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Plantar Pressure Asymmetries and Low Back Pain in Pregnancy: A Smart Insole-Based Analysis

Jennara Wongpalee¹ , Soodkhet Pojprapai^{2*} , Amornlert Phanvatr¹, Piyaphun Nunta³, Anon Seedapeng³, Supalak Luadlai⁴, Dipak Kumar Agrawal², Patcharin Jantata⁵

¹ Division of Maternal Newborn Nursing and Midwifery, Faculty of Nursing, Maejo University, Chiang Mai, Thailand

² School of Ceramic Engineering, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand

³ Health Development Section, Faculty of Liberal Arts, Maejo University, Chiang Mai, Thailand

⁴ Business Psychology Area, Faculty of Psychology, Chulalongkorn University, Bangkok, Thailand

⁵ Obstetrics and Gynecology Division, Antenatal Care Clinic, Sansai Hospital, Chiang Mai, Thailand

Abstract

Background: Low back pain is a common condition affecting pregnant women that arises from hormonal and biomechanical changes that alter posture, gait, and balance. Traditional studies focus on general biomechanical adaptations, often neglecting dynamic plantar pressure changes, left-right foot asymmetries, and their link to low back pain.

Objectives: To study the effects of plantar pressure analysis on walking and balance, and to explore the relationship between plantar pressure and low back pain in pregnant women.

Methods: This was a cross-sectional study of 85 pregnant women recruited through simple random sampling and participated in a 10-meter walk test using SuraSole insoles to collect plantar pressure data across eight-foot zones. Data were analyzed using descriptive statistics, paired *t* test assessed plantar pressure differences between the left and right feet in the pregnant women, and Pearson correlation, paired measurements, and relationships involving continuous variables. The Scheffe' method was used to test the mean of each pair of means. The relationship between low back pain and plantar pressure using a multiple linear regression analysis.

Results: Pregnant women exhibited significantly higher plantar pressure in the forefoot and heel zones ($P < .05$). Pregnant participants showed significantly greater plantar pressure in the left heel, medial forefoot, and medial midfoot than the right side ($P < .01$), reflecting left-side dominance. Plantar pressure positively correlated with gestational age and body mass index. Heel pressure was strongly associated with lower back pain, while toe and forefoot zones showed weaker correlations.

Conclusions: Pregnancy affects plantar pressure distribution and foot asymmetry. Increased plantar pressure, particularly in the heel zone, strongly correlates with low back pain. Left-right foot asymmetries in the pregnant women emphasize the need for targeted interventions, such as improving gait mechanics and suitable shoes and promoting walking exercises to reduce low back pain during pregnancy.

Keywords: Plantar pressure, Low back pain, Pregnant women, Smart insole

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* Corresponding Author: soodkhet@g.sut.ac.th

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Introduction

Low back pain is a common issue among pregnant women, impacting a substantial number of individuals during pregnancy.^{1,2} This discomfort largely stems from the hormonal

and biomechanical changes that occur throughout pregnancy. Increased levels of relaxin, a hormone associated with pregnancy, cause ligament laxity and stretching of the sacroiliac joint.³ These changes can lead to structural modifications, such as increased lumbar lordosis.⁴ As a result, the spine, pelvis, and intervertebral discs may be affected, often causing discomfort in the lumbar region, coccyx, and pelvis, which can radiate down to the legs and feet.⁵ Low back pain typically starts early in pregnancy and worsens during the second and third trimesters.^{6,7}

Pregnancy also induces significant musculoskeletal adaptations, including changes in posture, joint stability, and gait mechanics. As gestational age progresses, increased body weight and hormonal fluctuations shift the center of gravity forward, causing compensatory spinal curvature and joint laxity.^{5,8} These adjustments, particularly in the pelvis and lower limbs, result in biomechanical stress, reduced stability, and discomfort.^{6,9} The additional weight gain during pregnancy increases pressure on the lower back, pelvic joints, and lower extremities, heightening the risk of low back pain.¹⁰ Common issues include low back pain, leg cramps, and foot discomfort, affecting gait and balance.

Dynamic plantar pressure and walking mechanics undergo significant changes during pregnancy. The expanding uterus and associated weight gain increase pressure on the feet, leading to structural modifications such as flatfoot and decreased arch height.¹¹ These alterations impact plantar pressure distribution and vertical ground reaction forces, resulting in an unstable gait and a higher risk of falls.⁶ Studies have shown that plantar pressure rises throughout the trimesters, with notable shifts observed in the heel and forefoot zones.^{12,13} These adaptations correlate with alterations in gait, including a decrease in step length, an increase in double support time, and a greater reliance on the plantar fascia for maintaining stability.¹⁴⁻¹⁷

This study utilized wireless pressure sensor-embedded insoles (SuraSole) to analyze dynamic plantar pressure while walking and its relationship to balance and low back pain in pregnant women. The research examined correlations with gestational age, weight gain, body mass index (BMI), and asymmetries in left-right foot pressure during pregnancies. The insights gained from this study aim to inform targeted interventions, such as physiotherapy and footwear modifications, to alleviate low back pain, improve gait mechanics, and enhance women's overall quality of life during pregnancy.

Methods

Study Design and Participants

This cross-sectional study examined plantar pressure distribution and its relationship to low back pain in the pregnant women. The sample included 85 pregnant women recruited through simple random sampling and quota sampling using Yamane's formula.¹⁸

Pregnant participants were included if they were aged 16 to 45 years, had a normal pregnancy between 12 to 40 weeks of gestation, and total weight gain during pregnancy not exceeding 16 kg. These thresholds were selected based on the prior studies indicating their influence on plantar pressure and gait mechanics. Participants with musculoskeletal conditions, high-risk pregnancies, or histories of foot or spinal surgeries were excluded to minimize confounding factors.

This study was conducted at Sansai Hospital, Thailand, with the approval from Human Research Ethics Committee at Maejo University. All participants were required to agree to and sign an informed consent form prior to data collection.

Instruments

Plantar pressure data were collected using the SuraSole (Figure 1). These insoles feature 8 strategically placed force sensitive resistor (FSR) sensors. The sensor zones, including toes (great toe, lesser toes), forefoot (medial forefoot, central forefoot, lateral forefoot), midfoot (medial midfoot, lateral midfoot), and heel. Data were transmitted wirelessly via Bluetooth to the SuraSole Med application for analysis.

Low back pain was assessed using numerical pain rating scale (NPRS), a validated 10-point linear scale. Scores range from 0 (no pain) to 10 (worst pain imaginable), (1-3 indicating mild pain, 4-6 moderate pain, and 7-9 severe pain). The scale is divided into 10 equal segments along a 10-centimeter line for the precise scoring.^{19, 20}

Demographic and pregnancy-related data, gestational age, weight gain including BMI, walking patterns, balance assessments, were collected via a validated questionnaire.

Quality Assessment of Instruments

The SuraSole smart insole system underwent rigorous safety validation in compliance with IEC-62304 and IEC-60601-1 standards, conducted by National Electronics and Computer Technology Center (NECTEC) and Electrical and Electronic Products Testing Center (PTEC). Additional calibration was performed using a universal testing machine (UTM: Puller SK-10-500N press digital, SHSIWI) and validated against a force plate (Kistler Instrumente 187 AG, Winterthur, Switzerland) under ISO/IEC 17025 standards.²¹ The reliability of the questionnaire and the insole system was tested in a pilot study involving 19 pregnant women, achieving a Cronbach α of 0.92.

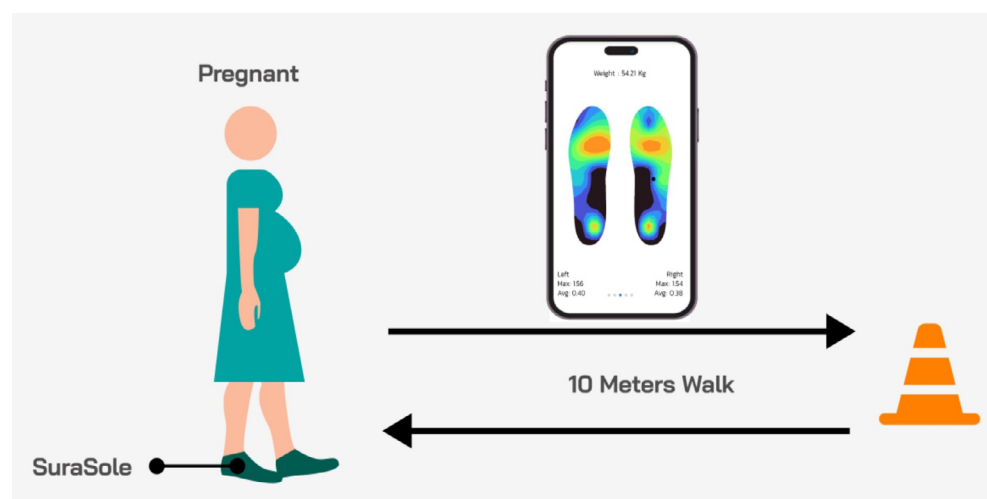
Data Collection Procedure

Participants attended a single session at the antenatal clinic. The process involved the following steps: 1) obtaining written informed consent after explaining the research objectives and procedures; 2) completing a demographic and pregnancy-related questionnaire, including the NPRS, to assess low back pain; and 3) wearing calibrated SuraSole smart insoles and performing a 10-meter walk test. Each participant walked back and forth once, and mean plantar pressure values were recorded for analysis (Figure 2).

Figure 1. The SuraSole Smart Insole and the SuraSole Med Application



Figure 2. Plantar Pressure Data Collection During a 10-Meter Walk Using SuraSole Smart Insoles and SuraSole Med Application



Statistical Analysis

Data were analyzed using SPSS version 27.0 (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp; 2020). Descriptive statistics for personal data, paired *t* tests assessed plantar pressure differences between the left and right feet, focusing on the key zones such as medial forefoot, medial midfoot, and heel. Pearson correlation examined the relationships among plantar pressure, gestational age, and low back pain. Multiple regression analyses for gestational age, body weight and BMI were performed.

Moderation analysis determined whether plantar pressure influenced the relationship between gestational age and low back pain. These statistical methods were chosen for their effectiveness in analyzing group comparisons, paired measurements, and relationships involving continuous variables. Statistical significance was set at $P < .05$.

Results

The study population had an average age of 27.85 years and an average weight of 65.76 kg. Among the participants, 42.35% had a normal BMI. The distribution of trimesters was as follows: 70.59% in the third trimester, 22.35% in the second trimester, and 7.06% in the first trimester. Regarding low back pain, 83.53% of participants reported experiencing it. Among them, 81.69% had moderate pain, 9.86% had mild pain, and 8.45% had severe pain. Additionally, 34.08% of participants in the third trimester reported moderate pain and 3.55% had severe pain.

This study also examines differences in plantar pressure between the left and right feet during pregnancy. The findings are organized into the following categories: correlation between plantar pressure and gestational variables; left vs right foot plantar pressure differences in pregnant women; and relationships between plantar pressure, gestational age, and low back pain.

Correlation Between Plantar Pressure and Gestational Variables

For the left foot, no significant correlations were found between plantar pressure zones and gestational age for the left foot. However, strong positive correlations were identified with body weight and BMI, particularly in the forefoot and heel zones. These findings underscore the influence of overall weight gain on plantar pressure during pregnancy. Detailed correlation coefficients are presented, the correlation patterns across left foot zones, illustrating strong relationship with the weight and BMI (Table 1).

For the right foot, no significant correlations were found with gestational age. However, plantar pressure exhibited significant positive correlations with body weight in all zones except the great toe and with BMI in all zones except the great toe and medial midfoot. These results highlight the dominant role of body weight and BMI in plantar pressure changes. Detailed correlation coefficients showed strong correlation patterns across right foot zones with weight and BMI (Table 2).

Across both feet, plantar pressure showed no significant correlation with gestational age, while weight and BMI emerged as stronger predictors. The absence of significant correlations with gestational age may suggest that plantar pressure is more strongly influenced by overall weight gain and BMI during pregnancy rather than pregnancy duration.

Left vs Right Foot Plantar Pressure Differences in Pregnant Women

Significant left-side plantar pressure dominance was observed in third-trimester pregnancies. This asymmetry, particularly in the medial forefoot, midfoot, and heel zones, reflects compensatory weight distribution due to fetal positioning and pelvic tilt.

The left medial forefoot exhibited significantly higher pressure compared to the right side (mean [SD], 83.97 [23.55] vs 74.49 [18.61] kPa; $P < .001$). This difference indicates asymmetrical propulsion and balance adjustments during walking.

The left midfoot also showed significantly higher pressure compared to the right (mean [SD], 4.60 [7.59] vs 2.85 [5.64] kPa; $P = .003$). While the differences in pressure between the midfoot zones are smaller, they still reflect the midfoot's role in stabilizing weight-bearing during walking.

The left heel presented significantly higher pressure than the right heel (mean [SD], 88.96 [20.50] vs 72.91 [17.93] kPa; $P < .001$), suggesting a compensatory shift in weight to maintain balance.

Relationships Between Plantar Pressure, Gestational Age, and Low Back Pain

The relationship between plantar pressure and low back pain was analyzed, with key results for the heel zone (Figures 3 and 4). Among all zones, the heel zone showed the strongest and most consistent association with low back pain. In contrast, the forefoot and midfoot zones exhibited weaker and less consistent correlations. No significant correlation between plantar pressure of the toe zone (great toe, lesser toes) and low back pain was found.

Moderate correlations with low back pain were found in the forefoot, particularly for the high-weight distribution. However, these trends were inconsistent.

Moderate correlations between midfoot pressure and low back pain were also noted in the midfoot, but they were less consistent compared to the heel zone.

Heel zone (high heel pressure) was strongly associated with increased low back pain and amplified spinal strain.

Moderate weight distribution in the heel corresponded to a balanced increase in low back pain, while low weight distribution was linked to the least amount of low back pain.

Table 1. Correlation Among Left Foot Plantar Pressure, Gestational Age, Weight, and Body Mass Index

Variable	Great Toe	Lesser Toes	Medial Forefoot	Central Forefoot	Lateral Forefoot	Medial Midfoot	Lateral Midfoot	Heel
Gestational age	0.050	-0.055	0.056	-0.034	0.026	0.121	0.084	0.060
Body weight	0.199	0.273*	0.373*	0.504*	0.364*	0.192	0.415*	0.457*
Body mass index	0.181	0.264*	0.398*	0.487*	0.343*	0.251*	0.369*	0.373*

* $P < .01$ **Table 2. Correlation Among Right Foot Plantar Pressure, Gestational Age, Weight, and Body Mass Index**

Variable	Great Toe	Lesser Toes	Medial Forefoot	Central Forefoot	Lateral Forefoot	Medial Midfoot	Lateral Midfoot	Heel
Gestational age	0.017	0.026	0.041	0.096	0.091	-0.054	0.056	0.013
Body weight	-0.170	0.362*	0.304*	0.471*	0.283*	0.203*	0.463*	0.472*
Body mass index	-0.095	0.268*	0.347*	0.489*	0.382*	0.189*	0.481*	0.422*

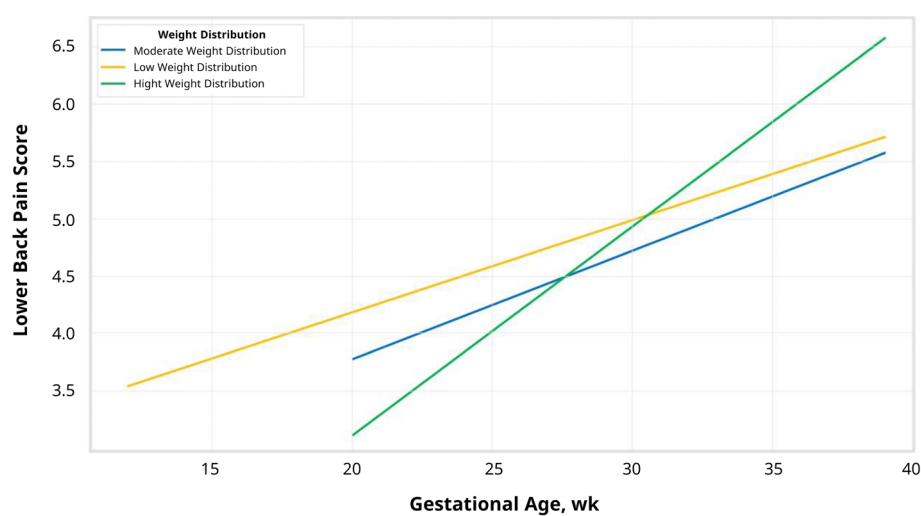
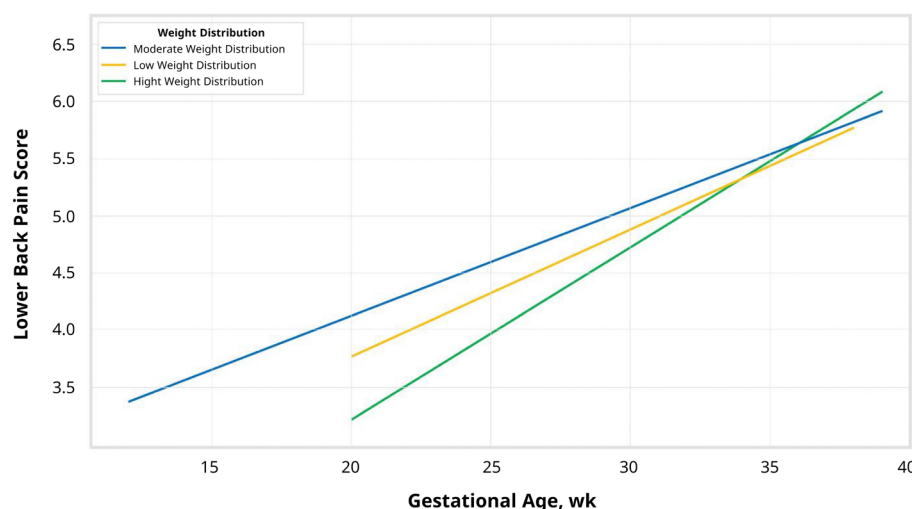
* $P < .01$ **Figure 3. The Relationship Between Gestational Age and Low Back Pain in Each Group for the Left Heel Zone**

Figure 4. The Relationship Between Gestational Age and Low Back Pain in Each Group for the Right Heel Zone



Discussion

This study investigated plantar pressure differences and its relationship with walking, balance, and low back pain in the pregnant women. The findings revealed significant increases in plantar pressure across specific foot zones in pregnant women. The left great toe, medial forefoot, and left heel exhibited the most notable differences. Among all zones, the heel consistently showed the strongest correlation with low back pain, underscoring its role in compensatory load distribution during pregnancy.

