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Knowledge, Attitude, and Practice Regarding Multi-Parameter Monitor Alarms Among ICU Nurses: A Multi-Center Cross-Sectional Study

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Abstract

Purpose: Investigate the knowledge, attitudes, and practices (KAP) status of ICU nurses towards multi-parameter monitor alarms in tertiary hospitals in China, and explore the influencing factors.

Methods: This is a multicenter, cross-sectional research. 813 ICU nurses from 9 tertiary hospitals in China were selected as study subjects from September 2024 to August 2025.The general information of the nurses and their KAP scores regarding multi-parameter monitor alarm management were collected via an online questionnaire method, followed by statistical analysis.

Results: The total KAP score for multi-parameter monitor alarm management among the 813 ICU nurses was 66.22 ± 6.70 (score rate: 80.76%). The results of linear mixed model analysis showed that education background, whether the nurse had participated in relevant training, whether the individual has had a personal hospitalization experience, and whether family members had ICU experience, were significant influencing factors on the ICU nurses' KAP regarding multi-parameter monitor alarms.

Conclusion: ICU nurses' KAP regarding multi-parameter monitor alarms is at a moderate level. Education background, relevant training, personal hospitalization experience, and family members' ICU experience are influencing factors on ICU nurses' KAP of multi-parameter monitor alarms. Nursing managers should focus on training and key populations.

Introduction

Background

With the development of medical technology and the improvement of medical standards, multi-parameter monitors are widely used in clinical settings. These monitors continuously assess changes in patients' physiological parameters and generate alarm signals for abnormal indicators, alerting healthcare providers to changes in patients' conditions [1]. In intensive care unit (ICU), nurses can closely monitor patients' conditions based on multi-parameter monitor alarms, which is of great significance. However, multi-parameter monitor alarms also present numerous issues. Studies have shown that each patient in an ICU generates 100 to 350 alarms per day, with 85% to 99% of these alarms being clinically insignificant or false [2–3]. The constant exposure of ICU nurses to frequent alarms can lead to alarm fatigue among the nursing staff. Currently, studies have reported numerous negative issues among ICU nurses regarding multi-parameter monitor alarms, such as "alarm fatigue" and "delayed response" [4–5]. In clinical practice, delays or misses in alarm responses often occur, which can result in patient safety hazards not being addressed promptly or correctly, further causing patients to miss the optimal rescue or treatment window. Therefore, nurses' correct cognition and active and effective intervention measures regarding multi-parameter monitor alarms are crucial factors influencing ICU patient safety. The Knowledge-Attitude-Practice (KAP) theory divides human behavior change into three continuous processes: acquiring knowledge, forming beliefs, and developing behaviors. Among them, knowledge is the foundation, beliefs are the motivation, and behavior change is the goal. This theory has been widely

applied in health education and nursing management for various diseases [6–8]. Studies have shown that issues such as "alarm fatigue" among ICU nurses are related to their levels of KAP [9].

Aims and objectives

This study aims to investigate the ICU nurses' KAP regarding multi-parameter monitor alarms through a nationwide multicenter survey, to understand the current status of Chinese ICU nurses' KAP regarding multi-parameter monitor alarms, discuss its influencing factors, and adopt targeted intervention measures. The ultimate goal is to improve the timeliness and effectiveness of ICU nurses' responses to multi-parameter monitor alarms, providing a theoretical basis for further enhancing clinical practice.

Methods

Study design

This study employs a cross-sectional design.

Setting and Sample

The surveyed medical institutions were all members of Specialty Committee of Critical Care Nursing of the Chinese Nursing Association. We selected 9 provinces and cities based on the regional distribution of hospital members of Specialty Committee of Critical Care Nursing of the Chinese Nursing Association. The sampling framework does not include Hong Kong, Macau, and Taiwan.

In this study, a convenience sampling method was used to select 813 ICU nurses from 9 ICUs across China from September 2024 to August 2025. The hospitals included were: Beijing Tiantan Hospital, Capital Medical University (H1), The First Affiliated Hospital of Dalian Medical University (H2), Jiangsu Cancer Hospital (H3), China-Japan Friendship Hospital (H4), The First Affiliated Hospital of Zhengzhou University (H5), West China Hospital of Sichuan University (H6), The First Affiliated Hospital of School of Shihezi University (H7), Sichuan Cancer Hospital (H8), and Hebei Chest Hospital (H9).

Inclusion criteria: (1) Clinical nurses with responsibilities in ICUs; (2) Have independently worked in ICUs for more than one year; (3) Possess a nurse qualification certificate; (4) Voluntarily participate in this study. Exclusion criteria: (1) On sick leave for 3 months or more; (2) Resigned during the study; (3) Nurse trainees.

