients undergoing prone ventilation.

Part Two: Perceptions of PI prevention in patients undergoing prone ventilation. This section was developed using the ASSKING framework,[35] referencing expert consensus and evidence summaries. The draft was initially prepared by the research team and revised following consultations with one clinical nursing expert, four ICU head nurses with over 20 years of experience, and one nursing educator with 15 years of academic experience. The final version included 9 items covering 7 core domains: (1) risk assessment, (2) skin assessment, (3) surface management, (4) repositioning, (5) moisture management, (6) device selection and usage, and (7) information provision (detailed items are shown in Table 1). Respondents selected all applicable items they agreed with. The scale-level content validity index/universal agreement (S-CVI/UA) was 0.89, indicating good content validity.

Part Three: Knowledge of PI prevention was measured using the Chinese version of PUKAT 2.0, originally developed and validated by Manderlier et al[36] and translated into Chinese by Liu et al.[37] The tool includes 21 items across six domains: (1)

Table 1 Perceptions of PI Prevention in Patients Undergoing Prone Ventilation

Item	n	Proportion (%)
T1. What method do you think is most appropriate for assessing the risk in patients undergoing prone position ventilation?		
A. Structured risk assessment tools.	110	43.65
B. Risk factors.	54	21.43
C. Combination of both.	88	34.92
T2. Do you think a specialized PI risk assessment scale is necessary for these patients?		
A. It is necessary.	233	92.46
B. It is not necessary.	15	5.95
C. Not paying attention to.	4	1.59
T3. In your opinion, how frequently should skin assessments be conducted for patients receiving prone position ventilation?		
A. 1 assessment per 2 hours.	126	50
B. 1 assessment per class.	41	16.27
C. 1 evaluation per day.	1	0.4
D. Depends on the patient's risk level.	84	33.33

(*Continued*)

Table 1 (Continued).

Item	n	Proportion (%)
T4. Which pressure-prone body areas should be prioritized when providing care to patients undergoing prone position ventilation?		
A. Cheeks (forehead/cheeks/chin, etc.)	251	99.6
B. Eyes, ears, mouth, nose	225	89.29
C. Elbow/upper limbs	219	86.9
D. Front chest	218	86.51
E. Bilateral rib/costal arch edges	218	86.51
F. Hip area	211	83.73
G. Genital organ	208	82.54
H. Lap	191	75.79
I. Lower limbs/shin	174	69.05
J. Foot	173	68.65
T5. What do you think are the best practices for managing the support surface in patients undergoing prone position ventilation?		
A. The bed surface is flat and clean.	236	93.65
B. Use a specific head pad/face pressure relief pad.	245	97.22
C. Place a soft pillow across the shoulders, hips, and shins.	244	96.83
D. When using a respirator, place a dressing between the respirator and the skin.	236	93.65
E. Use preventive dressings on medical device contacts and pressure areas.	244	96.83
F. Consider the patient's skin condition when selecting a dressing.	231	91.67
T6. What actions do you think should be taken when repositioning patients undergoing prone position ventilation?		
A. Change positions slowly and gradually, and check the patient's airway, oxygenation, etc. before and after the change.	246	97.62
B. Make sure there is no foreign matter underneath your body.	245	97.22
C. Change the electrode position (front chest → back).	244	96.83
D. After changing position, keep the patient's head high and feet low.	220	87.30
E. After changing body position, keep the foot in the functional position.	230	91.27
F. After changing body position, change the position of the head and limbs regularly.	242	96.03
T7. What measures do you think should be implemented to manage the moisture content in patients undergoing prone position ventilation?		
A. Place a moisture-absorbing pad under the head and clean the oral and nasal secretions promptly.	247	98.02
B. Use skin protection products such as film-forming agents on areas prone to moisture.	230	91.27
C. Use non-irritating emollients on the forward-facing torso.	225	89.29
D. Take good care of your eyes and check your eyes every morning and evening.	224	88.89
E. Manage incontinence.	237	94.05
T8. What guidelines do you think should be followed when selecting and using medical devices for patients undergoing prone position ventilation?		
A. Consider device shape, size, and patient treatment needs when selecting	243	96.43
B. Whenever possible, avoid placing the device on existing pressure injuries skin.	247	98.02

(*Continued*)

Table 1 (Continued).