Pressure differences between the left and right feet highlighted left-side dominance, particularly in the heel, medial forefoot, and medial midfoot zones, consistent with previous findings.^{22, 23} These findings suggest that pregnancy-induced gait adjustments are concentrated in the forefoot and heel zones, which bear the brunt of compensatory mechanisms to maintain balance.

Biomechanical Adaptations

The observed plantar pressure changes align with known musculoskeletal adaptations during pregnancy. Flattening of the midfoot arch and increased forefoot pressure reflected the structural changes caused by weight gain and altered center of gravity. Increased lumbar lordosis and backward upper body tilt are common compensatory postural adjustments, helping to maintain stability and reduce the risk of falls.^{22, 24}

The heel zone emerged as a critical area of focus, with high heel pressure contributing significantly to lumbar strain and the prevalence of low back pain,^{25, 26} particularly in the second and third trimesters. These findings emphasize the need to address heel pressure in interventions targeting pregnancy-related discomfort.

Plantar Pressure and Low Back Pain

A strong correlation was found between gestational age and low back pain, mediated by plantar pressure. However, across both feet, plantar pressure showed no significant

correlation with gestational age, while weight and BMI emerged as stronger predictors.^{22, 25} Increased heel pressure, particularly in the high-weight distribution, amplified lumbar strain and back pain. Left foot plantar pressure, especially in the heel zone, played a notable role, likely reflecting compensatory strategies to balance the growing uterus. These findings underscore the bilateral adjustments in the weight distribution during pregnancy, offering valuable insights for clinical care.

Pressure Distribution Across Zones

The heel zone showed a strongest correlation with low back pain. Elevated heel pressure amplifies lumbar strain, suggesting a need for heel-targeted interventions, such as cushioning or orthotic support.

The toe zone demonstrated minimal correlation with low back pain, indicating its primary role in balance and propulsion rather than spinal strain.

The forefoot zone showed moderate but inconsistent correlations with low back pain, likely mediated through gait mechanics rather than direct spinal loading.

Importantly, the relationship between heel zone plantar pressure and low back pain was consistent across different gestational ages, highlighting the critical role of heel pressure in contributing to back pain. These findings emphasize the need for targeted interventions to alleviate discomfort and improve maternal well-being.

Clinical Implications

These findings offer practical insights into mitigating pregnancy-related discomfort including 1) footwear modifications: enhanced heel cushioning and arch support can redistribute plantar pressure and reduce spinal strain; 2) physiotherapy: targeted exercises focusing on posture correction and pelvic alignment can reduce lumbar lordosis and mitigate low back pain; and 3) preventive monitoring: regular assessment of plantar pressure distribution and early interventions can mitigate the risk of flatfoot development and associated discomfort.

Conclusions

This study found that pregnancy significantly increases plantar pressure, particularly in the heel, medial forefoot, and medial midfoot zones, with the heel zone exhibiting the strongest correlation with low back pain. Left-right foot asymmetries in pregnant women further highlight the role of compensatory weight distribution during gait.

These findings underscore the importance of targeted interventions, such as footwear modifications and physiotherapy, to manage plantar pressure and reduce low back pain during pregnancy. Proper exercise should be promoted for a safe pregnancy. Future research should explore the long-term benefits of dynamic plantar pressure monitoring and orthotic solutions to improve gait mechanics and the overall quality of life of pregnant women.

Additional Information

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Ethics Approval: This study was approved by the Maejo University Human Research Ethics Committee (No. 5T004/66 on 16 June 2023). Written informed consent was obtained from all participants prior to data collection.

Clinical Trial Consideration: This study does not report on a clinical trial.

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Author Contributions:

Conceptualization: Jennara Wongpalee, Soodkhet Phojpapai

Data Curation: Jennara Wongpalee, Amornlert Phanvatr, Piyaphun Nunta, Anon Seedapeng, Patcharin Jantata

Formal Analysis: Jennara Wongpalee, Soodkhet Phojpapai, Amornlert Phanvatr

Funding Acquisition: Jennara Wongpalee

Investigation: Jennara Wongpalee, Soodkhet Phojpapai, Amornlert Phanvatr, Piyaphun Nunta, Anon Seedapeng

Methodology: Jennara Wongpalee, Soodkhet Phojpapai, Anon Seedapeng

Project Administration: Jennara Wongpalee, Soodkhet Phojpapai

Resources: Jennara Wongpalee, Soodkhet Phojpapai, Amornlert Phanvatr, Patcharin Jantata

Software: Soodkhet Phojpapai, Dipak Kumar Agrawal

Supervision: Jennara Wongpalee, Soodkhet Phojpapai

Validation: Jennara Wongpalee, Soodkhet Phojpapai, Dipak Kumar Agrawal

Visualization: Jennara Wongpalee, Supalak Luadlai, Dipak Kumar Agrawal

Writing – Original Draft: Jennara Wongpalee, Supalak Luadlai, Dipak Kumar Agrawal

Writing – Review & Editing: Supalak Luadlai, Dipak Kumar Agrawal

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Child and/or Guardian Satisfaction With Pediatric Anesthesia Services and Understanding of Enhanced Recovery After Surgery Protocols at Srinagarind Hospital

Duangned Litu¹ , Sirirat Tribuddharat^{2*} , Darunee Sripadungkul², Thepakorn Sathitkarnmanee² , Pantipha Talsoi¹, Junjira Kaewaun¹ 

¹ Nurse Anesthetist Division, Srinagarind Hospital, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

² Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

Abstract

Background: Pediatric anesthesia presents unique challenges requiring specialized expertise in managing both patient care and parental anxiety. Patient satisfaction has become a crucial quality indicator in anesthesia services, with satisfaction rates varying from 78% to over 95%. Enhanced recovery after surgery (ERAS) protocols have shown improved perioperative outcomes, but require significant patient education. However, most studies have been conducted in Western settings, with limited data from Southeast Asian healthcare contexts.

Objectives: To assess satisfaction with pediatric anesthesia care among children and their guardians at Srinagarind Hospital, while also evaluating their understanding of ERAS protocols.

Methods: A descriptive cross-sectional study collected data from 103 children/guardians between September 2024 to October 2024 using questionnaires with 4-point Likert scales. High satisfaction or understanding was defined as scores 3 to 4, and low satisfaction or understanding as 1 to 2.

Results: Respondents were predominantly female (87.4%) and aged 31 to 40 years (43.7%). General anesthesia was used in 94.2% of cases. Full satisfaction (100%) was reported for preoperative, intraoperative, and postanesthesia care unit services, with mean (SD) overall satisfaction scores of 3.96 (0.05), 3.99 (0.01), and 3.99 (0.01), respectively. Ward follow-up satisfaction reached 96.8%, with mean (SD) overall satisfaction scores of 3.88 (0.01). ERAS protocol understanding varied, with mean (SD) overall understanding score of 3.07 (0.79); high for fasting guidelines (99.0%), low for thrombosis prophylaxis (22.3%), and smoking cessation (23.3%).

Conclusions: While child/guardian satisfaction with anesthesia services was excellent, particularly during perioperative periods, targeted improvements in ERAS education are recommended, especially regarding thrombosis prophylaxis and lifestyle modifications.

Keywords: Patient satisfaction, Anesthesia service, Pediatric anesthesia, ERAS program

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* Corresponding Author:
sirirat.tribuddharat@gmail.com

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Introduction

Pediatric anesthesia represents a distinct challenge in healthcare, requiring specialized expertise due to anatomical, physiological, and pharmacological differences from adults.¹ The complexity extends beyond technical skills to managing parental anxiety and ensuring effective communication with families.² Recent studies have shown that parental anxiety

significantly impacts pediatric perioperative outcomes, highlighting the importance of comprehensive preoperative preparation.^{3,4}

Patient satisfaction has emerged as a crucial quality indicator in healthcare delivery, particularly in anesthesia services.⁵ An integrative review by Albalushi et al⁶ identified key determinants of satisfaction including preoperative information, provider communication, and postoperative pain management. Studies from various healthcare settings demonstrate that satisfied parents are more likely to comply with postoperative instructions and report better pediatric recovery outcomes.^{7,8}

The implementation of enhanced recovery after surgery (ERAS) protocols has revolutionized perioperative care, showing improved outcomes across various surgical specialties.⁹ The protocols include: basic anesthesia/surgery knowledge, exercise/rehabilitation before surgery, control of underlying diseases, smoking/alcohol cessation, breathing exercise, fasting guidelines, preoperative glucose intake, pain management information, postoperative nausea/vomiting (PONV) prevention, deep vein thrombosis (DVT) prophylaxis, and postoperative mobilization. In a meta-analysis study by Su et al¹⁰ in pediatric settings, ERAS protocols have demonstrated shorter length of stay and faster recovery, although their successful implementation requires significant parent education and engagement.¹¹

Previous satisfaction studies in pediatric anesthesia have reported varying results, with satisfaction rates ranging from 78% to more than 95%.^{12, 13} However, most studies were conducted in Western healthcare settings, with limited data from Asian contexts. Cultural differences in healthcare expectations and parent-provider relationships may influence satisfaction levels.^{14, 15}

Srinagarind Hospital, a major tertiary-care center in northeastern Thailand, provides comprehensive pediatric anesthesia services, managing approximately 1300 cases annually. Regular assessment of patient satisfaction is essential not only for quality improvement, but also for hospital accreditation requirements.^{16, 17} Understanding parent satisfaction and ERAS protocol comprehension can guide service improvements and enhance patient outcomes.^{13, 17}

This study aimed to evaluate child/guardian satisfaction with pediatric anesthesia services and assess understanding of ERAS protocols at Srinagarind Hospital, thereby addressing a significant gap in the literature regarding pediatric anesthesia satisfaction in Southeast Asian healthcare settings. The primary objective was to assess child/guardian satisfaction with anesthesia services across perioperative stages, and the secondary objective was to assess understanding of the ERAS protocols.

Methods

This descriptive cross-sectional study was approved by the Khon Kaen University Ethics Committee in Human Research on 12 July 2023 (HE661282) and was conducted at Srinagarind Hospital, Khon Kaen University. As this was a descriptive cross-sectional study, it did not perform a formal sample size calculation. Instead, all consecutive eligible patients who provided informed consent from their guardians were enrolled during the 2-month study period, from September 2024 to October 2024.

The study enrolled elective cases with ages under 18 years who received anesthesia services. It excluded emergency cases, American Society of Anesthesiologists (ASA) class 3 and 4 patients, and those with communication difficulties or cognitive impairment.

All participants underwent a preoperative visit during which information and instructions on perioperative management were provided. Also, the ERAS protocol — its processes and expected benefits for postoperative recovery — was also explained. Data were collected, 1 day after surgery, via face-to-face interviews conducted by anesthesia residents or nurses with patients or, when appropriate, their guardians, provided they were able to understand and cooperate. The guardians were defined as legal guardians, parents, grandparents, primary caregivers, or close relatives who served as the child’s primary caregivers in the absence of parents. Because most young children cannot reliably comprehend or participate in interviews, guardians’ responses were used as proxies for the children’s responses.

Data collection utilized a 4-part standardized questionnaire, developed by the research team and validated by a senior pediatric anesthesiologist, covering demographics, clinical characteristics, satisfaction assessment, and understanding of the ERAS protocol. Satisfaction and understanding were measured using a 4-point Likert scale (4 = most satisfied, 3 = satisfied, 2 = dissatisfied, and 1 = most dissatisfied), with high satisfaction or understanding defined as scores 3 to 4. The questionnaire was pilot-tested in 10 pediatric patients and their guardians, demonstrating good internal reliability with a Cronbach α coefficient of 0.89. Descriptive statistics were used. Categorical variables were presented as frequencies and percentages. The satisfaction and understanding rates were defined as the proportion of respondents reporting high satisfaction. Satisfaction scores were summarized as mean (SD) based on all valid responses. Data were analyzed using SPSS version 27.0 (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp; 2020).

Results

This study enrolled 103 children and guardians of pediatric patients. The study population comprised predominantly female respondents (87.4%), with most aged 31 to 40 years (43.7%). Two participants were patients aged 17 years who demonstrated comprehension and responded clearly; the other respondents were guardians. Educational backgrounds included vocational certificates (43.7%), bachelor’s degrees (26.2%), and below high school education (17.5%). Most cases were inpatients (79.6%), receiving general anesthesia (94.2%), with a small proportion receiving combined general/spinal anesthesia (5.8%) (Table 1).

Table 1. Baseline Demographics of Children/Guardians	
Item	No. (%)
Gender	
Female	90 (87.4)
Male	13 (12.6)
Age, y	
17	2 (1.9)
18-30	23 (22.3)
31-40	45 (43.7)
41-50	22 (21.4)
51-60	10 (9.7)
61-70	1 (1.0)

Table 1. Baseline Demographics of Children/Guardians (Continued)

Item	No. (%)
Marital status	
Single	20 (19.4)
Married	74 (71.8)
Divorced/separated	9 (8.7)
Education level	
Below high school	18 (17.5)
Junior high school	2 (1.9)
Senior high school	5 (4.9)
Vocational diploma	45 (43.7)
Bachelor's degree	27 (26.2)
Above bachelor's degree	6 (5.8)
Occupation	
Student	1 (1.0)
Government officer	21 (20.4)
Farmer	23 (22.3)
Private employee	28 (27.2)
Business owner	18 (17.5)
Housewife	8 (7.8)
Unemployed	4 (3.9)
Relationship to patient	
Patients	2 (1.9)
Parents	88 (85.5)
Grandparents	10 (9.7)
Close relatives	3 (2.9)
Type of patient care	
OPD	21 (20.4)
IPD	82 (79.6)
Patient experience with anesthesia	
Yes	69 (67.0)
No	34 (33.0)
Type of anesthesia service	
GA	97 (94.2)
Spinal block	0
Combined GA and spinal block	6 (5.8)

Abbreviations: GA, general anesthesia; IPD, inpatient department; OPD, outpatient department.

Preoperative recognition of the anesthesia team reached 81.6%. All participants received pre/postanesthesia instruction, with mostly, 89.3%, from the anesthesia team. The level of understanding after instruction was high (74.8% with good and 23.3% with moderate) (Table 2).

Satisfaction analysis revealed that 94.2%-100.0% of participants were satisfied with pre/post general anesthesia instruction, procedure steps, complications, postoperative pain management, and participation in general anesthesia decision, with an overall mean (SD) satisfaction score of 3.84 (0.10) (Table 3).

All participants (100%) were satisfied with pre, intra, and postoperative care at the postanesthesia care unit (PACU), with overall mean (SD) satisfaction scores of 3.96 (0.05), 3.99 (0.01), and 3.99 (0.01), respectively. Ward follow-up satisfaction, analyzed from 93 responses (90.3%) (10 missing), showed consistently high satisfaction (96.8%), with overall mean (SD) satisfaction scores of 3.88 (0.01) across postoperative visits, staff courtesy, and safety perception. Data completeness analysis showed no missing responses for any sections, except for 10 unanswered postoperative ward follow-up questions (9.7%), which were attributed to outpatient procedures, undergoing general anesthesia, not requiring inpatient admission (Table 4).