Instruments

Demographic questionnaire

Through literature review and expert panel meetings, a "General Information Survey Questionnaire" was developed. The content mainly includes hospital, department, gender, age, Years of service, education background, professional title, whether engaged in teaching, whether the individual has had a personal hospitalization experience (Q1), whether a family member has had ICU experience (Q2), whether the

individual has participated in relevant training (Q3), whether the individual has experienced a patient death due to not promptly addressing monitor alarms (Q4), and whether the individual has experienced an impact on patient prognosis due to not promptly addressing monitor alarms (Q5).

Questionnaire on nurses' KAP regarding multi-parameter monitor alarms

The survey questionnaire used in this study was the "Survey Questionnaire on Nurses' KAP Regarding Multi-Parameter Monitor Alarms" developed by Yang XK [10] in 2019. The questionnaire consists of three sub-questionnaires: the knowledge questionnaire, the attitude questionnaire, and the practice questionnaire, totaling 22 items. The knowledge questionnaire includes 7 items and uses a dichotomous scoring method, with "Yes" scored as 1 point and "No" scored as 0 points. The attitude questionnaire includes 6 items and uses a five-point Likert scale, ranging from 1 to 5 as "Strongly disagree, Disagree, Neutral, Agree, Strongly agree". The practice questionnaire includes 9 items and also uses a five-point Likert scale, with items 1 to 4 using a positive scoring method (1–5 points corresponding to "Never, Occasionally, Sometimes, Often, Always") and items 5 to 9 using a reverse scoring method (1–5 points corresponding to "Always, Often, Sometimes, Occasionally, Never"). The total score ranges from 15 to 82 points, with the sub-questionnaire scores for knowledge, attitude, and practice ranging from 0 to 7, 6 to 30, and 9 to 45 points, respectively. In the original validation, the test-retest reliability (Cronbach's α) for each sub-questionnaire was 0.755, 0.763, and 0.960, respectively. The Item-level Content Validity Index (I-CVI) for each sub-questionnaire ranged from 0.87–1.00, 0.87–1.00, and 0.80–1.00, respectively. The Scale-level Content Validity Index (S-CVI) for the entire questionnaire was 0.945. In our study, Cronbach's α for each sub-questionnaire was 0.798, 0.862, and 0.818. The Kaiser-Meyer-Olkin (KMO) measure was 0.831, and Bartlett's test of sphericity was significant ($\chi^2 = 2952.297$, $df = 231$, $p < 0.001$), indicating that the data were suitable for factor analysis. Score Rate (%) = (Actual Score / Full Score) × 100%. Based on the empirical threshold method, KAP levels were classified into three categories according to the Score Rate: low level: Score Rate < 60%; moderate level: 60% ≤ Score Rate < 80%; high level: Score Rate ≥ 80%.

Data Collection

Data were collected via the online platform WJX (www.wjx.cn), a website that allows for the free creation of electronic surveys and generates corresponding QR codes. The researchers contacted the head nurses of the ICUs in various hospitals. After obtaining consent, the questionnaire's QR code was sent to the WeChat work group. Eligible nurses who met the inclusion criteria were invited to participate and could complete the questionnaire after providing informed consent. The researchers provided training to the personnel responsible for sending out the questionnaire, informing them of the study's purpose, importance, and key considerations. All investigators responsible for distributing the questionnaire received unified training, during which they were informed of the study's purpose, significance, and key considerations. To ensure completeness and uniqueness of responses, all questionnaire items were set as mandatory, preventing submission if any questions were skipped or missed, and each IP address was restricted to a single submission. After collection, two researchers independently reviewed and

organized the data, excluding questionnaires with a completion time of less than 1 minute or more than 30 minutes, as well as those showing patterned responses.

Data Analysis

Data processing was conducted using the statistical software SPSS 26.0. For measurement data, the mean ± standard deviation ($\bar{x} \pm s$) was used when the data followed a normal distribution, while the median and quartiles were used for data that did not follow a normal distribution. Count data were described using frequency and composition ratio [n(%)]. Univariate analysis used independent t-tests between two groups and one-way ANOVA for three or more groups. To test for and control for potential clustering effects at the hospital level, a linear mixed model (LMM) was employed for the analysis. In the model, the total KAP score was set as the dependent variable. Items from the general questionnaire (excluding 'hospital') were treated as fixed effects, while 'hospital' was included as a random intercept. The model was estimated using the restricted maximum likelihood (REML) method. The Intraclass Correlation Coefficient (ICC) was used to assess the degree of variation at the hospital level. Exploratory factor analysis was used to examine the structural validity. Statistical significance was set at a p-value of < 0.05.