Item	n	Proportion (%)
C. Avoid using endotracheal tube fixation devices and use tape or ties to secure the endotracheal tube instead.	227	90.08
D. Avoid running pipes, monitoring lines, etc., directly under the patient.	242	96.03
T9. What support do you think is needed for the prevention of pressure injuries in patients undergoing prone position ventilation?		
A. Prevention programs should involve a multidisciplinary team.	243	96.43
B. Develop and implement a prone positioning procedure.	242	96.03
C. Ensure regular training, including practical operations, in the department.	229	90.87
D. Provide instructions for the use of products such as air mattresses, positioning devices, and preventive dressings.	230	91.27

etiology, (2) classification and observation, (3) risk assessment, (4) nutrition, (5) PI prevention strategies, and (6) special patient populations. While PUKAT 2.0 assesses general PI prevention knowledge, it lacks specificity for prone positioning, which is a methodological limitation. Nonetheless, it remains a practical foundation in the absence of a validated prone-specific instrument. Each correct answer was scored as 1, and incorrect or "don't know" responses as 0. Total scores ranged from 0 to 21 and were converted into percentage scores. A score of ≥60% was considered satisfactory. In previous validation studies, the tool demonstrated a Kuder–Richardson 20 (KR-20) coefficient of 0.713 and a test-retest reliability of 0.893.

Part four: Attitudes toward PI prevention were assessed using the Chinese version of the APuP, originally developed and validated by Beeckman et al[38] and translated by Wang et al.[39] The instrument consists of 13 items covering four themes: (1) personal competency to prevent PI, (2) prioritizing PI prevention, (3) the impact of PIs, and (4) confidence in the effectiveness of PI prevention. Each item is rated on a four-level Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). Negatively, narrative items are reverse-scored (items 3, 4, 5, 7, 8, 10, and 13). The total score ranged from 13 to 52, with higher scores reflecting more positive attitudes. Scores were converted into percentage values, with ≥75% considered satisfactory. In Wang et al's study, the APuP demonstrated a Cronbach's α of 0.814.

Data Collection Procedure

Data were collected using Questionstar, a widely used secure online platform in China for academic research. Head nurses of the participating ICUs were initially contacted to explain the study objectives, inclusion/exclusion criteria, and data collection process. Upon agreement, head nurses distributed an Email to eligible nurses, which contained a link to the online questionnaire.

The questionnaire began with an electronic informed consent form detailing the study's purpose, procedures, confidentiality assurances, and voluntary nature of participation. Participants were instructed to complete the survey independently, without assistance or consultation. A total of 252 fully completed responses were received.

Ethical Acknowledgment

Ethical approval was obtained from the Ethics Committee of Zhongshan Hospital, Fudan University (No B2024-060R2). All participants provided informed consent electronically prior to data collection.

Data Analysis

Descriptive statistics were used to summarize demographic characteristics, knowledge, attitude scores, and perceptions of PI prevention in patients undergoing prone ventilation. Specifically, the number and percentage of nurses selecting each option in the perception questionnaire were calculated. Continuous variables were expressed as means ± standard deviations, and categorical variables as frequencies and percentages. Pearson correlation coefficients, independent *t*-tests, and one-way analysis of variance (ANOVA) were used to explore associations between demographic factors and knowledge or attitude scores. Variables with significant univariate associations were included in multivariate linear regression analyses. All analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY), with statistical significance set at $p < 0.05$.

Results

Demographic Information of Participants

A total of 252 ICU nurses from nine tertiary hospitals in Shanghai participated in the study. The mean age of participants was 31.06 ± 6.67 years, with an average ICU work experience of 9.65 ± 7.57 years. The majority were female (n = 220, 87.3%) and held a bachelor's degree (n = 176, 69.8%). Most nurses worked in comprehensive ICUs (n = 201, 79.7%), while a smaller proportion were from respiratory ICUs (n = 19, 7.5%). Notably, 72.0% (n = 152) had received training on pressure injury (PI) prevention within the past year, and 89.7% (n = 226) had experience caring for patients receiving prone position ventilation (PPV). Detailed demographic characteristics are presented in Table 2.