Understanding of ERAS protocols varied significantly, with an overall mean (SD) understanding score of 3.07 (0.79). Fasting guidelines (99.0%), basic anesthesia knowledge (96.1%), and preexisting disease control (89.3%) showed high comprehension levels. However, understanding was notably lower for DVT prophylaxis (22.3%), smoking cessation (23.3%), and breathing exercises (60.2%) (Table 5).

Table 2. Patient Response With Information Provided by Anesthesia Staff

Item	No. (%)
Recognition of anesthesia team	
Recognized	84 (81.6)
Did not recognize	16 (15.5)
Uncertain	2 (1.9)
No response	1 (1.0)
Receipt of pre/postanesthesia instruction	
Received	103 (100.0)
Did not receive	0
Source of pre/postanesthesia instruction	
Anesthesia team	92 (89.3)
Ward staff	1 (1.0)
Anesthesia team and ward staff	1 (1.0)
Anesthesia team and medical student	1 (1.0)
Surgeon and anesthesia team	2 (1.9)
Surgeon, anesthesia team, and ward staff	3 (2.9)
Unknown	3 (2.9)
Level of understanding after instruction	
Good understanding (76%-100%)	77 (74.8)
Moderate understanding (50%-75%)	24 (23.3)
Poor understanding (25%-49%)	1 (1.0)
Not understanding (< 25%)	1 (1.0)

Table 3. Information/Instruction From Anesthesia Team

Item	Level of Satisfaction						Mean (SD)
	Level 4, No.	Level 3, No.	Levels 3+4, %	Level 2, No.	Level 1, No.	Levels 1+2, %	
Pre/post GA instruction	95	8	100.0	0	0	0	3.92 (0.27)
GA procedure steps	100	2	99.0	1	0	1.0	3.96 (0.24)
GA complications	87	10	94.2	3	3	5.8	3.76 (0.65)
Postoperative pain management	87	10	94.2	3	3	5.8	3.76 (0.65)
Participation in GA decision	92	6	95.1	0	5	4.9	3.80 (0.68)
Overall satisfaction	NA	NA	NA	NA	NA	NA	3.84 (0.10)

Abbreviations: GA, general anesthesia; NA, not applicable.

Table 4. Satisfaction With Perioperative Anesthesia Care

Item	Level of Satisfaction						Mean (SD)
	Level 4, No.	Level 3, No.	Levels 3+4, %	Level 2, No.	Level 1, No.	Levels 1+2, %	
Preoperative care (n = 103)							
Staff self-introduction/courtesy/ attentiveness	102	1	100.0	0	0	0	3.99 (0.10)
Empathetic care/good relationships	101	2	100.0	0	0	0	3.98 (0.14)
Respect for privacy/rights	100	3	100.0	0	0	0	3.97 (0.17)
Clear explanation of procedures	99	4	100.0	0	0	0	3.96 (0.19)
Attention to illness/gentle care	101	2	100.0	0	0	0	3.98 (0.14)
Staff knowledge/problem-solving ability	101	2	100.0	0	0	0	3.98 (0.14)
Opportunity for family questions	100	3	100.0	0	0	0	3.97 (0.17)
Involvement in decision-making	100	3	100.0	0	0	0	3.97 (0.17)
Service options availability	86	17	100.0	0	0	0	3.84 (0.37)
Overall satisfaction	NA	NA	NA	NA	NA	NA	3.96 (0.05)
Intraoperative care (n = 103)							
Staff courtesy and demeanor	102	1	100.0	0	0	0	3.99 (0.10)
Attention to care/gentle handling	102	1	100.0	0	0	0	3.99 (0.10)
Feeling of safety	101	2	100.0	0	0	0	3.98 (0.14)
Overall satisfaction	NA	NA	NA	NA	NA	NA	3.99 (0.01)
Postoperative care at PACU (n = 103)							
Staff courtesy and demeanor	102	1	100.0	0	0	0	3.99 (0.10)
Attention to care/gentle handling	102	1	100.0	0	0	0	3.99 (0.10)
Feeling of safety	101	2	100.0	0	0	0	3.98 (0.14)
Overall satisfaction	NA	NA	NA	NA	NA	NA	3.99 (0.01)

Table 4. Satisfaction With Perioperative Anesthesia Care (Continued)

Item	Level of Satisfaction						Mean (SD)
	Level 4,	Level 3,	Levels 3+4,	Level 2,	Level 1,	Levels 1+2,	
	No.	No.	%	No.	No.	%	
Postoperative visit by anesthesia team at ward (n = 93)*							
Postoperative visits	88	2	96.8	0	3	3.2	3.88 (0.55)
Staff courtesy	88	2	96.8	0	3	3.2	3.88 (0.55)
Feeling of safety	87	3	96.8	0	3	3.3	3.87 (0.56)
Overall satisfaction	NA	NA	NA	0	NA	NA	3.88 (0.01)

Abbreviations: NA, not applicable; PACU, postanesthesia care unit.

*Ten outpatient (OPD) respondents did not answer this question.

Table 5. Understanding of Enhanced Recovery After Surgery Program Components

Item	Level of Satisfaction						Mean (SD)
	Level 4, No.	Level 3, No.	Levels 3+4, %	Level 2, No.	Level 1, No.	Levels 1+2, %	
Basic anesthesia/surgery knowledge	91	8	96.1	2	2	3.9	3.83 (0.55)
Exercise/rehabilitation before surgery	43	43	83.5	6	11	16.5	3.15 (0.94)
Control of underlying diseases	73	19	89.3	3	8	10.7	3.52 (0.88)
Smoking/alcohol cessation	20	4	23.3	2	77	76.7	1.68 (1.21)
Breathing exercises	20	42	60.2	13	28	39.8	2.52 (1.09)
Fasting guidelines	99	3	99.0	0	1	1.0	3.94 (0.34)
Preoperative glucose intake.	77	11	85.4	4	11	14.6	3.50 (0.99)
Pain management information	74	17	88.3	3	9	11.7	3.52 (0.92)
PONV prevention	54	36	87.4	9	4	12.6	3.36 (0.80)
DVT prophylaxis	15	8	22.3	2	78	77.7	1.61 (1.13)
Postoperative mobilization	69	15	81.6	1	18	18.4	3.31 (1.14)
Overall understanding	NA	NA	NA	NA	NA	NA	3.07 (0.79)

Abbreviations: DVT, deep vein thrombosis; ERAS, enhanced recovery after surgery; NA, not applicable; PONV, postoperative nausea/vomiting.

Discussion

This study evaluated patient satisfaction with anesthesia care at Srinagarind Hospital and assessed understanding of the ERAS protocol among 103 pediatric patients and their guardians. The results demonstrated high overall satisfaction across all perioperative phases, with some opportunities for improvement in preoperative patient education.

Demographic characteristics showed a predominance of female respondents (87.4%), with the majority being guardians (98.1%), across a wide age range, and most being inpatients (79.6%). This suggests the findings may broadly represent the pediatric patient population and their families' perspectives.

Recognition of and satisfaction with the anesthesia team was high, with 81.6% of respondents able to identify the anesthesia providers. Importantly, all participants reported receiving pre and postanesthesia instructions, predominantly from the anesthesia

staff (89.3%), with most (74.8%) expressing a good understanding of the information provided. This aligned with previous studies which have emphasized the importance of preoperative education and provider-patient communication in enhancing satisfaction.^{18, 19}

Satisfaction with specific aspects of anesthesia information and care was consistently high, particularly regarding overall pre and postoperative instructions (100% levels 3+4 satisfaction). However, lower ratings were observed for information about anesthesia complications (94.2%) and postoperative pain management (94.2%), suggesting potential areas for improvement in preoperative counseling.

The results indicate excellent patient satisfaction across all perioperative phases. Preoperative care, including staff courtesy, empathy, respect for privacy, and clear communication, received 100% levels 3+4 satisfaction ratings. This trend continued in the intraoperative and PACU settings, with all measured aspects of care achieving 100% levels 3+4 satisfaction. This high level of perioperative satisfaction exceeds the findings of Shafer et al, which reported an overall perioperative satisfaction rate of 94.7%, in a similar surgical population.²⁰

Ward follow-up satisfaction (96.8%) compares favorably to international benchmarks.²¹ However, there were 10 missing responses; all received general anesthesia, and due to the outpatient surgery status of these cases, they did not require ward admission. This finding suggests the need for modified follow-up strategies tailored to outpatient populations. Implementing alternative methods, such as telephone or online surveys, could help capture the experiences and satisfaction of patients who do not have a postoperative ward stay. Additionally, providing clear written instructions and contact information for the anesthesia team at discharge could facilitate communication and address any concerns that may arise after leaving the hospital. Future research should explore the specific needs and preferences of outpatient surgery patients and their families to develop effective follow-up protocols that ensure continuity of care and patient satisfaction across all surgical settings.

The consistently high satisfaction scores in this study likely reflected the anesthesia department's strong emphasis on patient-centered care, effective communication, and teamwork across all perioperative stages. Regular staff training and adherence to evidence-based protocols may also contribute to these exemplary results. Cultural factors could also play a role, as Asian healthcare settings often report higher satisfaction levels compared to their Western counterparts, possibly due to differing expectations and doctor-patient relationship dynamics.²²⁻²⁴ However, the potential for response bias in our survey cannot be excluded, as patients may be reluctant to express dissatisfaction in face-to-face interviews. Future studies using validated instruments and alternative data collection methods could provide a more nuanced understanding of the factors driving perioperative satisfaction in this setting.

Notable gaps were identified in patients' understanding of certain ERAS components. While basic anesthesia knowledge (96.1%), fasting guidelines (99.0%), and postoperative nausea/vomiting prevention (87.4%) were well understood, other elements showed room for improvement. Exercise/rehabilitation (83.5%), breathing exercises (60.2%), and postoperative mobilization (81.6%) had lower levels 3+4 understanding rates. Strikingly, smoking/alcohol cessation and DVT prophylaxis had the lowest levels 3+4 understanding at 23.3% and 22.3%, respectively. This disparity suggests the need for targeted educational interventions, particularly for complex ERAS elements. Providing simplified, accessible information through multiple modalities (eg, verbal, written, and visual) may help to improve patient comprehension and engagement. Additionally, involving family members and

guardians in the education process could reinforce key concepts and promote adherence to the ERAS protocols. Future studies should explore the most effective strategies for delivering ERAS education in pediatric surgical populations, taking into account developmental stages, health literacy levels, and cultural factors.

Previous studies have shown that structured preoperative education can significantly improve patients' understanding of and adherence to ERAS protocols, leading to better outcomes. Strategies such as multimedia presentations, interactive sessions, and individualized counseling have proven effective in increasing patient knowledge and engagement.²⁵

Several limitations warrant consideration. First, the exclusion of emergency cases may have introduced selection bias, as the satisfaction and understanding of ERAS protocols among patients undergoing urgent or emergent procedures may differ from those of elective cases. Second, the single-center design limits the generalizability of the findings to other healthcare settings, particularly those with different patient populations, resources, and anesthesia practices. Third, social desirability bias may have influenced satisfaction ratings, particularly given the cultural context in which patients may be reluctant to express dissatisfaction or criticism. This bias could have been exacerbated by the face-to-face interview format, which might have made participants more likely to provide positive responses. Future research should address these limitations through multicenter studies that include a more diverse range of surgical cases and patient populations. Additionally, employing mixed-method approaches that combine quantitative surveys with qualitative interviews or focus groups could provide a more comprehensive understanding of patient satisfaction and the factors influencing ERAS protocol understanding. Qualitative data may also help identify potential barriers to effective patient education and inform the development of targeted interventions to improve ERAS knowledge and adherence. By prioritizing patient-centered care and continually refining perioperative education, healthcare providers can optimize the surgical experience for children and their families.

Conclusions

This study demonstrated high satisfaction with pediatric anesthesia services at Srinagarind Hospital, reflecting a strong commitment to patient-centered care. However, it also highlighted opportunities to enhance preoperative education, particularly regarding ERAS protocols. Targeted interventions using age-appropriate materials and engaging family members could improve patient understanding and adherence to evidence-based practices, leading to better outcomes and satisfaction.

Additional Information

Ethics Approval: This study was approved by the Khon Kaen University Ethics Committee in Human Research (HE661282 on 12 July 2023).

Clinical Trial Consideration: This study does not report on a clinical trial.

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Author Contributions:

Conceptualization: All authors

Formal Analysis: Duangned Litu, Sirirat Tribuddharat, Thepakorn Sathitkarnmanee

Methodology: All authors

Visualization: All authors

Writing – Original Draft: Sirirat Tribuddharat, Thepakorn Sathitkarnmanee

Writing – Review & Editing: All authors

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Effectiveness of a Hypothermia Prevention Guideline in Adult Patients Undergoing General Anesthesia at Srinagarind Hospital

Wilawan Somdee¹, Thepakorn Sathitkarnmanee^{2*} , Monsicha Somjit², Narin Plailaharn² , Viriya Thincheelong¹, Chongsuk Klaichanad¹, Chanoksuda Rattanaprasob¹, Kanya Panichakul¹

¹ Division of Nurse Anesthetist, Srinagarind Hospital, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

² Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

Abstract

Background: Perioperative hypothermia (POH), associated with various complications, has a reported incidence ranging from 30% to 70%. A previous incidence of 31% at Srinagarind Hospital prompted the development and implementation of a copyrighted clinical practice guideline (CPG) for the prevention and management of hypothermia in adults.

Objectives: To assess the effectiveness and user satisfaction of this CPG.

Methods: This retrospective descriptive study included adult patients undergoing general anesthesia, with or without regional anesthesia, at Srinagarind Hospital between 1 January 2023, and 30 April 2023. POH was defined as a core temperature below 36 °C. Following induction, all patients received forced-air warming using either upper-body warming (UBW) or lower-body warming (LBW) blankets, depending on the surgical procedure and patient position. Body temperature was recorded every 15 minutes for up to 120 minutes. Postoperative satisfaction with the CPG was assessed among patients and anesthesia nurses.

Results: A total of 356 patients, predominantly male with the American Society of Anesthesiologists (ASA) classifications I-II, were enrolled. Sixty-seven patients (18.8%) developed POH. Patients receiving LBW tended to experience POH more frequently than those receiving UBW, although the difference was not statistically significant ($P = .444$). No patient's temperature fell below 35.5 °C. High satisfaction with CPG implementation was reported by both patients (99.4%) and anesthesia nurses (100%).

Conclusions: Implementation of a CPG emphasizing forced-air warming effectively reduced the incidence of POH in adult patients. The CPG demonstrated high satisfaction among both patients and anesthesia nursing staff.

Keywords: Hypothermia, Perioperative, Clinical practice guideline, Forced-air warming, Satisfaction

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* Corresponding Author: thepakorns@gmail.com

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Introduction

Perioperative hypothermia (POH), defined as a core temperature below 36 °C, represents a significant challenge in surgical patient care, affecting approximately 30%-70% of patients undergoing surgery without active warming measures.¹⁻⁴ This condition has been recognized as a critical perioperative complication since the early 1990s, with extensive research documenting its adverse effects on patient outcomes.⁵ The consequences of POH extend beyond patient discomfort and include increased risk of surgical site infections,

impaired wound healing, platelet dysfunction, coagulopathy, cardiac events, prolonged drug metabolism, delayed emergence from anesthesia, increased postoperative shivering, extended post-anesthesia care unit stays, and prolonged hospitalization.⁶⁻⁹

The pathophysiology of POH is multifactorial and involves several mechanisms. General anesthesia disrupts the body's thermoregulatory mechanisms by lowering the threshold for vasoconstriction and inhibiting shivering responses.¹⁰ Inhalational anesthetics impair central thermoregulation in a dose-dependent manner, while the sympathetic blockade from neuraxial anesthesia causes peripheral vasodilation and heat redistribution from core to periphery.^{6, 10, 11} Additionally, the operating room environment, with temperatures typically maintained between 20 °C and 24 °C, contributes to heat loss through radiation, convection, conduction, and evaporation. Surgical exposure, irrigation with room-temperature solutions, and administration of unwarmed intravenous fluids further exacerbate heat loss during procedures.¹¹

Risk factors for developing POH include extremes of age, low body mass index (BMI), preexisting conditions (eg, hypothyroidism, severe trauma, burns), procedures involving large body cavities, lengthy surgical durations, and significant fluid shifts or blood loss.^{1, 3, 5, 7} Recognizing these risk factors is essential for implementing appropriate preventive measures.