Ethical and Institutional Approvals

This study was approved by the Ethics Committee of Beijing Tiantan Hospital, Capital Medical University (KY2024-341-02). All participants provided informed consent prior to their involvement. The procedure was as follows: the first page of the questionnaire presented a detailed informed consent form, which clearly outlined the study's purpose, content, estimated duration, potential risks and benefits, data confidentiality, the right to voluntary participation and withdrawal at any time, and the researchers' contact information. Participants were required to check the box stating, "I have read and understood the above information and voluntarily agree to participate in this study," before they could proceed to the main section of the questionnaire. Participants who did not provide consent were unable to access the subsequent pages or submit the questionnaire. This electronic consent process complies with the principles of the Declaration of Helsinki.

Results

Participant characteristics

Based on the data provided by the hospitals, a total of 1,194 potentially eligible nurses from nine ICUs across different centers were identified. In this study, 819 questionnaires were collected, yielding an overall response rate of 68.59%. Four cases were excluded due to completion times of less than 1 minute, and two cases were excluded due to completion times of more than 30 minutes. After excluding six invalid questionnaires, a total of 813 questionnaires were included. Among the participants, 618 (76.01%) were female, and 195 (23.99%) were male.

Survey on the ICU nurses' KAP regarding multi-parameter monitor alarms

The overall score for ICU nurses' KAP regarding multi-parameter monitor alarms was (66.22 ± 6.70), with a score rate of 80.76%. Specifically, the knowledge questionnaire was (6.63 ± 1.04), with a score rate of 94.71%; the attitude questionnaire was (28.39 ± 2.54), with a score rate of 94.63%; and the practice questionnaire was (31.20 ± 5.54), with a score rate of 69.33%. See Table 1 for details.

Table 1
ICU Nurses' KAP Regarding Multi-parameter Alarm Scores(x ± s)

Questionnaire	Item	Scores ($\bar{x} \pm s$)	Score Rate (%)
Total score		66.22 ± 6.70	80.76%
Knowledge		6.63 ± 1.04	94.71%
	I am familiar with the performance, parameter settings, and operation methods of the function keys for multi-parameter monitors in our department.	0.98± 0.14	98.00%
	I am aware of the alarm indicators (such as colors) and alarm sounds for different levels of danger on various multi-parameter monitors.	0.97± 0.18	97.00%
	I am knowledgeable about the setting standards and ranges for the alarm parameters on multi-parameter monitors.	0.99± 0.12	99.00%
	I am aware of the criteria for discontinuing the use of multi-parameter monitors.	0.93± 0.26	93.00%
	I am familiar with the management system or regulations regarding multi-parameter monitor alarms.	0.92± 0.27	92.00%
	I understand "alarm hazard".	0.96± 0.20	96.00%
	I understand "alarm fatigue".	0.89± 0.31	89.00%
Attitude		28.39± 2.54	94.63%
	The alarms of multi-parameter monitors can indicate changes in the patient's condition, reminding us to pay attention and take action.	4.89± 0.31	97.80%
	Reasonable use/timely discontinuation of multi-parameter monitor alarms can effectively reduce nuisance alarms.	4.58± 0.76	91.60%
	Standardizing the management system and usage process of multi-parameter monitors can reduce nuisance alarms.	4.71± 0.56	94.20%
	Applying intelligent alarm systems can effectively reduce nuisance alarms.	4.64± 0.66	92.80%
	Correct and effective alarm response is essential for ensuring patient safety.	4.80± 0.44	96.00%

Questionnaire	Item	Scores ($\bar{x} \pm s$)	Score Rate (%)
	Regularly organizing multi-parameter monitor knowledge and response training is conducive to improving my awareness of alarms and response capabilities.	4.77± 0.45	95.40%
Practice		31.20 ± 5.54	69.33%
	Before each use of the multi-parameter monitor, I will carefully check the instrument's performance status to reduce nuisance alarms.	4.56± 0.73	91.20%
	I will dynamically assess each alarm parameter and set them individually based on the patient's condition.	4.60± 0.64	92.00%
	I will schedule the patient's nursing operations centrally to reduce alarms caused by operations.	4.53± 0.72	90.60%
	Based on the patient's condition, I will suggest to the doctor to discontinue the use of the multi-parameter monitor in a timely manner.	3.07±1.68	61.40%
	Frequent nuisance alarms can reduce my response speed to multi-parameter monitor alarms.	2.94±1.36	58.80%
	When a nuisance alarm occurs, I will immediately turn off the alarms.	2.46±1.39	49.20%
	The severity of the illness will affect my speed in handling alarms.	2.89±1.53	57.80%
	The urgency of the alarm will affect my speed in handling alarms.	2.72±1.53	54.40%
	The time of day (such as during the night) when the alarm occurs will affect my speed in handling alarms.	3.44±1.60	68.80%

Univariate analysis of ICU nurses' KAP regarding multi-parameter monitor alarms

The results of the univariate analysis showed that there were statistically significant differences in scores among groups with different educational backgrounds, as well as between Q2 and Q3 (all $P < 0.05$). See Table 2.