Table 2 Demographic Information of Participants (n=252)

Variables	**n (%)**
Age (years) (M=31.06, SD=6.67)	
<25	65 (25.8)
25-30	73 (29.0)
31-35	48 (19.0)
36-40	39 (15.5)
>40	27 (10.7)
Gender	
Male	32 (12.7)
Female	220 (87.3)
Working years in ICU	
≤5	94 (37.3)
6-10	63 (25.0)
11-15	36 (14.3)
16-20	31 (12.3)
>20	28 (11.1)
Professional title	
Registered Nurse (RN)	60 (23.8)
Primary Nurse Practitioner (PNP)	133 (52.8)
Senior Nurse Practitioner	56 (22.2)
Chief Nurse Practitioner	3 (1.2)
Education	
Diploma or below	68 (27.0)
Bachelor's degree	176 (69.8)
Master's degree	8 (3.2)
Job position	
Clinical Nurse	231 (91.7)
Nurse Educator	4 (1.6)
Specialist Nurse	8 (3.2)
Chief Nurse	9 (3.6)
Unit	
Comprehensive ICU	201 (79.8)
Respiratory ICU	19 (7.5)
Emergency ICU	15 (6.0)
Neurological ICU	12 (4.8)
Medical ICU	5 (2.0)

(*Continued*)

Table 2 (Continued).

Variables	n (%)
Have you ever received training related to PI?	
Yes No	211 (83.7) 41 (16.3)
How long has it been since you last attended related training? (n=211)	
<1 year 1-2 years 2-5 years >5 years	152 (72.0) 43 (20.4) 10 (4.7) 6 (2.8)
Have you ever received training related to prone position ventilation?	
Yes No	217 (86.1) 35 (13.9)
Have you ever cared for patients undergoing prone position ventilation as the primary nurse?	
Yes No	226 (89.7) 26 (10.3)
Does your department have a procedure for prone position ventilation?	
Yes No	229 (90.9) 23 (9.1)
Do you follow the items outlined in the procedure when performing prone position ventilation? (n=229)	
Yes No	229 (100) 0 (0)

Notes: In this study, "Professional Title" refers to nursing ranks commonly used in China, including:

- Registered Nurse (RN): Certified nurses providing direct patient care
- Primary Nurse Practitioner (PNP): Nurses with basic clinical experience are involved in care management
- Senior Nurse Practitioner: Experienced nurses with advanced skills and supervisory roles
- Chief Nurse Practitioner: Nurses are responsible for nursing management and leadership

Registered Nurse (RN): Certified nurses providing direct patient care
Primary Nurse Practitioner (PNP): Nurses with basic clinical experience are involved in care management
Senior Nurse Practitioner: Experienced nurses with advanced skills and supervisory roles
Chief Nurse Practitioner: Nurses are responsible for nursing management and leadership

"Job Position" refers to functional nursing roles, including:

- Clinical Nurse: Nurses delivering direct patient care
- Nurse Educator: Responsible for the training and education of nursing staff
- Specialist Nurse: Focused on specific clinical specialties
- Chief Nurse: Nursing management position

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Perceptions of PI Prevention in Patients Undergoing Prone Ventilation

Overall, participants exhibited a generally positive perception of PI prevention strategies in PPV patients.

Risk Assessment: When assessing PI risk in PPV patients, 43.65% of nurses reported using structured risk assessment tools, 21.43% relied on clinical judgment of risk factors, and 34.92% employed both approaches. A majority (92.46%) expressed the need for a specific PI risk assessment scale tailored to prone positioning.

Skin Assessment: Most nurses recommended skin inspections every 2 hours (50%) or based on patient risk level (33.33%). However, attention to the knees, lower limbs, and feet was notably less frequent than assessments of the head, face, and trunk.

Support Surface Management: While nurses demonstrated adequate knowledge regarding support surface management, some gaps remained. Specifically, several participants did not consider the patient's skin condition when selecting dressings.