Interventions for POH prevention are categorized as passive or active. Passive interventions include increasing ambient temperature, applying warm blankets, removing wet clothing, protecting patients against wind, and using heat and moisture exchangers. While these measures help reduce heat loss, they are generally insufficient to maintain normothermia during longer procedures.⁷ Active warming methods encompass infrared light, electric blankets, circulating-water mattresses or blankets, forced-air warming (convective air warming), heated intravenous and irrigation fluids, and humidified anesthetic gases.^{12, 13} Among these, forced-air warming has emerged as the most widely recommended active intervention due to its effectiveness, safety profile, and cost-efficiency.^{4, 14, 15}

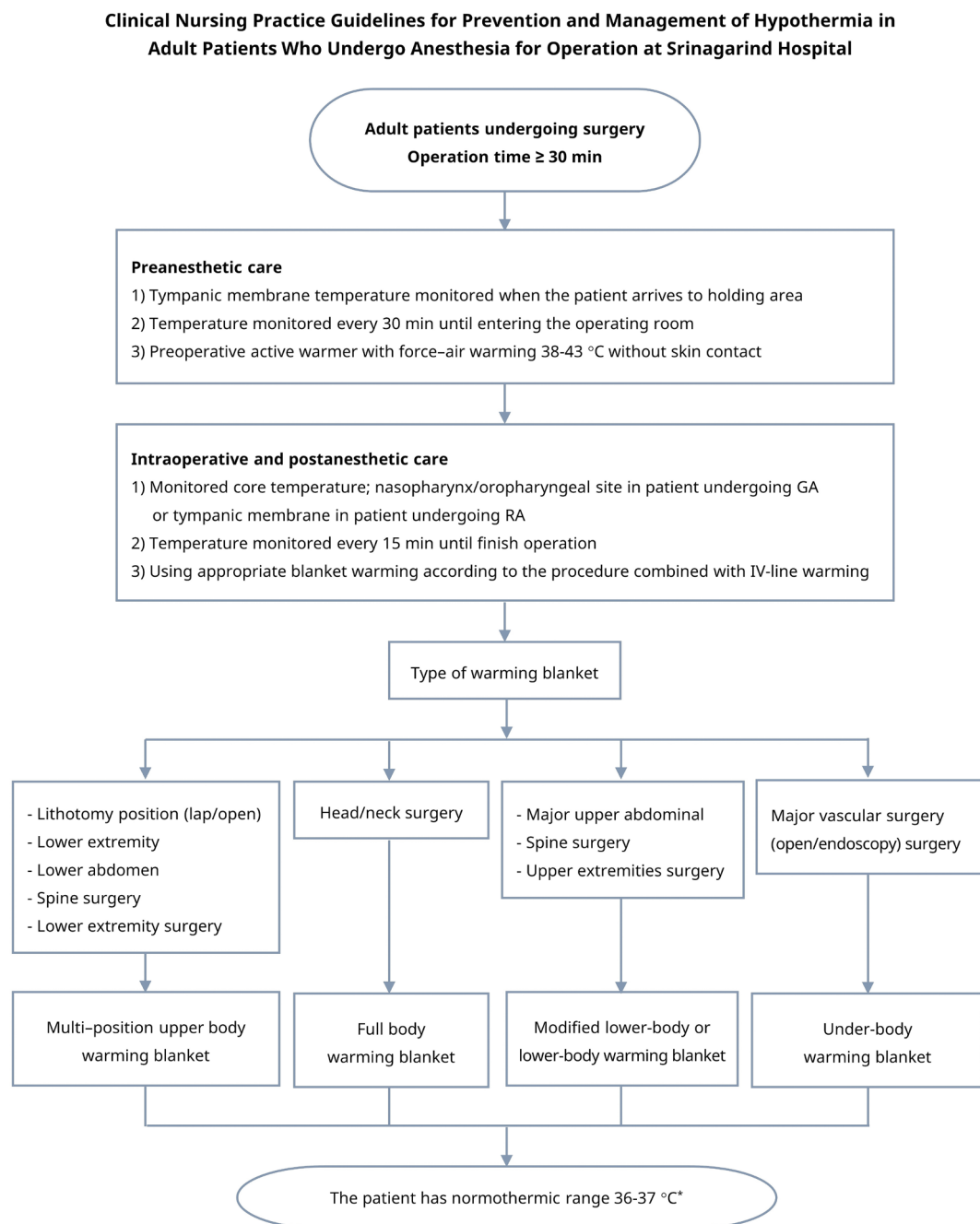
Multiple professional organizations, including the American Society of PeriAnesthesia Nurses (ASPAN), the Association of periOperative Registered Nurses (AORN), the National Institute for Health and Care Excellence (NICE), and the Royal College of Anesthesiologists of Thailand, have published guidelines recommending routine temperature monitoring and active warming strategies for surgical patients.¹⁶⁻²⁰ These guidelines emphasize the importance of prewarming patients before anesthesia induction, maintaining appropriate operating room temperatures, and implementing active warming measures throughout the perioperative period.

A systematic review and meta-analysis demonstrated that active body surface warming, particularly forced-air warming, significantly reduces the risk of surgical site infections and postoperative complications compared to passive insulation.²¹ Similarly, Nieh et al's²² meta-analysis found that forced-air warming was more effective than passive insulation and circulating-water mattresses for maintaining normothermia and provided superior thermal comfort compared to other warming methods.

Despite substantial evidence supporting perioperative warming, implementation of comprehensive hypothermia prevention protocols remains inconsistent across healthcare facilities. Forced-air warming was not part of the routine perioperative care for patients undergoing surgeries exceeding 30 minutes at this study's institution. A 2014 survey at Srinagarind Hospital indicated a 31% incidence of POH, highlighting the need for standardized prevention protocols. In response to this challenge, this study's department developed and implemented a clinical practice guideline (CPG) emphasizing forced-air warming, copyrighted

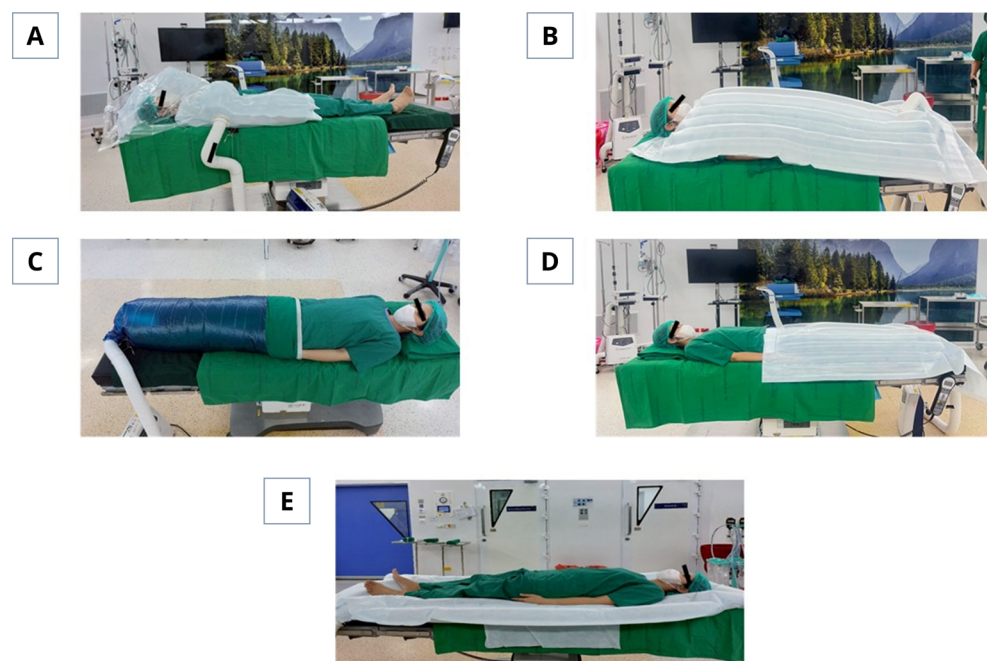
by Khon Kaen University and implemented in August 2022 (Figure 1). The CPG recommends specific warming blanket positions (multi-position upper body, full body, modified lower-body or lower-body, and under-body) (Figure 2) based on the surgical procedure and patient position. The CPG has been in effect since that time.

Figure 1. Clinical Practice Guideline for Prevention and Management of Hypothermia in Adults at Srinagarind Hospital



Abbreviations: GA, general anesthesia; IV, intravenous; RA, regional anesthesia.

Figure 2. Types of Warming Blankets



A, Multi-position upper-body warming blanket.

B, Full body warming blanket.

C, Modified lower-body blanket.

D, Lower-body warming blanket.

E, Under-body warming blanket.

This study aimed to evaluate the effectiveness of the CPG in reducing the incidence of POH and to assess user satisfaction with the guideline. The findings of this study may contribute to the optimization of perioperative care protocols and the prevention of POH-related complications in surgical patients.

Methods

Study Design and Participants

This retrospective descriptive study was approved by the Khon Kaen University Ethics Committee in Human Research (HE661371, approved on 9 August 2023). The requirement for individual patient consent was waived due to the retrospective nature of the study and the use of anonymized data. For the photographs showing warming blanket positions (Figure 2), informed consent was obtained from the individuals shown, and all identifiable features were obscured to protect privacy.

This study included adult patients who underwent general anesthesia, with or without regional anesthesia, at Srinagarind Hospital between 1 January 2023, and 30 April 2023. Inclusion criteria were age of at least 18 years, elective surgical procedures, surgical duration exceeding 120 minutes, and ASA physical status classification I-IV. Exclusion criteria encompassed patients undergoing total intravenous anesthesia for

endoscopic procedures, lung or heart surgery (due to different temperature management protocols), incomplete medical records that lacked essential temperature measurements, and emergency surgeries.

Based on previous literature reporting POH incidence rates between 30% and 70% and this study hospital's baseline incidence of 31%, this study calculated that a sample size of 340 patients would provide 80% power to detect a reduction in POH incidence to 20% with a significance level of .05. Accounting for potential incomplete data, this study aimed to include at least 350 patients in the study.

Temperature Measurement Protocol

Body temperature was measured using 3 different methods at various perioperative stages: 1) preoperatively, a calibrated tympanic membrane thermometer (Braun ThermoScan PRO 6000, Welch Allyn, USA) was used to measure body temperature during the preanesthetic evaluation; 2) intraoperatively, a nasopharyngeal temperature probe (General Purpose Temperature Probe, Smith Medical, USA) connected to the anesthesia monitoring system (Philips IntelliVue MP70, Philips Healthcare, Netherlands) was inserted to a depth of 10 to 15 cm from the nostril after anesthesia induction. The probe placement was verified by resistance at the nasopharynx and the absence of a fluctuating temperature reading that would indicate placement near the endotracheal tube; 3) postoperatively, the same tympanic membrane thermometer used preoperatively measured body temperature upon arrival at the postanesthesia care unit (PACU). Hypothermia was defined as a core temperature below 36 °C, consistent with the definition used by ASPAN and NICE.¹⁶

Implementation of the Hypothermia Prevention Guideline

All patients received standard monitoring according to ASA guidelines, including electrocardiography, noninvasive blood pressure measurement, pulse oximetry, capnography, and temperature monitoring. Anesthetic management followed standard protocols for the respective surgical procedures.

After anesthesia induction, patients were positioned according to surgical requirements. The appropriate warming blanket was selected based on the CPG recommendations: 1) upper-body warming (UBW) blanket, used for surgeries where the lower body was the surgical site or required exposure (eg, urological procedures, lower limb orthopedic surgeries); 2) lower-body warming (LBW) blanket, used for surgeries involving the head, neck, thorax, or upper extremities (eg, thyroidectomy, breast surgery, upper limb orthopedic procedures).

Forced-air warming devices (Bair Hugger Model 775, 3M, USA) were activated immediately after blanket placement and set to 38 to 43 °C according to the manufacturer's recommendations. The operating room temperature was maintained between 20 °C and 24 °C as per institutional protocol.

Intravenous fluids were administered at room temperature for volumes less than 1 L. For procedures anticipated to require larger fluid volumes (> 1 L) or blood transfusions, fluid warming devices (Ranger Blood/Fluid Warming System, 3M, USA) were employed.

Data Collection

Demographic and clinical data were extracted from electronic medical records, including: 1) patient characteristics (age, sex, weight, height, BMI, ASA classification, and comorbidities);

2) surgical details (type of surgery, surgical position, and duration of anesthesia and surgery); 3) anesthetic management (anesthetic technique, fluid administration, and blood transfusion); 4) temperature measurements (preoperative, intraoperative [every 15 minutes for up to 120 minutes], and postoperative temperatures); and 5) complications (presence and grade of shivering, cardiovascular events, and wound complications).

The primary outcome was the incidence of POH, defined as a core temperature below 36 °C at any point during the perioperative period. Secondary outcomes included temperature trends over the 120-minute observation period, and the incidence and severity of postoperative shivering, graded on a 5-point scale (grade 0: no shivering; grade 1: piloerection or peripheral vasoconstriction without visible shivering; grade 2: muscular activity in only one muscle group; grade 3: muscular activity in more than one muscle group, but not generalized; grade 4: whole body shivering).

Satisfaction Assessment

Postoperative satisfaction with the CPG implementation was evaluated among patients with a simple binary question (satisfied/unsatisfied) which was asked during the routine postoperative visit, focusing on thermal comfort during the perioperative period, and anesthesia nurses with a survey which was conducted among the anesthesia nursing staff responsible for implementing the CPG, assessing satisfaction with the guideline's clarity, feasibility, and perceived effectiveness.

Statistical Analysis

Statistical analysis was performed using SPSS version 26.0 (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp; 2019). Continuous data were presented as mean (SD) or median (interquartile range [IQR]) based on the normality of distribution as assessed by the Shapiro-Wilk test. Categorical data are presented as counts and percentages. Temperature measurements collected at multiple time points were analyzed using repeated measures analysis of variance (ANOVA). The incidence of POH between warming techniques was compared using the chi-square test or Fisher exact test as appropriate. A *P* value less than .05 was considered statistically significant for all analyses.

Results

Patient Characteristics

All recruited patients demonstrated full compliance with the CPG. Of the 356 enrolled patients, the majority were female (59.3%) and had an ASA classification of I-II (85.1%). The mean (SD) age was 51.6 (17.1) years, and the mean (SD) BMI was 24.0 (5.8) kg/m². The most common surgical procedures were general surgery (39.6%) and orthopedic surgery (23.3%) (Table 1).

Incidence of Perioperative Hypothermia

The overall incidence of POH in this study population was 18.8% (67/356 patients), representing a significant reduction from the previously reported 31% incidence at this study's institution prior to CPG implementation. Analysis by warming technique revealed that patients receiving LBW experienced POH more frequently (41/203, 20.2%) than those receiving UBW (26/153, 17.0%), although this difference did not reach statistical significance (*P* = .444) (Table 2).

Temperature Trends

Despite the differences in POH incidence between warming techniques, both UBW and LBW groups exhibited similar intraoperative temperature patterns over the 120-minute observation period. There was an initial gradual decrease in core temperature during the first 30 to 45 minutes after anesthesia induction, followed by a gradual increase as the active warming took effect (Figure 3).

The mean temperature nadir occurred at approximately 45 minutes after induction in both groups. The mean (SD) lowest recorded temperature was 36.1 (0.4) °C in the UBW group and 36.0 (0.5) °C in the LBW group ($P = .073$). Notably, no patient’s temperature fell below 35.5 °C during the study period, indicating that while mild hypothermia occurred in some patients, moderate to severe hypothermia was effectively prevented.

Repeated measures ANOVA revealed a significant time effect on temperature changes ($P < .001$), confirming the observed pattern of initial temperature drop followed by recovery. The interaction between time and warming technique was not statistically significant ($P = .396$), suggesting that the temperature trends were similar regardless of which warming technique was used.

Postoperative Shivering

Postoperative shivering was observed in only 7 patients (1.9%), with mild manifestations (grade 1-2) in all cases (Table 2). No patient experienced moderate to severe shivering (grade 3-4). Among patients who developed POH, 5 (7.5%) experienced shivering, compared to 2 (0.7%) in the normothermic group ($P = .002$), indicating a significant association between hypothermia and shivering despite active warming measures.

Satisfaction With CPG Implementation

High satisfaction with CPG implementation was reported by nearly all patients (354/356, 99.4%) and all participating anesthesia nurses (85/85, 100%) (Table 3). Two patients who reported dissatisfaction both experienced mild hypothermia (core temperatures of 35.7 °C and 35.8 °C) and grade 1 shivering during the postoperative period.