Table 2
Univariate Analysis of the Total KAP Score of ICU Nurses Regarding Multi-Parameter Monitor Alarms (x ± s)

Characteristics	Classification	Study sample [n(%)]	Scores (x ± s)	F/t	P
Gender	Male	195 (23.99%)	65.86±6.07	-0.871	0.384
	Female	618 (76.01%)	66.34±6.87		
Age	≤ 25 years	126 (15.50%)	66.14±6.62	0.338	0.798
	26–30 years	264 (32.47%)	66.78±6.23		
	31–40 years	384 (47.23%)	65.85 ± 7.12		
	41–50 years	39 (4.80%)	66.31 ± 6.09		
	≥ 51 years	0 (0%)			
Hospital	H1	304 (37.39%)	66.19 ± 6.82	0.650	0.736
	H2	138 (43.40%)	66.85 ± 6.89		
	H3	115 (14.15%)	65.58 ± 7.23		
	H4	78 (9.59%)	66.55 ± 6.05		
	H5	56 (6.89%)	65.66 ± 5.92		
	H6	42 (5.17%)	67.10 ± 5.78		
	H7	42 (5.17%)	66.62 ± 6.73		

Note: *P < 0.05; H1: Beijing Tiantan Hospital, Capital Medical University; H2: The First Affiliated Hospital of Dalian Medical University; H3: Jiangsu Cancer Hospital; H4: China-Japan Friendship Hospital; H5: The First Affiliated Hospital of Zhengzhou University; H6: West China Hospital of Sichuan University; H7: The First Affiliated Hospital of School of Shihezi University; H8: Sichuan Cancer Hospital; H9: Hebei Chest Hospital; EICU: Emergency Intensive Care Unit; ICU: Intensive Care Unit; NICU: Neurological Intensive Care Unit; CCU: Cardiovascular Intensive Care Unit; RICU: Respiratory Intensive Care Unit; Q1: whether the individual has had a personal hospitalization experience; Q2: whether a family member has had ICU experience; Q3: whether the individual has participated in relevant training; Q4: whether the individual has experienced a patient death due to not promptly addressing monitor alarms; Q5: whether the individual has experienced an impact on patient prognosis due to not promptly addressing monitor alarms.

Characteristics	Classification	Study sample [n(%)]	Scores (x ± s)	F/t	P
	H8	24 (2.95%)	64.63 ± 5.60		
	H9	14 (1.72%)	65.57 ± 7.96		
Department	EICU	330 (40.59%)	66.30 ± 7.49	0.384	0.820
	General ICU	309 (38.01%)	66.27 ± 6.28		
	NICU	99 (12.18%)	66.27 ± 5.84		
	CCU	57 (7.01%)	66.05 ± 6.08		
	RICU	18 (2.21%)	64.33 ± 3.50		
Years of service	0–2 years	81 (9.96%)	66.00±7.34	1.158	0.330
	3–5 years	183 (22.51%)	67.33±6.30		
	6–10 years	249 (30.63%)	65.10±6.52		
	11–15 years	201 (24.72%)	66.82±7.60		
	≥ 16 years	99 (12.18%)	65.97±5.07		
Education background*	College degree or below	111 (13.65%)	68.16±6.44	3.154	0.044
	Bachelor's degree	662 (81.63%)	66.09±6.65		
	Master's degree or above	39 (4.80%)	63.00±7.11		

Note: *P < 0.05; H1: Beijing Tiantan Hospital, Capital Medical University; H2: The First Affiliated Hospital of Dalian Medical University; H3: Jiangsu Cancer Hospital; H4: China-Japan Friendship Hospital; H5: The First Affiliated Hospital of Zhengzhou University; H6: West China Hospital of Sichuan University; H7: The First Affiliated Hospital of School of Shihezi University; H8: Sichuan Cancer Hospital; H9: Hebei Chest Hospital; EICU: Emergency Intensive Care Unit; ICU: Intensive Care Unit; NICU: Neurological Intensive Care Unit; CCU: Cardiovascular Intensive Care Unit; RICU: Respiratory Intensive Care Unit; Q1: whether the individual has had a personal hospitalization experience; Q2: whether a family member has had ICU experience; Q3: whether the individual has participated in relevant training; Q4: whether the individual has experienced a patient death due to not promptly addressing monitor alarms; Q5: whether the individual has experienced an impact on patient prognosis due to not promptly addressing monitor alarms.