Repositioning: Standard repositioning practices were generally followed. However, 12.7% of nurses disagreed with maintaining a head-elevated and feet-lowered position during PPV.

Moisture Management: Approximately 10% of nurses were unfamiliar with appropriate skin protection practices, such as the use of film-forming agents in moisture-prone areas and non-irritating emollients. Awareness of eye care protocols during PPV was also limited.

Device Selection and Use: Lower agreement was observed regarding the recommendation to avoid endotracheal tube fixation devices in favor of tape or ties.

Information Provision: Most participants supported the need for multidisciplinary collaboration and the establishment of unit-specific protocols for PI prevention in PPV patients.

Further details are summarized in Table 1.

Knowledge and Attitudes Regarding PI Prevention

The mean knowledge score was 40.24% (M = 8.45; SD = ±2.55), which fell below the satisfactory threshold of ≥60%. Only 5.95% (n = 15) of nurses achieved a score of ≥60%. Among the six themes, "Risk assessment" had the highest mean score at 56.5%, while "Nutrition" and "Prevention" had the lowest mean scores of 28.3% and 27.4%, respectively (Table 3). The accuracy of each item varied significantly, ranging from 12.7% to 77.38%. The five items with the lowest accuracy are shown in Table 4.

The mean attitude score was 75.75% (M = 39.39; SD = ±4.38), meeting the satisfactory threshold of ≥75%. However, only 56.75% (n = 143) of nurses reached the ≥75% mark. Among the four themes, "Prioritizing PI prevention" had the highest mean score of 83.13%, while "Personal competency to prevent PI" had the lowest mean score of 66.13% (Table 3).

Correlations

Pearson correlation analysis revealed a significant positive correlation between PI prevention knowledge and attitude scores ($r = 0.215$, $p < 0.05$). Attitudes were also positively associated with knowledge in the domains of "Risk Assessment" ($r = 0.192$, $p < 0.001$) and "Specific Patient Groups" ($r = 0.182$, $p < 0.001$). No other significant correlations were observed ($p > 0.05$) (Table 5).

Table 3 Descriptive Statistics of Knowledge and Attitudes (Domains and Total)

Domain	Min-Max	Mean ± SD	Correct Answers (%)
Knowledge (Range: 0–21)	**1-15**	**8.45±2.55**	**40.24**
1. Etiology	0-4	1.90±0.92	47.5
2. Classification and observation	0-3	1.58±0.83	52.7
3. Risk assessment	0-2	1.13±0.71	56.5
4. Nutrition	0-3	0.85±0.73	28.3
5. PI Prevention	0-5	1.92±1.14	27.4
6. Special Patient Group	0-2	1.08±0.64	54.0
Attitude (Range: 13–52)	**27-49**	**39.39±4.38**	**75.75**
1. Personal competency to prevent PI	4-15	10.58±1.23	66.13
2. Prioritizing PI prevention	7-16	13.30±2.18	83.13
3. Impact of PI	4-12	9.29±1.43	77.42
4. Confidence in the effectiveness of PI prevention	2-8	6.22±1.08	77.75

Table 4 Entries with the Bottom 5 Scores on the Pressure Injury Knowledge Questionnaire

Item	Accuracy (%)
T11 Which nutrients are most important for preventing PI?	12.7
T17 What is the most effective position for the patient while sitting?	12.7
T19 How does repositioning prevent PI?	18.65
T16 How can bedding be used to prevent PI?	19.44
T15 Is it true that using a ring cushion is effective in preventing PI for patients in a wheelchair?	21.83

Table 5 Significant Correlations Among Variables

Correlated Variables	Correlations
Knowledge/Attitude	($r = 0.215$; $p < 0.05$)
Attitude/ Risk assessment (knowledge)	($r = 0.192$; $p < 0.001$)
Attitude/ Specific patient groups (knowledge)	($r = 0.182$; $p < 0.001$)

Differences in Knowledge and Attitudes by Demographic Characteristics

One-Way Analysis of Variance

As shown in Table 6, significant differences in knowledge scores were observed across several demographic variables, including gender, age, ICU experience, education level, professional title, job position, time since the last training session, and experience as a primary nurse for patients undergoing prone ventilation (all $p < 0.05$). Similarly, significant differences in attitude scores were found by gender, age, professional title, job position, working years in ICU, time since the last training session, experience as a primary nurse for patients undergoing prone ventilation, and whether a protocol for patients undergoing prone ventilation in the department, all significantly influenced nurses' attitudes toward PI (all $p < 0.05$).