Table 1. Demographic and Clinical Data of the Patients	
Data	No. (%)
Age, mean (SD), y	51.6 (17.1)
Sex	
Male	145 (40.7)
Female	211 (59.3)
ASA	
I	95 (26.7)
II	208 (58.4)
III	52 (14.6)
IV	1 (0.3)
BMI, mean (SD), kg/m ²	24.0 (5.8)
MAP, mean (SD), mmHg	77.3 (9.7)
HR, mean (SD), beat/min	66.0 (10.9)

Table 1. Demographic and Clinical Data of the Patients (Continued)

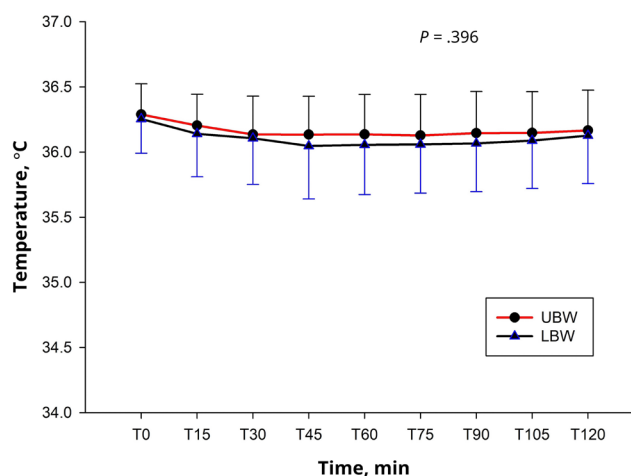
Data	No. (%)
Types of surgery	
Dental	3 (0.8)
Ear, nose, and throat	47 (13.2)
Eye	6 (1.7)
Gynecology	42 (11.8)
Orthopedic	83 (23.3)
General surgery	141 (39.6)
Neurosurgery	12 (3.4)
Plastic surgery	14 (3.9)
Urology	5 (1.4)
Vascular	3 (0.8)
Blood transfusion, unit	
0	434 (96.9)
PRC 1	10 (2.2)
PRC 2	1 (0.2)
PRC 2 + FFP 1	1 (0.2)
PRC 5	2 (0.5)
Anesthetic technique	
GA	330 (92.7)
GA + PNB	6 (1.7)
GA + EPB	10 (2.8)
GA + SB	10 (2.8)
Preoperative body temperature, mean (SD), °C	36.4 (2.0)

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; EPB, epidural block; FFP, fresh frozen plasma; GA, general anesthesia; HR, heart rate; MAP, mean arterial pressure; PNB, peripheral nerve block; PRC, packed red cell; SB, spinal block.

Table 2. Main Outcomes

Outcome	No. (%)
Core temperature < 36 °C	67 (18.8)
UBW (n = 153)	26 (7.3)
LBW (n = 203)	41 (11.5)
Postoperative shivering	7 (1.9)
Grade 1	3 (0.8)
Grade 2	4 (1.1)

Abbreviations: LBW, lower body warming; UBW, upper body warming.

Figure 3. Perioperative Body Temperature of Both Groups

Abbreviations: LBW, lower body warming; UBW, upper body warming.

Table 3. Patients' and Anesthesia Nurses' Satisfaction

Satisfaction	No. (%)
Patients (n = 356)	
Satisfied	354 (99.4)
Unsatisfied	2 (0.6)
Anesthesia nurses (n = 85)	
Satisfied	85 (100.0)
Unsatisfied	0

Discussion

Implementation of the CPG for prevention and management of hypothermia in adults at Srinagarind Hospital successfully reduced the incidence of POH from the previously reported 31% to 18.8% in this study population. This represents a relative reduction of 39.4%, demonstrating the effectiveness of a standardized approach to perioperative temperature management with forced-air warming as the primary intervention. Moreover, the severity of hypothermia was markedly decreased, with no patient's temperature falling below 35.5 °C, indicating effective prevention of moderate to severe hypothermia. These findings were consistent with those of previous studies evaluating active warming interventions. Yoo et al¹⁵ conducted a randomized controlled trial comparing perioperative active forced-air warming with passive cotton blanket covering and reported that active warming significantly reduced the incidence of intraoperative and postoperative hypothermia (19.0% vs 57.1%, $P < .001$; 3.3% vs 16.9%, $P = .013$, respectively). Similarly, Horn et al²³ demonstrated that preoperative forced-air warming for just 15 minutes reduced the incidence of intraoperative hypothermia by approximately 50% in patients undergoing spinal anesthesia. A systematic review by Moola et al⁴ concluded that single strategies such as forced-air warming were more effective than passive warming, although

combined strategies, including preoperative commencement, use of warmed fluids plus forced-air warming as other active strategies were more effective in vulnerable groups (age or durations of surgeries).

The temperature profiles which were observed in this study, showing an initial decrease followed by a gradual increase over time, were consistent with the known pathophysiology of perioperative temperature changes. The initial drop in core temperature during the first 30 to 45 minutes after anesthesia induction primarily reflects redistribution of body heat from the core to peripheral tissues due to anesthetic-induced vasodilation. This phase is typically followed by a more gradual linear decrease in temperature due to heat loss exceeding metabolic heat production, and finally, a plateau phase as thermoregulatory vasoconstriction is activated.^{7, 11, 15} The gradual increase in temperature observed in this study after the 45-minute mark likely reflects the effectiveness of the forced-air warming intervention in counteracting heat loss and eventually restoring normal body temperature.

The temperature patterns observed in both UBW and LBW groups were similar, suggesting that both warming techniques effectively prevent progressive heat loss during surgery. However, the slightly higher incidence of POH in the LBW group (20.2% vs 17.0% in UBW) warrants further investigation. This difference might be related to the larger surface area covered by upper-body blankets compared to lower-body blankets, or potential differences in the surgical procedures and body areas exposed during surgery. Previous studies have suggested that UBW might be more effective than LBW due to differences in heat transfer efficiency and the density of arteriovenous anastomoses in different body regions.¹²

The low incidence of postoperative shivering (1.9%) in this study's population is particularly noteworthy, as shivering is associated with increased oxygen consumption, carbon dioxide production, cardiac work, and patient discomfort.²⁴ The ASPAN guidelines recognize shivering as a significant complication of POH and recommend active warming interventions to prevent it.¹⁶ This study's findings support the effectiveness of forced-air warming in reducing shivering, which was consistent with a systematic review and meta-analysis, which reported that active warming significantly decreased the incidence of shivering compared to passive warming (relative risk, 0.39; 95% CI, 0.28-0.55).²⁵

There has been concern that the use of forced-air warming might increase the risk of surgical site infections (SSIs), particularly during orthopedic procedures involving implants. Augustine et al.²⁶ reported a 78% reduction in joint implant infections after switching from forced-air warming to an air-free conductive fabric electric warming system for joint replacement surgeries, suggesting a potential link between forced-air warming devices and periprosthetic joint infection. However, that study has been criticized for methodological limitations, including insufficient control of other factors influencing SSI rates.⁹ More rigorous investigations have failed to establish a causal relationship between forced-air warming and increased infection risk. Haeberle et al.²⁷ conducted a systematic review examining this issue and concluded that there is no evidence in the literature directly linking forced-air warming to increased SSI rates. These findings support the continued use of forced-air warming devices as a safe and effective method for maintaining intraoperative normothermia.

The high satisfaction rates reported by both patients (99.4%) and anesthesia nurses (100%) in this study indicate excellent acceptability of the CPG. Patient satisfaction is particularly important, as thermal comfort significantly influences overall perioperative

experience and satisfaction. Madrid et al's¹⁴ systematic review and meta-analysis demonstrated that forced-air warming provides superior thermal comfort compared to passive insulation, resistive heating blankets, and radiant warming systems. From the healthcare providers' perspective, the high satisfaction among anesthesia nurses suggests that the CPG was well-designed, practical, and easy to implement in clinical practice. Several professional organizations have emphasized the importance of implementing comprehensive hypothermia prevention protocols. The NICE guidelines recommend that patients should be kept comfortably warm preoperatively, that active warming should be used intraoperatively for procedures lasting longer than 30 minutes, and that temperature should be measured and documented regularly throughout the perioperative period.¹⁹ Similarly, the Royal College of Anesthesiologists of Thailand has published guidelines emphasizing preoperative risk assessment, temperature monitoring, and active warming strategies.²⁰ This study's CPG incorporates these evidence-based recommendations and provides specific guidance for selecting appropriate warming methods based on surgical procedure and patient position.

Clinical Implications

The successful implementation of this study's hypothermia prevention CPG has several important clinical implications which include 1) standardization of care: the CPG provides a structured approach to perioperative temperature management, reducing practice variations and ensuring consistent application of evidence-based interventions; 2) resource optimization: by specifying appropriate warming techniques for different surgical procedures; the CPG helps optimize the use of warming devices and minimizes unnecessary resource utilization; 3) quality improvement: the significant reduction in POH incidence demonstrates the value of quality improvement initiatives focused on addressing common perioperative complications; 4) education and awareness: the development and implementation of the CPG has increased awareness among healthcare providers about the importance of perioperative temperature management; and 5) patient-centered care: the high patient satisfaction rates reflect improved perioperative comfort, an important aspect of patient-centered care.

Future enhancements to the CPG could include the incorporation of preoperative warming for high-risk patients, implementation of closed-loop temperature control systems, and integration with electronic health records for automated documentation and decision support.

Limitations

This study has several limitations that should be acknowledged. First, its retrospective design introduces potential biases in data collection and analysis. Although this study attempted to minimize selection bias by including consecutive eligible patients within the specified timeframe, the retrospective nature of the study means that unmeasured confounders might have influenced the results. Second, the single-center setting limits the generalizability of this study's findings to other healthcare facilities with different patient populations, surgical case mixes, or available resources. Multicenter studies would be valuable to validate the effectiveness of the CPG across diverse clinical settings. Third, this study's assessment of patient satisfaction was limited to a simple binary question (satisfied/unsatisfied) without detailed exploration of specific aspects of thermal comfort or overall perioperative experience. More comprehensive satisfaction assessment tools

would provide richer insights into patients' perspectives. Fourth, this study did not include a direct comparison group of patients who did not receive forced-air warming, as this would raise ethical concerns given the established benefits of active warming. Instead, this study compared this study's results to historical data from this study's institution, which may be subject to temporal biases related to other changes in perioperative care practices. Fifth, this study's observation period was limited to 120 minutes intraoperatively, which may not capture the full trajectory of temperature changes in longer procedures. However, this duration was chosen based on previous research suggesting that body temperature typically normalizes with appropriate temperature control beyond this point.¹⁵ Sixth, the routine use of forced-air warmers increases the cost. Finally, this study did not assess long-term outcomes such as surgical site infections, length of stay, or other complications that might be influenced by perioperative temperature management. Further multicenter, prospective research with longer-term follow-up and inclusion of cost-effectiveness evaluation would provide more robust insight into these outcomes.

Conclusions

Implementation of a CPG emphasizing forced-air warming for the prevention of hypothermia in adults successfully reduced the incidence of POH from 31% to 18.8% at this study's institution. The severity of hypothermia was markedly decreased, with no patient experiencing moderate to severe hypothermia. Only a small number (1.9%) of patients experienced mild shivering. The temperature patterns observed in both the UBW and LBW groups showed similar trajectories, with an initial decrease followed by gradual recovery, consistent with the known pathophysiology of perioperative temperature changes.

The CPG was associated with high satisfaction rates among both patients and anesthesia nurses, indicating excellent acceptability and feasibility in clinical practice. These findings support the value of standardized approaches to perioperative temperature management and the effectiveness of forced-air warming as the primary intervention for preventing POH. Future research should focus on further optimizing warming protocols for high-risk populations, evaluating the impact of combined warming strategies, and assessing long-term outcomes associated with improved perioperative temperature management. Multicenter prospective studies would enhance the generalizability of this study's findings and contribute to the continued refinement of evidence-based practices for preventing perioperative hypothermia.

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Author Contributions:

Conceptualization: All authors

Formal Analysis: Wilawan Somdee, Thepakorn Sathitkarnmanee, Monsicha Somjit, Narin Plailaharn

Methodology: All authors

Visualization: All authors

Writing – Original Draft: Thepakorn Sathitkarnmanee, Monsicha Somjit, Narin Plailaharn

Writing – Review & Editing: All authors

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Incidence and Factors Related to Reintubation After Planned Extubation in Patients Receiving General Anesthesia in Srinagarind Hospital

Krittiya Wanphon¹ , Saranyoo Nonphiaraj¹ , Siwalai Sucher^{1*} , Kunrisa Bunworawatthana¹ ,
Laksanawadee Chairatana¹, Thirada Jimrsa¹ , Sasiwan Poorakorn¹ 

¹ Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

Abstract

Background: Reintubation after planned extubation (RAP) is associated with adverse outcomes. Understanding the incidence and related factors can reduce complications and improve outcomes.

Objectives: To identify the incidence, related factors, causes, and outcomes of RAP in patients undergoing general anesthesia (GA).

Methods: This retrospective descriptive study was done at the Srinagarind Hospital. After screening incident reports from January 2022 to June 2024, an RAP, which is defined as an intubation conducted within 24 hours after surgery was identified. The primary outcome was the incidence of RAP. The secondary outcomes were the characteristics, causes, and outcomes. Logistic regression analysis was used to identify the factors related to poor long-term outcomes.

Results: The incidence of RAP was 8.59 per 10 000 GA (40/46 543 patients). The incidence per 10 000 GA was higher among male (12.08), the elderly (22.80), patients with an American Society of Anesthesiologists (ASA) classification of 4 (24.72), patients with respiratory disease (63.09), and individuals undergoing hepatobiliary surgery (26.90). Most RAP (50%) occurred in the postanesthesia care unit. The most common indications for RAP were hypoxemia (32.5%), altered consciousness (25%), and airway obstruction (20%). RAP was primarily attributed to patient factor (65%). Male gender was associated with an odds ratio of 0.11 for poor long-term outcomes (95% CI, 0.02-0.51; $P = .005$).

Conclusions: RAP occurred at a lower rate than previously reported. Incidence of RAP was high among males, the elderly, classified as ASA 4, preexisting respiratory diseases, and hepatobiliary surgery. The major cause of RAP was related to patient-related factors.

Keywords: Incidence, Factors, Reintubation, RAP, General anesthesia, Planned extubation

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* Corresponding Author:
siwalai@kku.ac.th

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Introduction

In the process of general anesthesia (GA), endotracheal tube (ETT) intubation is necessary to secure the airway and ensure adequate ventilation throughout the surgery. The ETT also allows for the administration of inhalation anesthesia agents. Once the surgery is completed, the following extubation criteria, which are standard in our institution, are assessed to determine whether it was safe to extubate the patient; hemodynamic stability, spontaneous breathing with a tidal volume greater than 5 mL/kg, oxygen saturation (SpO_2) greater than 94%, end tidal carbon dioxide (EtCO_2) less than 50 mmHg, intact gag reflex, the ability to follow commands, sustained head raise for 5 seconds, and hand grasp.¹

Planned extubation occurs when the patient is considered stable enough and meets all extubation criteria. However, reintubation may be required if the patient experiences respiratory compromise.

Reintubation after planned extubation (RAP) refers to intubation that occurs after intended extubation following GA, typically within the first 24 hours after surgery.² RAP is a significant clinical concern for patients who have undergone GA. The need for reintubation indicates a potential failure of the planned extubation process, which can be associated with adverse outcomes such as increased morbidity, mortality, longer hospital stays, and higher healthcare costs.^{2,4}

Published reports indicate that the incidence of RAP in Thailand ranges from 8.5 to 35 cases per 10 000 procedures.^{2,3} Several factors may increase RAP risk, including patient-related factors (age, comorbidities), surgical factors (type and duration of surgery, complications), and anesthetic factors (duration of anesthesia, use of muscle relaxants).^{5,6} Despite these findings, the exact incidence of reintubation varies by clinical settings, regional practices, the type of anesthesia, and patient population.⁷

In 2011, Srinagarind Hospital reported the RAP incidence of 16.9 per 10 000 GA cases.⁶ Despite advances in anesthesia practices and changes in patient profiles over the past decade, RAP remains a concern. Decreasing the incidence of RAP is an indicator of anesthesia quality.⁵ Understanding the incidence and identifying the risk factors associated with RAP can contribute to reducing complications and improving patient outcomes. Furthermore, it is essential for the development of region-specific guidelines and interventions aimed at improving the safety of extubation and preventing the need for unnecessary reintubation. The study aimed to assess the incidence, related factors, potential causes, and clinical outcomes of RAP in patients undergoing GA.

Methods

Setting

Data were collected from January 2022 to June 2024 at Srinagarind Hospital, Khon Kaen University. Perioperative complications, including RAP, that occurred within 24 hours postoperatively were recorded on an incident report form and subsequently entered into the anesthesia database. The present study was approved by the Khon Kaen University Ethics Committee for Human Research (HE671154) in accordance with the Declaration of Helsinki and International Conference on Harmonisation (ICH) good clinical practice guideline. Written informed consent was not needed due to the retrospective and anonymous nature of the study.

Design and Participants

The present study was a retrospective descriptive study. All patients who received GA between January 2022 and June 2024 were included; patients who experienced RAP were eligible for this study. RAP was defined as intubation that was performed after considering extubation when undergoing surgery under GA during the first 24 hours postoperatively.⁶ The incident reports from the department database during the study period were screened, if an RAP was identified, the data record form was completed. The exclusion criteria were incomplete data and patients who had reintubation after unplanned or accidental extubation. The research team, which consisted of anesthesiologists and nurse anesthetists from the risk management committee, analyzed each factor.