Characteristics	Classification	Study sample [n(%)]	Scores (x ± s)	F/t	P
Professional title	Nurse	114 (14.02%)	66.03±6.04	0.810	0.489
	Nursing Practitioner	498 (61.25%)	66.66±6.60		
	Nurse-in-Charge	198 (24.35%)	65.29±7.29		
	Deputy Chief Nursing Officer	3 (0.37%)	62.00 ± 4.16		
	Chief Nursing Officer	0 (0%)			
Whether engaged in teaching	Yes	312 (38.38%)	65.87±6.18	0.476	0.491
	No	501 (61.62%)	66.44±7.01		
Q1	Yes	378 (46.49%)	66.71±6.70	1.278	0.259
	No	435 (53.50%)	65.79±6.69		
Q2*	Yes	174 (21.40%)	67.76±6.26	3.932	0.048
	No	639 (78.60%)	65.80±6.76		
Q3*	Yes	708 (87.08%)	66.97±6.20	24.582	0.000
	No	105 (12.92%)	61.20±7.77		

Note: *P < 0.05; H1: Beijing Tiantan Hospital, Capital Medical University; H2: The First Affiliated Hospital of Dalian Medical University; H3: Jiangsu Cancer Hospital; H4: China-Japan Friendship Hospital; H5: The First Affiliated Hospital of Zhengzhou University; H6: West China Hospital of Sichuan University; H7: The First Affiliated Hospital of School of Shihezi University; H8: Sichuan Cancer Hospital; H9: Hebei Chest Hospital; EICU: Emergency Intensive Care Unit; ICU: Intensive Care Unit; NICU: Neurological Intensive Care Unit; CCU: Cardiovascular Intensive Care Unit; RICU: Respiratory Intensive Care Unit; Q1: whether the individual has had a personal hospitalization experience; Q2: whether a family member has had ICU experience; Q3: whether the individual has participated in relevant training; Q4: whether the individual has experienced a patient death due to not promptly addressing monitor alarms; Q5: whether the individual has experienced an impact on patient prognosis due to not promptly addressing monitor alarms.

Characteristics	Classification	Study sample [n(%)]	Scores (x ± s)	F/t	P
Q4	Yes	36 (4.43%)	66.75±4.20	0.078	0.780
	No	777 (95.57%)	66.20±6.79		
Q5	Yes	78 (9.59%)	65.73±6.38	0.154	0.695
	No	735 (90.41%)	66.27±6.74		

Note: *P < 0.05; H1: Beijing Tiantan Hospital, Capital Medical University; H2: The First Affiliated Hospital of Dalian Medical University; H3: Jiangsu Cancer Hospital; H4: China-Japan Friendship Hospital; H5: The First Affiliated Hospital of Zhengzhou University; H6: West China Hospital of Sichuan University; H7: The First Affiliated Hospital of School of Shihezi University; H8: Sichuan Cancer Hospital; H9: Hebei Chest Hospital; EICU: Emergency Intensive Care Unit; ICU: Intensive Care Unit; NICU: Neurological Intensive Care Unit; CCU: Cardiovascular Intensive Care Unit; RICU: Respiratory Intensive Care Unit; Q1: whether the individual has had a personal hospitalization experience; Q2: whether a family member has had ICU experience; Q3: whether the individual has participated in relevant training; Q4: whether the individual has experienced a patient death due to not promptly addressing monitor alarms; Q5: whether the individual has experienced an impact on patient prognosis due to not promptly addressing monitor alarms.

LMM of influencing factors ICU nurses' KAP regarding multi-parameter monitor Alarms

The assignment of independent variables is shown in Table 3. The LMM revealed that the variance component for the hospital intercept was close to 0, with an Intraclass Correlation Coefficient (ICC) of 0. The model confirmed the following factors as having an independent effect on the total KAP score: educational background, personal hospitalization experience, family members' ICU experience, and participation in relevant training. No statistically significant differences were found for the remaining variables (all p > 0.05). See Table 4.

Table 3
Assignment of Independent Variables

Independent variable	Assignment
Gender	Male = 1; Female = 2
Age	≤ 25 years = 1; 26–30 years = 2; 31–40 years = 3; 41–50 years = 4; ≥51 years = 5
Department	EICU = 1; General ICU = 2; NICU = 3; CCU = 4; RICU = 5
Years of service	0–2 years = 1; 3–5 years = 2; 6–10 years = 3; 11–15 years = 4; ≥16 years = 5
Education background	College degree or below = 1; Bachelor's degree = 2; Master's degree or above = 3
Professional title	Nurse = 1; Nursing Practitioner = 2; Nurse-in-Charge = 3; Deputy Chief Nursing Officer = 4; Chief Nursing Officer = 5
Whether involved in teaching or mentoring	Yes = 1; No = 0
Q1	Yes = 1; No = 0
Q2	Yes = 1; No = 0
Q3	Yes = 1; No = 0
Q4	Yes = 1; No = 0
Q5	Yes = 1; No = 0
Total score	Continuous variable. Use the original scale score.