Table 6 Comparison of Participants' PI Prevention Knowledge and Attitudes by Demographic Characteristics

Demographic Characteristics	Knowledge		Attitudes	
	M ± SD	Statistics (P)	M ± SD	Statistics (P)
Gender		-2.760^{t} (0.009)		-2.310^{t} (0.027)
Male	7.34±2.42		37.47±5.16	
Female	8.61±2.53		39.67±4.20	
Age(years)		4.789^{F}(<0.001)		3.843^{F}(0.005)
<25	7.62±2.54		38.06±4.66	
25-30	8.25±2.77		38.89±4.32	
31-35	8.5±2.07		40.17±4.08	
36-40	9.46±1.94		40.97±3.99	
>40	9.48±2.76		40.3±3.98	
Unit		0.274^{F}(0.894)		0.607^{F}(0.658)
Comprehensive ICU	8.48±2.58		39.36±4.17	
Respiratory ICU	8±2.77		39.95±5.67	
Emergency ICU	8.33±2.16		39±5.36	
Neurological ICU	8.92±2.64		38.5±4.12	
Medical ICU	8.2±1.3		41.8±5.63	

(*Continued*)

Table 6 (Continued).

Demographic Characteristics	Knowledge		Attitudes	
	M ± SD	Statistics (P)	M ± SD	Statistics (P)
Working years in the ICU		4.256[F](0.002)		5.682[F](<0.001)
≤5	7.71±2.67		37.8±4.41	
6-10	8.51±2.57		39.92±3.84	
11-15	8.92±1.68		40.75±4.17	
16-20	9.03±2.33		40.81±4.67	
>20	9.57±2.64		40.25±3.95	
Education		7.728[F](<0.001)		1.807[F](0.166)
Diploma or below	7.71±2.81		38.54±4.62	
Bachelor's degree	8.63±2.33		39.73±4.24	
Master's degree	11±2.62		39.25±5.01	
Professional title		6.987[F](<0.001)		6.238[F](<0.001)
Registered Nurse	7.63±2.54		37.6±4.63	
Primary Nurse Practitioner	8.32±2.59		39.59±4.34	
Senior Nurse Practitioner	9.48±1.99		40.63±3.6	
Chief Nurse Practitioner	11.33±2.89		43.67±2.08	
Job position		4.431[F](0.005)		2.507[F](0.060)
Clinical Nurse	8.28±2.5		39.29±4.38	
Nurse Educator	10.75±1.71		41.5±4.12	
Specialist Nurse	10±2.88		37.63±5.15	
Chief Nurse	10.44±2.13		42.67±1.87	
Have you ever received training related to PI?		0.438[F](0.662)		0.199[F](0.843)
Yes	8.48±2.49		39.42±4.46	
No	8.29±2.86		39.27±4.01	
How long has it been since you last attended related training? (N=211)		2.840[F](0.039)		3.128[F](0.027)
<1 year	8.27±2.28		39.03±4.45	
1-2 years	8.98±2.98		40.51±4.38	
2-5 years	8.2±2.82		38.2±4.05	
>5 years	10.83±1.83		43.33±3.01	
Have you ever received training related to prone position ventilation?		1.422[F](0.156)		1.365[F](0.174)
Yes	8.54±2.44		39.54±4.42	
No	7.89±3.11		38.46±4.08	
Have you ever cared for patients undergoing prone position ventilation as the primary nurse?		2.354[F](0.025)		2.574[F](0.015)
Yes	8.6±2.46		39.65±4.29	
No	7.19±2.93		37.19±4.64	
Does your department have a procedure for prone position ventilation?		0.292[F](0.771)		2.497[F](0.019)
Yes	8.47±2.49		39.59±4.37	
No	8.3±3.13		37.39±4	

Notes: [t] Independent *t*-test, [F]one-way analysis of variance.