The reported variables were based on the seminar supported by more than two-thirds of the participants.

Data Collection

The data collected in RAP patients included demographics, baseline characteristics, characteristics of the event such as the location of the event, time of the event, initial indication of intubation, the main cause of RAP, decision for planned extubation, and clinical outcomes. The main causes of RAP were categorized into 3 groups; anesthesia-related factors (including the prolonged anesthetic effect or respiratory depression from opioids), patient-related factors (such as age, severe comorbidities, and poor medical condition), and surgical-related factors (such as type and duration of surgery, and surgical complications). The immediate outcome was collected at 24 hours, and the long-term outcomes were collected at 7 days after RAP. The long-term outcomes were categorized as complete recovery, prolonged respiratory support (requiring mechanical ventilation), and death.

The number of patients who received GA during the study period was extracted from the Anesthesiology Department's annual report to calculate the incidence, number of patients were classified according to the baseline characteristics and intraoperative data included sex, age group (pediatric, adult, and elderly), American Society of Anesthesiologists (ASA) classification, emergency surgery, underlying disease, and type of surgery.

Outcome Measures

The primary outcome was the incidence of RAP in patients who received GA. The secondary outcomes were related factors, characteristics of event, causes, clinical outcomes, and predictors for poor long-term clinical outcomes in RAP patients.

Statistical Analysis

The incidence of RAP was calculated according to baseline characteristics and expressed per 10 000 GA. The data were analyzed using descriptive statistics and presented as numbers and percentages. Logistic regression analysis was used to identify factors related to poor long-term outcomes (prolonged respiratory support for more than 7 days or death within 7 days). The odds ratio (OR) and 95% CI were estimated. All the tests were 2-tailed. A *P* value less than .05 was considered significant. Data were analyzed and exported using the Stata version 18.0 (StataCorp. Version 18. College Station, TX: StataCorp LLC; 2023).

Results

From January 2022 to June 2024, 46 543 patients underwent GA with 40 patients experiencing RAP leading to an incidence of 8.59 per 10 000 GA cases. The reintubation rate was higher among males (67.5%) with an incidence of 12.08 per 10 000 GA. The median (range) age of reintubation patients was 67 (2-90) years. The incidence of reintubation varied by age group: 22.80, 5.97, and 4.42 per 10 000 GA for the elderly, pediatric, and adult populations, respectively. As ASA classification increased the rate of RAP corresponding increased; ASA classification 4 had the greatest incidence of RAP, at 24.72 per 10 000 GA. The most common coexisting diseases in our participants were hypertension, respiratory disease, and neurological diseases. The RAP rates were higher among patients with respiratory disorders (63.09 per 10 000 GA), neurological illnesses (41.21 per 10 000 GA),

and chronic kidney diseases (32.57 per 10 000 GA). The majority of RAP patients were undergoing head and neck surgery; however, the highest incidence was found in patients who underwent hepatobiliary surgery (26.90 per 10 000 GA) (Table 1).

Table 1. Incidence of Reintubation After Planned Extubation Per 10 000 General Anesthesia Categorized by Baseline Characteristics

Characteristic	No. of Patients		Incidence Per 10 000 GA
	Total Anesthetics	Reintubation	
Total case	46 543	40	8.59
Sex			
Male	22 343	27	12.08
Female	23 142	13	5.62
Age, y			
1-17	8 370	5	5.97
18-65	27 119	12	4.42
> 65	10 086	23	22.80
ASA classification			
1	11 276	0	0
2	24 408	24	9.83
3	9035	12	13.28
4	1618	4	24.72
5	111	0	0
Emergency surgery	7430	12	16.15
Underlying disease			
Hypertension	13 230	17	12.85
Respiratory disease	1902	12	63.09
Neurological disease	1941	8	41.21
Chronic kidney disease	2456	8	32.57
Diabetes	5487	4	7.29
Cardiovascular disease	1441	2	13.88
Type of surgery			
Head and neck	5048	9	17.85
General surgery	10 507	6	5.71
Hepatobiliary surgery	1859	5	26.90
Neurosurgery	3328	5	15.02
Eye	4290	4	9.32
Orthopedic	5450	4	7.34
Endoscopy	10 369	4	3.86
Thoracic surgery	988	2	20.24
Kidney, ureter, and bladder	1332	1	7.51

Abbreviations: ASA, American Society of Anesthesiologists; GA, general anesthesia.

The majority of RAP occurred in the postanesthesia care unit (PACU) (50%) and ward (27.5%), and in the operating room (22.5%), respectively. Many RAP events (62.5%) happened during normal working hours. The 3 most indicated signs requiring reintubation were hypoxemia (32.5%), altered of consciousness (25%), and airway obstruction (20%). Regarding the main cause of RAP, patient factors accounted for 65%, followed by surgical factors (20%) and anesthesia-related factors (16%). The 2 most specific causes of patient-related factors were respiratory distress (30%) and seizure or stroke (15%). Most reintubations (57.5%) resulted from an inappropriately planned extubation (Table 2).

The immediate outcome within 24 hours was a retained endotracheal intubation (97.5%). There were 19 patients (47.5%) who had unplanned intensive care unit (ICU) admission. At 7 days after surgery, 12 patients (30%) experienced poor long-term outcomes, 11 patients (27.5%) required prolonged mechanical ventilation and there was 1 patient death (Table 3).

The estimated OR (95% CI) for factors associated with poor long-term clinical outcomes were determined. Univariable logistic regression analyses were performed to identify clinically relevant potential risk factors for poor long-term outcomes in patients who required reintubation. Variables included sex, aged 65 years or older, ASA classification 3 or greater, emergency surgery, presence of underlying disease, type of surgery, occurrence during non-working hours, and the primary cause of reintubation. The analysis demonstrated that male sex was significantly associated with a reduced risk of poor long-term outcomes (OR [95% CI], 0.11 [0.02-0.51]; $P = .005$) (Table 4).

Table 2. Characteristics of Events in Reintubation After Planed Extubation

Characteristic	No. (%)
Event location	
Operating room	9 (22.5)
Postanesthesia care unit	20 (50.0)
Ward	11 (27.5)
Time of events	
Working hour	25 (62.5)
Non-working hour	15 (37.5)
Initial indication for reintubation	
Hypoxemia	13 (32.5)
Alteration of consciousness	10 (25.0)
Airway obstruction	8 (20.0)
Respiratory failure	7 (17.5)
Hypoventilation/apnea	2 (5.0)
Hemodynamic instability	0 (0)

Table 2. Characteristics of Events in Reintubation After Planned Extubation (Continued)

Characteristic	No. (%)
Main cause of reintubation	
Anesthesia-related factor	6 (15.0)
Prolong anesthetic effect	5 (12.5)
Respiratory depression from opioids	1 (2.5)
Patient's factor	26 (65.0)
Respiratory distress	12 (30.0)
Seizure or stroke	6 (15.0)
Upper airway obstruction	5 (12.5)
Pulmonary edema	2 (5.0)
Shock or multiple medical problems	1 (2.5)
Surgical factor	8 (20.0)
Upper airway obstruction after head and neck surgery	6 (15.0)
Seizure after neurosurgery	2 (5.0)
Decision for planned extubation	
Appropriate	17 (42.5)
Inappropriate	23 (57.5)

Table 3. Clinical Outcomes of Reintubation After Planned Extubation

Characteristic	No. (%)
Immediate outcome (within 24 h)*	
Retained endotracheal tube > 24 h	39 (97.5)
Unplanned intensive care unit admission	19 (47.5)
Desaturation	18 (45.0)
Hypotension	1 (2.5)
Cardiac arrest	1 (2.5)
Complete recovery	1 (2.5)
Long-term outcome within 7 d	
Complete recovery	28 (70.0)
Prolonged respiratory support	11 (27.5)
Death	1 (2.5)

* Patient may impact multiple immediate outcomes.

Table 4. Logistic Regression Analysis for Predictors of Poor Long-Term Outcomes of Reintubation After Planned Extubation

Variable	OR (95% CI)	P Value
Male sex	0.11 (0.02-0.51)	.005
Age > 65 y	0.65 (0.17-2.53)	.531
ASA classification ≥ 3	0.95 (0.24-3.75)	.952
Emergency surgery	3.00 (0.73-12.40)	.129

Table 4. Logistic Regression Analysis for Predictors of Poor Long-Term Outcomes of Reintubation After Planned Extubation (Continued)

Variable	OR (95% CI)	P Value
Underlying		
Hypertension	2.52 (0.63-10.05)	.190
Respiratory disease	0.36 (0.07-1.98)	.240
Neurological disease	3.00 (0.61-14.86)	.178
Chronic kidney disease	1.53 (0.30-7.79)	.606
Diabetes	0.76 (0.07-8.12)	.819
Type of surgery		
General surgery	1.00 (Reference)	NA
Head and neck surgery	4.00 (0.32-49.60)	.280
Neurosurgery	20.00 (0.93-429.90)	.056
Non-working hour	2.11 (0.53-8.41)	.289
The main cause of reintubation		
Anesthesia factor	0	NA
Patient factor	1.94 (0.43-8.79)	.390
Surgical factor	1.53 (0.30-7.79)	.606

Abbreviations: ASA, American Society of Anesthesiologists; NA, not applicable; OR, odds ratio.

Discussion

This study's incidence of RAP was 8.59 per 10 000 GA, which was lower than the 16.9 per 10 000 GA found in our institution's 2011 study.⁶ The incidence of RAP in Thailand was shown to be as high as 27 per 10 000 GA in early 21st century studies,^{2, 8} although it has now decreased to between 8.6 and 14.16 per 10 000 GA in recent years.^{5, 9, 10} Reintubation was one of the respiratory complications that were significantly related to postoperative respiratory depression.¹¹ The recent decline in RAP rates likely from advancements in anesthetic practices, which now incorporate short-acting drugs, less-sedating agents, regional anesthesia, and enhanced recovery after surgery (ERAS) protocols to facilitate faster recovery and minimize respiratory depression.¹² The decreasing incidence of RAP also reflects improvements in the quality of our anesthesia care. The study in developed countries reported the incidence of RAP was 6 to 9.9 per 10 000 GA which is comparable with our study.^{13, 14}

According to our findings, RAP occurred in men at twice the rate of women. This result was consistent with research by Chen et al¹⁵ on patients who experienced acute airway compromise following GA and Wilson et al¹⁶ on patients who had anterior cervical discectomy and fusion surgery.

When considering age groups, we discovered that the highest incidence of RAP was seen in elderly patients (age > 65 years). The elderly were also found to be a significant independent risk factor for RAP in many previous studies.^{3, 15, 17} Chinachoti et al² found that extreme age group (< 1 year and > 70 years) increased the incidence of RAP. Infants and geriatrics are more susceptible to respiratory depression following GA. In these patients, careful anesthetic drug selection, dosage titration, and monitoring are crucial to minimize this risk.

Our results showed the incidence of RAP increased along with ASA classification which might be due to higher ASA classification related to more severe illnesses and comorbidities. This study reported a high incidence of RAP seen in patients with respiratory diseases, neurological diseases, and chronic kidney disease. Previous research has also shown that patients with ASA classification of 3 or higher and patients with respiratory disease (chronic obstructive pulmonary disease) were at risk for RAP.¹⁵⁻¹⁸

In regard to the type of operation, the majority of previous research demonstrated RAP most frequently happened in thoracic, airway, and head and neck surgeries.^{3, 14, 15, 18} Contrary to our findings, the highest incidence of RAP (26.90 per 10 000 GA) was found in patients undergoing hepatobiliary surgery. It might be because our institution is in the pandemic area of liver disease and hepatobiliary surgery is on the rise every year.¹⁹

Most RAP events (75%) happened immediately after surgery in the operating room or postanesthesia care unit, which is comparable to the Thai study's findings (67.5%).² The most common causes of RAP in the present study were patient factors, surgical-related factors, and anesthesia-related factors, respectively. This result is similar to a recent study conducted in 2022 at Songkhla Hospital, which found that patient factors accounted for 55% of RAP.¹⁰ In contrast, RAP was mostly caused by anesthesia-related risk factors in most of the earlier reports.^{2, 5, 6, 8} This decrease in anesthesia-related factors may suggest an overall improvement in anesthetic safety. One possible explanation, though not directly assessed in our study, is the widespread adoption of modern practices such as rapid-recovery anesthetic drugs and ERAS protocols, which have been shown to improve postoperative outcomes.^{12, 20} This hypothesis warrants further prospective studies to confirm the association.

We found that inappropriate decisions for planned extubation contributed to 57% of RAP. Identifying high-risk patients for RAP can help clinicians decide whether to delay extubation, use noninvasive ventilation or other alternative techniques, or prepare for potential complications postextubation. A better understanding of the underlying mechanisms and predictive factors associated with RAP may lead to improved guidelines for anesthesia management and post-operative care.

Despite males having a higher incidence of RAP, however, they had lower odds of poor long-term outcomes after RAP. In critically ill patients also found that men are admitted to the ICU more commonly than women but have better functional outcomes than women.²¹ Further investigation is needed to explore the reasons behind this trend.

Our study had some limitations. The retrospective nature resulted in missing data and lack of systematically documented extubation criteria for individual RAP cases, limiting our ability to analyze the relationship between specific extubation criteria and RAP outcomes. Hence, a prospective study will help to clarify the findings. Our sample size may have been insufficient to identify possible risk factors for poor long-term outcomes. In the future, we hope to increase the sample size by performing a multicenter prospective survey.

Conclusions

RAP occurred infrequently and at a lower rate than in previous reports. The incidence of RAP was high among males, the elderly, patients with ASA classification 4, patients with preexisting respiratory disease and neurological disease, and hepatobiliary surgery. The major cause of RAP was patient-related factors.

Additional Information

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Ethics Approval: The present study was approved by the Khon Kaen University Ethics Committee in Human Research (HE671154 on 13 March 2025).

Clinical Trial Consideration: This study does not report on a clinical trial.

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Author Contributions:

Conceptualization: Krittiya Wanphon, Saranyoo Nonphiaraj, Siwalai sucher

Formal Analysis: Krittiya Wanphon, Saranyoo Nonphiaraj, Siwalai sucher, Sasiwan Poorakorn

Investigation: All authors

Methodology: All authors

Visualization: Krittiya Wanphon, Saranyoo Nonphiaraj, Siwalai sucher, Sasiwan Poorakorn

Writing – Original Draft: Krittiya Wanphon

Writing – Review & Editing: Saranyoo Nonphiaraj, Siwalai sucher

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Psychometric Testing of the Thai Version of the Short-Form Practice Environment Scale of the Nursing Work Index Among Nurses Within the Thai Social Context

Vachira Posai^{1*}, Niphon Watada², Armarapas Atthachaiwat¹, Teeraporn Sathira-Angkura¹, Kanogporn Jamsomboon¹, Uraiporn Janta-Um-Mou¹, Patcharee Kladjomphong¹, Supisara Phonkrut¹, Supitcha Udomchai¹

¹ Division of Nursing, Ministry of Public Health, Nonthaburi, Thailand

² Department of Nursing, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand

Abstract

Background: A standardized assessment of the nursing practice environment is essential as a foundation for planning and implementing improvements that enhance the suitability and efficiency of nurses' work settings. While comprehensive evaluations provide valuable insights, they can be resource-intensive, particularly in settings with limited capacity. The Practice Environment Scale of the Nursing Work Index (PES-NWI) is a widely validated instrument for assessing nursing work environments, and its short-form version, the PES-5, was developed to reduce respondent burden. Adapting the PES-5 to the Thai context ensures cultural and organizational appropriateness, thereby enhancing its applicability and utility in Thai healthcare settings.

Objectives: To translate the PES-5 into Thai and assess its psychometric properties among Thai nurses.

Methods: A cross-sectional design was employed. The PES-5 was translated into Thai using a systematic forward and backward translation process to ensure conceptual and linguistic equivalence. Data were collected from 250 full-time registered nurses working in public hospitals under Thailand's Ministry of Public Health via an online survey. Psychometric evaluation was conducted using Rasch model analysis, performed with Jamovi software (version 2.6.26). Internal consistency was assessed using Cronbach α and item-total correlation. Rasch analysis was used to examine item fit, response category functioning, and person separation reliability.

Results: The Thai version (T-PES-5) demonstrated excellent content validity (S-CVI = 1.00). Rasch analysis showed acceptable Infit and Outfit statistics (0.81-1.24 and 0.79-1.31, respectively), indicating good item fit. Cronbach α was 0.73, reflecting satisfactory internal consistency. The Wright map revealed a well-balanced item difficulty distribution with no evidence of floor or ceiling effects.