Table 4
LMM of Influencing Factors ICU Nurses' KAP Regarding Multi-Parameter Monitor Alarms

	Term	Estimate	Standard error	t	p	95% CI	
						Lower	Upper
Department	NICU	reference					
	EICU	-0.073	0.751	-0.098	0.922	-1.548	1.402
	General ICU	-0.609	0.736	-0.828	0.408	-2.054	0.836
	CCU	-1.969	1.091	-1.805	0.071	-4.110	0.172
	RICU	-2.128	1.641	-1.297	0.195	-5.350	1.094
Gender	Female	reference					
	Male	-0.962	0.595	-1.616	0.107	-2.130	0.207
Age	41–50 years	reference					
	≤ 25 years	-0.144	1.724	-0.083	0.934	-3.528	3.240
	26–30 years	0.753	1.468	0.513	0.608	-2.129	3.635
	31–40 years	-0.942	1.261	-0.747	0.455	-3.417	1.533
Years of service	≥ 16 years	reference					
	0–2 years	0.329	1.540	0.214	0.831	-2.694	3.352
	3–5 years	0.767	1.295	0.592	0.554	-1.775	3.310
	6–10 years	-0.992	1.021	-0.972	0.332	-2.996	1.012
	11–15 years	1.008	0.921	1.095	0.274	-0.799	2.815
Education background*	Master's degree or above	reference					
	College degree or below	2.671	1.316	2.029	0.043	0.087	5.254
	Bachelor's degree	0.398	1.200	0.332	0.740	-1.958	2.754

Note: *P<0.05; Q1: whether the individual has had a personal hospitalization experience; Q2: whether a family member has had ICU experience; Q3: whether the individual has participated in relevant training; Q4: whether the individual has experienced a patient death due to not promptly addressing monitor alarms; Q5: whether the individual has experienced an impact on patient prognosis due to not promptly addressing monitor alarms.

	Term	Estimate	Standard error	t	p	95% CI	
						Lower	Upper
Professional title	Deputy Chief Nursing Officer reference						
	Nurse	0.764	4.051	0.189	0.850	-7.188	8.716
	Nursing Practitioner	2.290	3.943	0.581	0.562	-5.450	10.031
	Nurse-in-Charge	1.346	3.923	0.343	0.732	-6.355	9.046
Whether engaged in teaching	No	reference					
	Yes	-0.005	0.568	-0.008	0.993	-1.120	1.110
Q1*	No	reference					
	Yes	1.165	0.520	2.243	0.025	0.145	2.185
Q2*	No	reference					
	Yes	1.910	0.553	3.455	0.001	0.825	2.995
Q3*	No	reference					
	Yes	5.974	0.713	8.370	0.000	4.573	7.375
Q4	No	reference					
	Yes	0.403	1.229	0.328	0.743	-2.009	2.815
Q5	No	reference					
	Yes	-0.962	0.868	-1.109	0.268	-2.665	0.741

Note: *P<0.05; Q1: whether the individual has had a personal hospitalization experience; Q2: whether a family member has had ICU experience; Q3: whether the individual has participated in relevant training; Q4: whether the individual has experienced a patient death due to not promptly addressing monitor alarms; Q5: whether the individual has experienced an impact on patient prognosis due to not promptly addressing monitor alarms.

Discussion

Current status of ICU Nurses' KAP regarding multi-parameter monitor alarms

The results of this study showed that the total KAP score of ICU nurses regarding multi-parameter monitor alarms was 66.22 ± 6.70, with a score rate of 80.76%, indicating a moderate level, which was higher than the findings reported by Chen et al. [11]. This discrepancy may be attributed to differences in

study populations or measurement instruments. Further analysis revealed that the score rates for the knowledge and attitude dimensions were 94.71% and 94.63%, respectively, both at relatively high levels, whereas the score rate for the practice dimension was only 69.33%. This indicates that although ICU nurses possess solid theoretical knowledge and a positive attitude, and have a sufficient understanding of multi-parameter monitor alarms, there remains a notable deficiency in practical operation and behavioral implementation, suggesting a "knowledge-practice gap."