Multifactorial Analysis

Multiple linear regression analysis was conducted to identify predictors of knowledge and attitude scores. Dummy variables were created for categorical data (eg, education levels). No multicollinearity was detected (Tolerance > 0.1, VIF < 10). Full coding details are provided in Supplementary Table 1. The results showed that education level and experience as a primary nurse caring for patients undergoing prone ventilation were significant factors influencing knowledge about PI prevention ($p < 0.05$). Nurses with a master's degree scored higher compared to those with secondary vocational or junior college education. Similarly, nurses who had cared for PPV patients as primary nurses scored higher than those

Table 7 Multiple Linear Regression Analysis of Factors Influencing Participants' PI Prevention Knowledge and Attitudes

Domain	Variant	Unstandardized Coefficient	Standardized Coefficient	t-value	P-value
Knowledge	(Constant)	7.281	—	6.665	<0.01
	• Education Master's degree	3.387	0.234	3.145	0.002
	• Have you ever cared for patients undergoing prone ventilation as the primary nurse?	−1.061	−0.127	−2.015	0.045
Attitude	(Constant)	39.591	—	18.951	<0.001
	• Working years in the ICU 6–10 years 11–15 years	 2.364 3.031	 0.234 0.243	 2.425 2.292	 0.016 0.023

Notes: R^2_{adj} = 0.101, F = 2.344, p < 0.001 (Knowledge); R^2_{adj} = 0.099, F = 2.385, p < 0.001 (Attitude); "–" means no such data; only statistically significant variables are presented.

who had not. In terms of attitudes toward PI prevention, ICU work experience was a significant influencing factor ($p < 0.05$). Compared to nurses with less than 5 years of work experience, those with 6–10 years and 11–15 years of experience scored higher. Detailed results are presented in Table 7.

Discussion

This study evaluated the self-reported ICU nurses' perceptions of PI prevention in prone positioning patients across nine key hospitals in Shanghai, China, as well as observed knowledge and attitudes toward PI prevention. The findings demonstrated nurses' positive perception of PI prevention in patients undergoing prone positioning. However, nurses' PI prevention knowledge was insufficient, and their attitudes were moderate.

ICU Nurses' Perception of PI Prevention in Prone Positioning Patients

Our findings suggest that ICU nurses held a generally acceptable perception of PI prevention in prone-positioned patients. Since the onset of COVID-19, its rapid spread has resulted in a global pandemic.[40] In early March 2022, Shanghai experienced its largest COVID-19 outbreak since 2020, lasting nearly four months.[41] This clinical shift was accompanied by a surge in relevant literature[42,43] and best practice recommendations.[44,45] Many participants in our study had received training on PI or prone ventilation-related care, with over 90% having served as primary nurses for patients undergoing prone positioning. This high level of exposure likely contributed to the acceptable perception of PI prevention.

Risk assessment forms the cornerstone of PI prevention. Standardized tools help clinicians quantify risks and implement targeted preventive interventions based on different risk levels.[46] Clinical practice guidelines[26] recommend using structured risk assessment tools in conjunction with comprehensive skin examinations and other risk factors to assess PI risk. However, only 35% of ICU nurses in our study adopted guideline-recommended tools, indicating a gap between knowledge and clinical practice. Notably, nurses expressed the need for a dedicated risk assessment tool tailored to the prone positioning context.

Skin inspection practices were largely consistent with those used for supine patients, yet additional vigilance is needed for pressure-prone areas unique to the prone position, such as the forehead, cheeks, chin, ears, chest, genital area, knees, and dorsum of the feet.[47] Skin assessment is essential not only for the early detection of pressure-related damage but also for identifying individuals' susceptibility to such injuries and maintaining optimal skin moisture balance.[48] Recognizing the sources of moisture is a key component of effective skin management. The application of barrier creams to moisture-prone areas is recommended to protect the skin from excessive humidity,[49] while non-irritating emollients

can be used to hydrate dry skin.[50] However, approximately 10% of nurses in this study were unfamiliar with these appropriate skin protection strategies, highlighting a need for further training in moisture management.