Conclusions: The T-PES-5 is a psychometrically sound instrument for evaluating the nursing practice environment in Thailand. Its brevity and validity make it particularly suitable for large-scale assessments in public healthcare settings, supporting efforts to improve work environments and, ultimately, patient care quality.

Keywords: Nurses, Practice Environment Scale of the Nursing Work Index, Validation, Psychometric properties

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* Corresponding Author:
vachira.nurse1991@gmail.com

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Introduction

The global shortage of nurses is a critical issue affecting healthcare systems worldwide. Countries such as the US, Japan, Australia, and several in Europe have reported increasing difficulty in maintaining an adequate nursing workforce.^{1, 2} Thailand, similarly, faces a shortage that significantly affects healthcare delivery.³ Among the many factors influencing nurse retention, the nursing practice environment has been recognized as one of the most influential.^{4, 5} A supportive work environment contributes to improved nurse satisfaction, reduced turnover, and better patient care outcomes.^{6, 7}

Lake⁸ defined the nursing practice environment as 'the organizational characteristics of a work setting that facilitate or constrain professional nursing practice'. To assess this construct, Lake⁸ developed the Practice Environment Scale of the Nursing Work Index (PES-NWI), which evolved from the original Nursing Work Index. The PES-NWI has been extensively validated and widely used in many countries and contexts. It includes 31 items grouped into 5 subscales that address key organizational dimensions related to nursing practice.⁸⁻¹⁰

The 5 subscales of the PES-NWI are: 1) nurse participation in hospital affairs, which assesses the degree to which nurses are involved in institutional governance-for example, through participation in decision-making processes, serving on hospital committees, or contributing to policy development; 2) nursing foundations for quality of care, which evaluates the presence of care standards, professional development opportunities, and evidence-based practice guidelines that support high-quality nursing care; 3) nurse manager ability, leadership, and support, which focuses on the supervisory role of nurse managers, including leadership effectiveness, support for staff, and advocacy for nursing concerns; 4) staffing and resource adequacy, which measures whether staffing levels and resources are sufficient to meet patient care demands and support safe practice; and 5) collegial nurse-physician relations, which examines the quality of interprofessional collaboration and mutual respect between nurses and physicians.⁸⁻¹⁰ These subscales collectively offer a comprehensive assessment of the organizational environment in which nurses deliver care.

Although the PES-NWI has demonstrated robust psychometric properties and cross-cultural validity, having been translated into more than 24 languages and used in over 35 countries, its length has been a noted limitation.¹¹⁻¹³ In Thailand, the full 31-item version has been translated and used in several studies,¹⁴ but researchers have reported that the instrument's length can lead to survey fatigue, decreased response rates, and potential item redundancy.^{13, 15} These limitations have practical implications, particularly when administered in clinical settings where nurses face time constraints.

To address these concerns, Lake et al¹⁰ developed a short-form version of the instrument known as the PES-5. This concise version includes 5 representative items, one from each subscale, allowing for a quicker yet effective assessment of the nursing practice environment. Despite its proven utility in other international contexts, the PES-5 has not been adapted or validated in Thailand. Given the limitations identified in previous Thai studies and the growing need for efficient and contextually appropriate tools, the present study aimed to translate the PES-5 into Thai and evaluate its psychometric properties among Thai nurses working in government hospitals. The objective was to translate the PES-5 into Thai (T-PES-5) and assess its psychometric properties among nurses in Thailand.

Methods

Study Design

This study employed a quantitative, cross-sectional design, incorporating Rasch model analysis to evaluate the measurement properties of the instrument. Data collection was purposefully focused on tertiary government hospitals, as these institutions provide highly complex nursing practice environments that offer richer insights into specialized roles, advanced patient care, and organizational structures compared to primary and secondary hospitals. Such complexity includes higher patient acuity levels, specialized nursing roles, and advanced healthcare resources. Limiting the sample to tertiary settings thus ensured the instrument's applicability and validity within the context most relevant to advanced nursing practice. This study obtained ethical approval from the Institute for the Development of Human Research Protections (IHRP), under the Health Systems Research Institute (HSRI). Permission to use and adapt the original PES-5 was granted by the scale's author. All procedures followed the Declaration of Helsinki. Participants received detailed study information and provided written informed consent. They were assured of voluntary participation, with the right to withdraw at any time. Confidentiality was strictly maintained, and findings were used solely for academic purposes.

Participants

A purposive-convenient sampling approach was employed to recruit full-time registered nurses who held at least a bachelor's degree in nursing and were currently employed at tertiary government hospitals. Nurses who were on maternity leave, extended sick leave, or study leave at the time of data collection were excluded to ensure that participants were actively engaged in their work environments. This sampling strategy was selected due to logistical constraints and the need for timely data collection, as it allowed efficient access to eligible participants within the targeted institutions. Participants were recruited from 35 tertiary government hospitals located across Thailand's 5 major geographic regions — North, Central, Eastern, Northeastern, and Southern in order to enhance geographic diversity and reflect variation in healthcare delivery contexts. The selected hospitals represented a range of institutional sizes and service capacities typically found in the public tertiary care system. The proportion of participants recruited from each hospital ranged from 15% to 25%, resulting in a balanced distribution of the nursing workforce across sites and improving the representativeness of the sample within the public healthcare sector. Based on the guidelines of Smith et al,¹⁶ a sample size between 250 and 500 was considered optimal for Rasch analysis of a well-targeted scale. In this study, 250 nurses were included.

Instruments

Two instruments were utilized in this study. Permission for their use and translation, where applicable, was obtained from the original authors. The first instrument was a demographic questionnaire developed by the primary investigator (PI) to collect information on participants' age, gender, marital status, educational background, nursing specialty training, work experience, monthly income, and employment status. The second instrument was the PES-5 which was assessed using the 5 items adapted from Lake et al.¹⁰ This scale had been widely recognized for its validity and reliability in measuring the nurse practice environment. The original scale demonstrated strong internal consistency, with a Cronbach α of 0.94.¹⁰ The items were assessed on a 4-point Likert scale,

with '1' indicating 'strongly disagree' and '4' indicating 'strongly agree'. The total score for the scale ranged from 1 to 4. A score above 2.5 typically reflected a positive work environment, while a score below 2.5 indicated a less favorable environment.^{8, 10}

Translation of Instrument

The translation process of the PES-5 followed established and internationally recognized guidelines, specifically the back-translation method with bilingual testing as recommended by Beaton et al¹⁷ and Curtis et al.¹⁸ Initially, 2 bilingual translators including a linguistic expert and a clinical specialist who independently conducted forward translations from English to Thai. The researcher reviewed and reconciled the versions to ensure conceptual equivalence. A second draft was then evaluated by 2 additional experts, who were blinded to the original instrument to minimize bias. Subsequently, a back-translation from Thai to English was performed by an independent translator. The back-translated version was compared with the original to confirm linguistic and conceptual consistency. Through iterative discussions among the translators, experts, and researcher, discrepancies in wording and grammar were resolved, finalizing a Thai version that accurately reflected the original instrument's intent. This rigorous process ensured the translation's validity and cultural appropriateness for the target population.

Five experts, each holding a master's or PhD in Psychiatry or Nursing Science, evaluated the content validity of the T-PES-5. They rated each item on a 4-point scale (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = very relevant) and provided suggestions for clarification. The content validity index (CVI) was then calculated, with a score of 0.80 or higher deemed acceptable.¹⁹ Both the scale-level content validity index (S-CVI) and the item-content validity index (I-CVI) of the T-PES-5 reached a perfect score of 1.00, indicating excellent content validity.

Data Collection

Data collection was conducted from 1 to 31 January 2025, using an online survey distributed through multiple channels, including official hospital announcements, email invitations with a secure Google Forms link, and QR codes posted within nursing units. The survey platform was configured to accept up to 250 responses, after which access was automatically closed to align with the predetermined sample size. Prior to participation, nurses reviewed study information and provided electronic informed consent. The survey required approximately 3 to 5 minutes to complete and participation was entirely voluntary. To ensure confidentiality and minimize response bias, no identifiable information — such as names, employee IDs, email addresses, or IP addresses — was collected, and all responses were submitted anonymously.

Statistical Analysis

The data were analyzed using SPSS version 29.0 (IBM SPSS Statistics for Windows, Version 29.0. Armonk, NY: IBM Corp; 2023). Descriptive statistics were applied to summarize the sample characteristics.^{20, 21} To assess the scale's reliability, Cronbach α coefficient was calculated, with a value of 0.70 or higher being deemed acceptable.²² The corrected item-total correlation was computed to measure the strength of each item's relationship with the total scale score, with values above 0.50 indicating a strong correlation, and those between 0.30 and 0.50 considered acceptable.²³

Rasch analysis was performed using Jamovi version 2.6.26 and the snowIRT modules. Infit and outfit values between 0.60 and 1.40 were interpreted as indicating a good fit.^{24, 25} Values below 0.60 or above 1.40 suggested item redundancy or poor alignment with the underlying construct, respectively. Chi-square probability values greater than the Bonferroni-adjusted 5% threshold confirmed adequate item fit.²⁴ Item characteristic curves (ICCs) were examined visually for item fit, and threshold ordering was evaluated both statistically and graphically to ensure the response categories functioned as expected.^{24, 25}

Results

Descriptive Analysis

The study included 250 nurses, the majority of participants were female (89.20%), with mean (SD) age of 38.78 (10.84) years. Married individuals were the largest marital status group, comprising 48.80% of the sample. Regarding education, 84.40% held bachelor's degrees, and 58.00% had completed a nursing specialty course. The mean (SD) years of professional experience was 8.04 (6.87). Additionally, 36.00% of participants reported earning a monthly salary of at least ₦45 000. A significant proportion of participants (92.80%) were employed as government officers (Table 1).

The normality of the T-PES-5 was checked using skewness and kurtosis, which showed a slight negative skew which suggested the distribution was close to normal or slightly platykurtic (skewness = -0.14 to -0.72, kurtosis = -0.30 to 1.36). These findings indicated that the data's departure from normality was within an acceptable range.

To assess content validity, floor and ceiling effects were analyzed, with a threshold set at less than 15%. In this study, 1 participant scored the lowest possible total on the T-PES-5 (1.20 points), which represented 0.40% of the sample, while 3 participants reached the highest possible score (4.00 points), accounting for 1.2%. As the percentage of participants with either the lowest or highest scores remained well below 15% threshold, the instrument was determined to have good content validity.

The Rasch analyses were deemed appropriate, as the summary model indicated no significant difference between the observed data and the model expectations, thereby supporting a good overall fit ($\chi^2 = 20.62$, $df = 12$, $P = .06$). The person separation reliability was 0.72 ($P < .001$), meeting the acceptable standard. The results of the Rasch analysis for the T-PES-5, showed infit values ranging from 0.81 to 1.24 and outfit values from 0.79 to 1.31, all of which were within the acceptable range (Table 2). These results indicated that the model fit was satisfactory and that the test reliably measured individual ability. The Wright map showed that items T-PES2, T-PES3, and T-PES5 had logit values below -3, which suggested they were easy for participants, while no items had logit values above 3 (Figure 1). This pattern aligned with the ICC, which showed a strong correlation between ability and the likelihood of answering items correctly, following an S-shaped curve. Comparisons the empirical and theoretical ICCs, demonstrated steepness of the curve, which reflected strong sensitivity in measuring individual ability (Figure 2). Finally, this confirmed the appropriate distribution of response categories across items (Figure 3).

Reliability

Cronbach α for the total scale score was 0.73, demonstrating strong internal consistency. When individual items were removed, the alpha values ranged from 0.65 to 0.75.

Furthermore, all item-total correlations were positive, ranging from 0.34 to 0.60, exceeding the 0.30 threshold, which indicated that each item made a positive contribution to the scale's overall consistency (Table 3).

Table 1. Demographic Characteristics of Participants

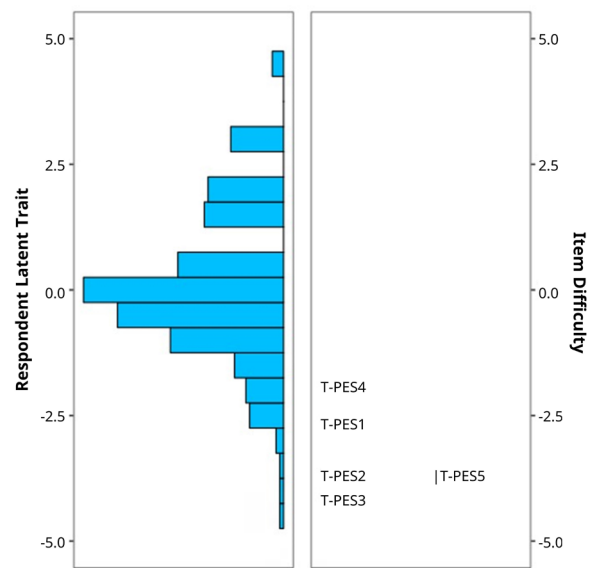
Characteristic	No. (%)
Age, mean (SD), y	38.78 (10.84)
Gender	
Male	27 (10.80)
Female	223 (89.20)
Marital status	
Single	114 (45.60)
Married	122 (48.80)
Other (divorced, widowed)	14 (5.60)
Education	
Bachelor's degree	211 (84.40)
Master's degree	39 (15.60)
Nursing specialty course	
No	105 (42.00)
Yes	145 (58.00)
Work experience, mean (SD), y	8.04 (6.87)
Salary per month, ฿	
15 000-29 999	86 (34.40)
30 000-44 999	74 (29.60)
≥ 45 000	90 (36.00)
Employment status	
Government officers	232 (92.80)
Nongovernment officers	18 (7.20)

Table 2. Item Statistics and Tau-Parameters for the T-PES-5

Item	Measure of Item Difficulty	SE	Infit	Outfit	Tau-Parameter			
					1	2	3	4
T-PES1	-2.74	0.11	1.03	1.05	-28.98	7.58	8.94	12.47
T-PES2	-3.67	0.12	1.09	1.05	-28.65	8.07	8.65	11.93
T-PES3	-4.06	0.12	0.82	0.81	-26.95	7.16	7.92	11.87
T-PES4	-1.79	0.10	1.24	1.31	-29.76	7.75	9.55	12.46
T-PES5	-3.78	0.12	0.81	0.79	-27.50	7.16	7.95	12.39

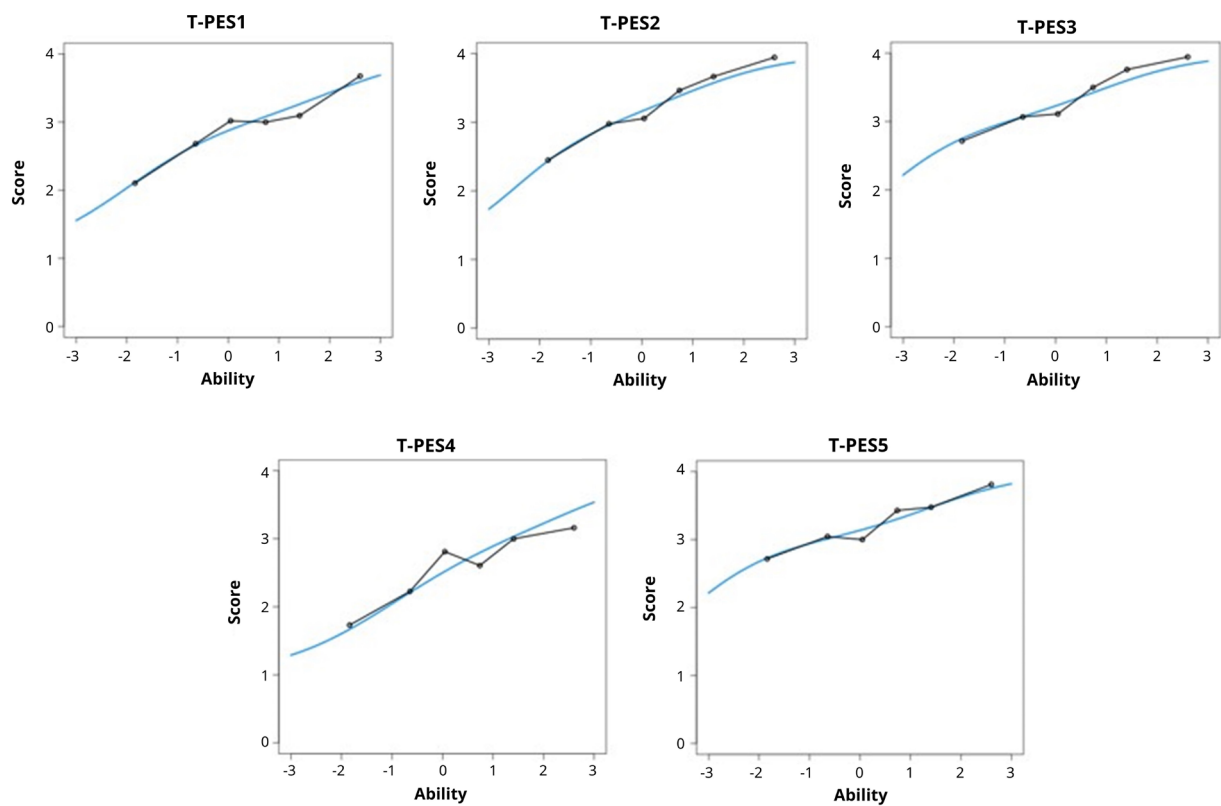
Abbreviations: SE, standard error; T-PES-5, Thai version of the short-form Practice Environment Scale of the Nursing Work Index.