Research has shown that knowledge can only lead to behavioral change after being actively processed and internalized into beliefs, which then shape positive attitudes. However, in a high-pressure work environment, nurses find it difficult to fully apply their acquired knowledge to clinical practice [12-13]. Therefore, it is recommended that nursing managers shift their focus from "knowledge training" to "behavioral facilitation." Specific strategies may include: incorporating scenario-based simulation exercises following theoretical training; optimizing the clinical work environment and establishing positive incentive mechanisms; and developing quality indicators for multi-parameter monitor management with ongoing dynamic evaluation. Through these measures, the effective translation of knowledge about multi-parameter monitors into clinical behavior among ICU nurses can be promoted.

Nuisance alarms and Alarm fatigue

The analysis revealed that items related to “alarm fatigue” or “nuisance alarms” scored the lowest, indicating that nurses' understanding of this issue remains inadequate and that systematic coping strategies are lacking. This finding aligns with multiple international studies: alarm overload commonly interferes with clinical care and undermines nurses' trust in alarm systems [14]. A systematic review [15] noted that appropriately widening alarm parameter ranges can reduce unnecessary alarms to some extent, but caution is needed to avoid potential patient safety risks from excessive adjustments [16]. Currently, there is no globally unified standard for setting alarm thresholds. For example, the American Nurses Association guidelines [16] recommend following the American Heart Association's standards for multi-Parameter monitoring, while the National Institute for Health and Care Excellence (NICE) guidelines on the diagnosis and management of hypertension [17] adopt age-stratified blood pressure control targets. Therefore, future research could explore individualized alarm thresholds based on disease characteristics to achieve a balance between clinical safety and alarm burden.

In addition, nurses should master necessary measures to eliminate nuisance alarms. Nyarko et al. [18] indicated that educational interventions can effectively reduce false alarms. Accordingly, hospitals should develop relevant policies and training programs to help nurses master best practices in alarm management. Specific measures include: regularly checking the performance of multi-parameter monitors; adjusting alarm parameters in advance or temporarily turning off non-essential alarms before procedures such as turning or suctioning [19]; and developing the ability to identify and manage common sources of nuisance alarms, such as electrode pad displacement and signal interference [18]. Through these measures, nurses can effectively reduce the incidence of nuisance alarms, enhance the clinical significance of alarms, and thereby improve the quality of patient monitoring [20].

Factors influencing the ICU nurses' KAP regarding multi-parameter monitor alarms

To account for the potential nested structure of the multicenter data, a LMM was employed for re-analysis. The model showed that the variance component for the hospital intercept was close to 0, with an ICC of 0. This indicates that the variance in the total KAP score in this study was almost entirely attributable to the individual level, and the clustering effect between hospitals was negligible. The findings of this study are generalizable and can be applied in a wider range of hospitals.

Educational background

The results of this study indicate a negative correlation between educational background and the total KAP score regarding multi-parameter monitor alarms among ICU nurses. This finding, which differs from previous research [19,21,22], should be interpreted with caution. Several factors may account for this result.

First, differences in sample characteristics and experience may be a significant reason. In this study, the sample size of nurses with a master's degree or higher was small (n=39, 4.80%), and this group predominantly consisted of research-oriented nurses with relatively shorter clinical tenure. Their profound theoretical knowledge may not have yet fully translated into clinical judgment. Conversely, nurses with a junior college diploma may have more extensive clinical experience and be more familiar with practical operations. Although the univariate analysis did not show significant differences in work experience between groups, the interaction between education level and years of service remains a potential explanation.

Second, the characteristics of the measurement tool may have influenced the results. This study employed a self-report questionnaire. It is possible that nurses with higher educational attainment have a deeper or more critical understanding of complex concepts like "alarm fatigue," leading them to adopt stricter standards when self-assessing, thus resulting in lower scores. In contrast, nurses in other educational groups might have been more inclined to provide socially desirable responses. Furthermore, the knowledge section was scored using a "yes/no" format, which may not have effectively captured the nuanced knowledge of the higher-educated nurses.

Additionally, differences in professional roles and job focus could be influential. Nurses with higher degrees may undertake more research, teaching, or administrative duties. Consequently, the specific contexts and frequency of their exposure to and handling of monitor alarms may differ from those of frontline clinical nurses, thereby affecting their responses on the self-assessment scale. This finding is consistent with similar results reported by Chen Jie et al. [23], who found an inverse relationship between education level and operational performance.

In summary, the negative correlation between educational attainment and KAP scores is a preliminary finding and should not be simplistically interpreted as "the higher the education, the lower the competence." This suggests that nursing managers should focus on the unique characteristics of nurses

with different educational backgrounds and develop differentiated training programs. Future research is warranted, utilizing larger samples, more balanced designs, and incorporating objective assessments while controlling for confounding factors such as work experience to further clarify the relationship between these variables.