An increasing number of studies have reported that the use of specific dressings can reduce underlying tissue load and protect the skin surface.[51] However, the selection of appropriate wound dressings also remains a challenge. While most nurses acknowledged the importance of selecting dressings based on ulcer characteristics, fewer reported familiarity with dressing types and their proper application. This finding aligns with previous research by Li et al,[31] highlighting a knowledge gap in the clinical use of modern dressings. Current evidence suggests[52–54] that foam dressings can reduce skin pressure and effectively absorb moisture, making them recommended for use on anterior-facing skin areas in patients undergoing prone ventilation to prevent pressure injuries. Additionally, before applying prophylactic adjuncts, it is essential to assess the current skin condition and the ease of dressing removal to prevent mechanical stripping,[55] ensuring that dressings are applied to dry and intact skin. As noted by Neuberg et al,[56] additional practical training is needed for the proper application of modern dressings.

Finally, ICU nurses demonstrated relatively strong awareness regarding the prevention of medical device–related pressure injuries (MDRPI). Most nurses were able to identify the types of devices used and reposition them at regular intervals to relieve pressure. They also acknowledged the importance of temporarily removing devices—and dressings if needed—during skin assessments to ensure thorough evaluation. However, in patients undergoing prone ventilation, comprehensive evaluation of anterior-facing skin surfaces remains challenging due to patient acuity and staffing limitations. Whenever feasible, nurses avoided placing devices over already compromised skin.[54] Overall, while ICU nurses demonstrated an acceptable level of awareness regarding PI prevention in PPV patients, targeted interventions remain necessary, particularly in the areas of knowledge translation and skill application. Efforts should also be made to minimize barriers that hinder nurses from implementing preventive measures, thereby further improving patient outcomes.

ICU Nurses' Knowledge and Attitudes Toward PI Prevention

Despite their clinical exposure, ICU nurses demonstrated insufficient knowledge regarding PI prevention. Only 40.24% of participants answered knowledge items correctly, and a mere 5.95% met the proficiency threshold (≥60%). These findings are consistent with recent literature,[30–32,57–60] which indicates that nurses generally lack adequate understanding of PI management. For instance, a large-scale study in China involving 16,599 nurses reported that their PI-related knowledge required improvement.[60] Similarly, surveys from Turkey (n = 604),[30] Slovakia (n = 225),[59] and Sweden (with only 3.4% of participants achieving satisfactory scores),[58] as well as another investigation involving 950 ICU nurses from 15 hospitals[31] and a study assessing 510 ICU nurses,[32] all demonstrated low levels of PI-related knowledge. However, a study conducted in Iran reported nurses' knowledge at an ideal level. This discrepancy may be attributed to variations in the nurses' work environments. Overall, although ICU nurses are routinely exposed to high-risk patients, this experience does not necessarily translate into better knowledge of PI prevention.[31] Regarding specific dimensions of PI management, ICU nurses scored relatively high in risk assessment, a finding that aligns with previous research.[58] However, their knowledge regarding nutrition and prevention was notably lower, particularly in "which nutrients are most important for PI prevention", where they scored the lowest. Despite national guidelines promoting the use of nutritional screening tools[61] and expert consensus on the critical role of nutrition in PI management,[62] awareness among ICU nurses remains inadequate. Notably, this finding contrasts with results from Slovakian,[59] which may be attributed to differences in the work environment. Furthermore, the lower incidence of PI in the Slovakian healthcare system highlights the pivotal role of nutritional assessment in PI prevention. Therefore, hospital administrators should implement systematic training programs to enhance ICU nurses' ability to accurately understand and apply nutritional support in PI prevention, ultimately optimizing clinical practice and reducing PI incidence.

Furthermore, our study found that nurses holding master's degrees performed significantly better in PI prevention than those with bachelor's degrees or lower, corroborating previous research.[63,64] This discrepancy may be due to the more comprehensive theoretical instruction provided in bachelor's programs, as opposed to the limited coverage at the secondary or diploma level.[32,65,66] Additionally, nurses with higher education typically possess stronger independent

learning capabilities and are more familiar with evidence-based practices, which enables them to actively seek and integrate the latest PI prevention evidence.[60]

In terms of attitudes, ICU nurses exhibited a moderate outlook toward PI prevention, consistent with studies conducted in Iran,[67] Turkey,[30] and Sweden.[58] Despite their limited knowledge, nurses demonstrated a positive attitude, as reflected in their participation in training programs—nearly all participants had undergone relevant training. This suggests that they actively seek to acquire new knowledge to enhance patient care quality. Additionally, since this study employed a convenience sampling method, it is possible that the participants were already aware of their knowledge gaps in pressure injury management and voluntarily enrolled in the study to assess their current level and seek improvement. Nevertheless, they scored lowest in confidence regarding the effectiveness of PI prevention measures and highest in prioritizing PI prevention. This suggests that although nurses recognize the importance of preventing pressure injuries, they may lack the necessary competence and confidence to implement effective measures. This is consistent with the findings of Jiang et al.[68] The culture of accountability and punitive responses in Chinese hospitals[69] may contribute to this phenomenon, although support from supervisors has been shown to enhance confidence.[70] Consequently, hospital administrators should foster a supportive work environment, provide strong clinical leadership, and actively engage with staff to encourage proactive PI reporting and management.

Finally, ICU work experience emerged as a significant predictor of nurses' attitudes toward PI prevention, echoing the findings of Khojastehfar,[71] Tubaishat[72] et al. Nurses with 6 to 15 years of experience demonstrated higher levels of PI prevention knowledge and a more proactive stance, likely due to their extensive exposure to critically ill patients with elevated PI risks. However, increased tenure may also lead to burnout and diminished empathy, which could adversely affect preventive efforts,[30,73] potentially hindering their preventive efforts. Tailored training and support based on years of experience are therefore essential to continuously enhance PI prevention awareness and practical competencies. Moreover, the significant positive correlation between knowledge and attitude toward PI prevention supports the theory of planned behavior, and similar findings have been reported in other studies.[34,59,74,75] This suggests that enhancing nurses' knowledge, interest, and behavioral intentions regarding pressure injury prevention can foster a more positive attitude, which, in turn, has a beneficial impact on nursing practice.

Limitations

This study has several limitations. First, the use of convenience sampling may limit the generalizability of the findings, and participant bias may have occurred due to their self-identified need for improved pressure injury prevention knowledge. Second, despite the anonymity of data collection, social desirability bias may have influenced responses in the attitude assessment, leading to more favorable results. Third, the study was limited to hospitals in Shanghai, so caution is needed when generalizing the findings to other regions. Finally, this study exclusively explored ICU nurses' knowledge of pressure injury prevention in prone-ventilated patients. Future research should consider developing a targeted knowledge, attitude, and practice (KAP) survey and incorporating PI incidence data to gain a more comprehensive understanding of the current state of prevention efforts.

Conclusions

Intensive care nurses generally exhibited a positive perception of PI prevention in patients undergoing prone positioning. However, their knowledge in this area was insufficient, with most nurses scoring below the proficiency threshold of 60% on the PUKAT 2.0 assessment. Their attitudes toward PI prevention remained moderate. Given the significant adverse effects of PI on patient outcomes, healthcare administrators should develop and refine targeted prevention strategies, including the implementation or revision of evidence-based protocols specifically tailored for patients receiving prone ventilation. Nursing managers are encouraged to establish a comprehensive, evidence-based training curriculum that integrates PI prevention with prone positioning practices, emphasizing the unique challenges posed by prone ventilation compared to the supine position. Targeted training should address identified knowledge gaps and be customized to nurses' characteristics and individual learning needs. Strengthening nurses' knowledge and fostering a proactive attitude toward PI prevention can ultimately lead to improved clinical practices and better patient outcomes.

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The lead corresponding author, Wei Qin, supervised the study and is the main contact for correspondence. The co-corresponding author, Qi Zhang, is responsible for data availability and method clarification.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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