Participation in relevant training

The results of this study show a positive correlation between training on multi-parameter monitors and the KAP scores of ICU nurses, indicating that ICU nurses who have received relevant training score higher. This suggests that actively conducting training on monitor alarm-related knowledge can enhance ICU nurses' cognitive level and behavior regarding monitor alarms, consistent with the findings of other scholars [24,25]. The Clinical Alarm Management Practice Guidelines for Multi-parameter Monitors also emphasize the importance of initial and ongoing training for nurses related to alarms [16]. However, currently, tertiary hospitals face issues such as limited training content on multi-parameter monitors, with multi-Parameter monitoring not included in the routine training content for nurses, uneven training content, and insufficient innovation in training formats. Most training sessions focus on conventional content such as monitoring purposes, operating methods, alarm limit settings, alarm recognition, and response, lacking in-depth judgment on the essence of monitor alarms and the relationship between alarms and patients' conditions. Additionally, the training formats are monotonous, primarily theoretical lectures, which leads to insufficient learning motivation among nurses. Therefore, nursing managers should prioritize training ICU nurses on cutting-edge knowledge related to monitor alarms and basic disease knowledge such as condition assessment, establishing scientific training programs and systems, which will significantly promote the ICU nurses’ KAP regarding monitor alarms. At the same time, actively innovating training formats can enhance nurses' learning motivation and improve training effectiveness by adopting a combination of various teaching methods such as live demonstrations, Problem-Based Learning (PBL), and Virtual Reality (VR) scenario simulations, thereby effectively improving the current KAP status of ICU nurses regarding monitor alarms.

Personal hospitalization and family members’ ICU experience

This study found that ICU nurses who had personal hospitalization experience or a family member with an ICU experience had significantly higher KAP scores. Personal hospitalization and family members’ ICU experience may influence a nurse's KAP level through several potential pathways, although the specific mechanisms require further validation. First, Personally experiencing a family member's critical moment can provide nurses with a more direct and profound understanding of the clinical risks represented by monitor alarms, leading them to adopt a more serious attitude and more vigilant behaviors. Furthermore, this experience may foster nurses’ empathy and enhance their understanding of the situations faced by patients and their families, thereby leading them to adopt more proactive and cautious responses to clinical alarms. Research has found that empathy is the ability to understand a patient's situation, perspective, feelings, and actions; it is an approach to helping or treating based on patient perception and is a cornerstone of high-quality healthcare [26,27]. In nursing training,

"experiential learning" could be incorporated - for instance, by using high-fidelity simulation scenarios or narrative pedagogy to deepen nurses' understanding of the clinical significance of alarms. Future research could employ qualitative interviews to explore these influential pathways in greater depth and design training interventions developed based on this factor.

Limitation

This study has certain limitations in the selection of measurement tools. Firstly, for the assessment of “alarm fatigue” among nurses-a complex, multidimensional construct-this study relied only on a few items in the KAP questionnaire for a rough estimation, rather than employing a validated, specialized alarm fatigue scale for systematic and in-depth measurement. This may have constrained a comprehensive and precise understanding of the phenomenon. Secondly, in the knowledge assessment section, the use of a “yes/no” binary response format, while convenient for analysis, made it difficult to differentiate levels of knowledge mastery in a nuanced manner. Future research could consider incorporating theoretical examinations to allow for a more objective and stratified evaluation of nurses’ knowledge.

Recommendations or Implications for Practice

In the ICU, nurses closely monitor patients' conditions based on multi-parameter monitors. The timely and effective handling of alarm signals from these monitors plays a crucial role in ensuring patients' safety. Nursing managers should strengthen training for junior nurses to help ICU nurses better grasp knowledge related to multi-parameter monitor alarms. At the same time, efforts should be made to foster a positive attitude among nurses toward monitor alarms, thereby improving their response behaviors.

Conclusions

This study employed a multicenter, cross-sectional approach to investigate the KAP levels of Chinese ICU nurses regarding multi-parameter monitor alarms. The results revealed that the KAP level of ICU nurses regarding multi-parameter monitor alarms is at a moderate level, indicating room for improvement. The influencing factors of ICU nurses' KAP towards monitor alarms include educational background, participation in relevant training, personal hospitalization experience and family members’ ICU experience. Therefore, nursing managers should strengthen training for key nurses, diversify training methods, and enhance training effectiveness. This, in turn, will prompt nurses to form positive attitudes and ultimately improve their response to monitor alarms.

Declarations

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Author Contribution

Huiyue Li: Research design, questionnaire editing, data collection, data analysis/interpretation, Writing – original draft; Xiaonv Lin: Research design, data collection, research guidance, quality control, Writing – review; Yuan Yuan, Xueyi Sun, Dan Wei, Tao Wang, Yang Pang, Suhua Pei, Rong Yu, Huilan Zhang: Data collection; Rui Zhao, Yue Du: Research guidance, organization and implementation.

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