Figure 1. Wright Map (Person-Item Map) of the T-PES-5



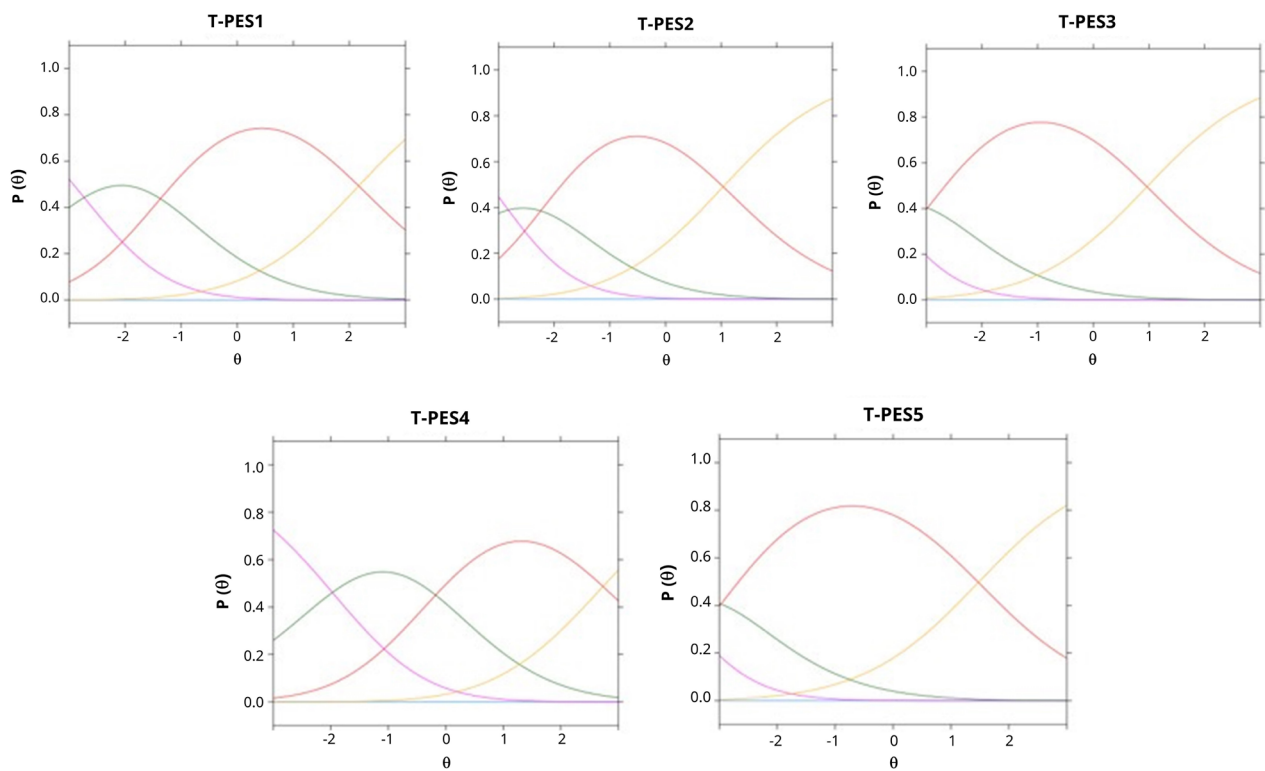
Abbreviation: T-PES-5, Thai version of the short-form Practice Environment Scale of the Nursing Work Index.

Figure 2. Item Characteristic Curve of the T-PES-5



Abbreviation: T-PES-5, Thai version of the short-form Practice Environment Scale of the Nursing Work Index.

Figure 3. Response Option Characteristic Curves for the Items of the T-PES-5



Abbreviation: T-PES-5, Thai version of the short-form Practice Environment Scale of the Nursing Work Index.

Table 3. The Reliability of the T-PES-5

Item	Mean (SD)	Corrected Item-Total Correlation	Cronbach α If Item Deleted
T-PES1	2.82 (0.74)	0.49	0.69
T-PES2	3.11 (0.74)	0.58	0.65
T-PES3	3.22 (0.62)	0.60	0.65
T-PES4	2.46 (0.83)	0.34	0.75
T-PES5	3.14 (0.59)	0.51	0.68

Abbreviation: T-PES-5, Thai version of the short-form Practice Environment Scale of the Nursing Work Index.

Discussion

This study was the first to apply Rasch analysis to assess the psychometric properties of the T-PES-5, offering both statistical rigor and practical relevance. The results demonstrated that the T-PES-5 is a psychometrically robust instrument, displaying unidimensionality, acceptable item fit, internal consistency, and person separation reliability. These findings support its validity as a brief, yet effective tool for evaluating the professional practice environment among Thai nurses.

The application of Rasch modeling adds methodological strength to the validation process. The nonsignificant chi-square statistic ($\chi^2 = 20.62, df = 12, P = .06$) reflects a good

overall model fit, consistent with Rasch model expectations and prior validation studies.²⁶ Infit and outfit mean square values, which fell within acceptable ranges (infit, 0.81-1.24; outfit, 0.79-1.31), suggested that all 5 items performed in line with theoretical expectations, indicating strong item-level functioning and contributing to measurement precision.^{24, 25}

The Wright map analysis further illustrated that the scale captured a wide range of respondent abilities. Items such as T-PES2, T-PES3, and T-PES5 were found to be easier for respondents to endorse, reflecting sensitivity at the lower end of the ability distribution.^{22, 23} The absence of items with extreme difficulty ensured that the scale avoided floor and ceiling effects, thereby increasing its versatility for use across diverse nursing populations.

The ICCs supported the expected S-shaped form, indicating that items performed predictably in relation to respondents' latent trait levels.^{27, 28} The steep slopes of the ICCs underscored the scale's ability to differentiate among varying levels of perceived practice environment quality, which is an essential feature for any instrument intended for both assessment and monitoring purposes.

The T-PES-5 also demonstrated acceptable internal consistency, with a Cronbach α of 0.73, meeting widely accepted benchmarks for reliability in social science research.^{29, 30} Positive item-total correlations, and a stable alpha when individual items were excluded further reinforced the scale's internal coherence and unidimensional structure.

Beyond its psychometric performance, the T-PES-5 offers distinct practical advantages in the context of the Thai healthcare system. With only 5 items, the scale is well-suited for use in high-demand clinical settings where time and personnel resources are limited.¹⁰ The brevity of the instrument reduces respondent burden, making it feasible for routine deployment without compromising measurement quality.

Equally important, the T-PES-5 was adapted with careful consideration of cultural nuances relevant to the Thai nursing context. Factors such as hierarchical work structures, collectivist organizational culture, and interpersonal dynamics influence how nurses experience their practice environment.^{31, 32} The content and wording of the scale were refined to reflect these cultural realities, enhancing its face validity and acceptability among Thai nurses. This cultural alignment strengthens the instrument's utility, not only for measurement, but also for promoting engagement and trust in the evaluation process.³³

In practical terms, the validated T-PES-5 equips hospital administrators, nursing leaders, and policymakers with a reliable and efficient tool to assess and monitor the quality of the nursing practice environment. Such assessments can guide targeted interventions aimed at improving nurse satisfaction, reducing turnover, and fostering environments conducive to high-quality patient care.^{34, 35} Given the rising complexity of care and the ongoing challenges of nurse staffing in Thailand, the T-PES-5 represents a timely and actionable contribution to workforce development and health system strengthening.

In summary, the T-PES-5 is not only a psychometrically sound instrument, but also a culturally relevant and practically viable tool. Its validated short-form structure supports efficient, meaningful, and context-sensitive assessments of the nursing work environment. The integration of this instrument into research and practice may support system-level improvements, contributing to a stronger, more resilient nursing workforce and better patient care outcomes in the Thai healthcare system.

This study had key limitations. The instrument was developed and validated exclusively among nurses working in tertiary-level government hospitals under the Ministry of Public Health, which may limit its applicability to private facilities or lower-tier healthcare settings. Additionally, the focus on psychiatric nurses within specialized wards

further restricted generalizability to broader nursing populations, such as those working in internal medicine, surgical, or obstetric units. Regional disparities in healthcare infrastructure and administrative practices were also not accounted for in the current sample.

Future research should aim to validate and refine the T-PES-5 across a wider range of healthcare institutions, including private hospitals, secondary-level facilities, and various clinical specialties. Incorporating a geographically diverse sample would improve the generalizability of findings and allow for exploration of regional differences in nursing work environments across Thailand. Longitudinal studies are also recommended to assess the instrument's sensitivity to organizational or policy changes over time, enhancing its value as a monitoring and evaluation tool in ongoing workforce development efforts.

Conclusions

The findings from this study have indicated that the T-PES-5 is a psychometrically sound instrument that offers a concise yet comprehensive assessment of the nursing practice environment. Its alignment with the Rasch model, acceptable item fit statistics, and strong internal consistency support its use in both research and applied contexts. Notably, the instrument's precision in detecting individual differences and the absence of floor or ceiling effects suggest its practical utility for routine assessments within clinical settings. Beyond its measurement properties, the T-PES-5 holds potential as a diagnostic tool for hospital administrators and nursing leaders. Data derived from the instrument could inform targeted interventions aimed at improving workplace conditions by for instance identifying areas where nurses lack participation in decision-making or where managerial support is perceived as insufficient. By translating assessment findings into policy or practice changes, healthcare institutions can promote more supportive, equitable, and effective work environments.

Additional Information

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Ethics Approval: Permission to use the original PES-5 instrument was obtained from the author prior to the commencement of the study. Ethical approval was subsequently granted by the Institute for the Development of Human Research Protections (IHRP), Health Systems Research Institute (HSRI), Thailand (IHRP2024184 on 23 December 2024). The study was conducted in full compliance with the ethical principles outlined in the Declaration of Helsinki.

Clinical Trial Consideration: This study does not report on a clinical trial.

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Author Contributions:

Conceptualization: All authors

Formal Analysis: Vachira Posai, Niphon Watada

Funding Acquisition: Vachira Posai

Investigation: Vachira Posai, Niphon Watada, Supisara Phonkrut, Supitcha Udomchai

Supervision: Armarapas Attachaiwat, Teeraporn Sathira-Angkura, Kanogporn Jamsomboon, Uraiporn Janta-Um-Mou, Patcharee Kladjomphong

Writing – Original Draft: Vachira Posai, Niphon Watada, Supisara Phonkrut, Supitcha Udomchai

Writing – Review & Editing: Vachira Posai

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Incidence and Types of Cardiac Arrhythmias Detected by Telemetry Monitoring in Hospitalized Patients at a Tertiary Care Hospital

Sopita Areerob¹ , Urasri Imsomboon^{1*} , Rungaroon Phuengyaem¹ , Krissada Meemook¹ ,
Naline Niyomthai¹ , Chaiwat Wanchuay¹ 

¹ Nursing Services Division, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Abstract

Background: Cardiac arrhythmia constitutes a significant clinical complication among hospitalized patients, with elevated prevalence in individuals presenting with underlying cardiovascular pathology. Continuous telemetry monitoring provides real-time electrocardiographic surveillance, facilitating prompt arrhythmia detection and therapeutic intervention. Despite widespread clinical implementation globally, Thailand lacks standardized hospital guidelines governing telemetry monitoring utilization.

Objective: To determine the incidence, classification, and morphological characteristics of cardiac arrhythmias in patients subjected to continuous telemetry surveillance at a tertiary medical hospital in Thailand.

Methods: A cross-sectional study was conducted at Ramathibodi Hospital. The study comprised 331 hospitalized patients aged 18 years or older who received telemetry monitoring between June 2022 and December 2022. Clinical data were systematically extracted from electronic health records and subjected to descriptive statistical analysis.

Results: Among 331 monitored patients, cardiac arrhythmias were documented in 212 patients (64.05%). According to the American Heart Association classification criteria, most patients were categorized as class II (118 of 212 patients, 55.60%). Out of the 387 detected episodes, premature ventricular contractions constituted the most frequently observed arrhythmic pattern (34.37%), followed by premature atrial contraction (19.90%) and atrial fibrillation (15.76%). Conservative clinical observation represented the predominant management approach (41.69%). Hospital discharge constituted the primary indication for telemetry monitoring discontinuation (59.21%).

Conclusions: This study demonstrated a substantial incidence of cardiac arrhythmias under continuous telemetry surveillance, with premature ventricular contractions representing the most prevalent finding. These findings underscore the clinical utility of telemetry monitoring in hospitalized patients and support the development of standardized monitoring protocols in Thai healthcare hospitals.

Keywords: Arrhythmias, Cardiac, Telemetry, Incidence, Electrocardiography, Hospitalization

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* **Corresponding Author:**
urasri.ims@mahidol.ac.th

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Introduction

Cardiovascular diseases constitute a predominant global health burden, representing the leading cause of mortality worldwide. According to the World Health Organization (WHO) statistics from 2019, cardiovascular pathologies accounted for approximately 17.9 million deaths, constituting 32.1% of global mortality.¹ In Thailand, the Division of Non Communicable

Disease Control under the Ministry of Public Health documented an incidence of 554.8 cardiovascular disease cases per 100 000 population in 2022.² Cardiac pathophysiology may arise from structural cardiac abnormalities, myocardial ischemia, or compromised ventricular contractility, all of which can disrupt the cardiac electrical conduction system and precipitate arrhythmic events.³

Cardiac arrhythmias are defined as abnormalities in cardiac rhythm resulting from aberrant electrical conduction manifesting as excessively rapid or delayed impulse propagation, ultimately producing irregular cardiac rhythm patterns. Clinical presentations commonly include palpitations, perceived skipped cardiac beats, bradycardic or tachycardic episodes, chest discomfort, presyncope, or transient loss of consciousness.⁴

Contemporary technological advances and evolving medical knowledge have facilitated the development of diverse monitoring modalities of the electrocardiography (ECG) beyond conventional 12-lead ECG, which remains the gold standard for detecting cardiac electrical abnormalities in hospitalized patients. Ambulatory ECG monitoring enables continuous rhythm surveillance while preserving patients' normal daily activities, thereby facilitating detection of intermittent arrhythmias not observable during hospitalization or routine ambulatory encounters. These technologies encompass continuous 24-48-hour Holter monitoring and intermittent recording devices, including patient-activated event recorders and loop recorders, which provide targeted arrhythmia capture capabilities.⁵⁻⁸

In critical care and intermediate care units, continuous bedside cardiac monitoring provides round-the-clock rhythm surveillance. Additionally, telemetry monitoring — a mobile ECG system utilizing radiofrequency signal transmission to central receivers — offers enhanced patient mobility while maintaining continuous cardiac surveillance. Telemetry devices are compact monitoring systems typically employed for patients who no longer require intensive care but necessitate ongoing arrhythmia surveillance, enabling ambulatory activities within the transmission range while providing continuous ECG data acquisition.

However, optimal ECG monitoring modality selection depends upon specific clinical indications and physician clinical judgment. Consequently, telemetry monitoring implementation generally follows 2 operational models: specialized step-down cardiovascular units providing comprehensive telemetry surveillance for all admitted patients with real-time monitoring of vital signs, cardiac rhythm, and oxygen saturation; or distributed patient care across general wards with centralized ECG monitoring, where abnormality alerts are communicated to ward nursing staff or attending physicians for timely clinical intervention.⁹⁻¹²

The American College of Cardiology has established clinical practice guidelines for ECG monitoring of hospitalized patients at risk for cardiac arrhythmias requiring diagnostic surveillance. The 2004 guideline first established standardized criteria for inpatient ECG monitoring using telemetry, categorized by clinical indications and disease classifications to minimize inappropriate utilization and reduce healthcare expenditures. The guidelines classify patients into 3 risk categories: class I encompasses high-risk patients requiring mandatory continuous ECG monitoring due to life-threatening arrhythmia potential; class II includes moderate-risk patients for whom telemetry monitoring may provide clinical benefit in selected cases; and class III comprises low-risk patients for whom telemetry is generally contraindicated but may be considered in specific clinical contexts.^{8, 12-14} In resource-constrained healthcare environments, particularly in developing nations like Thailand, the implementation of comprehensive telemetry monitoring systems presents significant challenges. These systems require substantial capital investment in sophisticated

equipment and necessitate specialized personnel with expertise in cardiac rhythm interpretation and device management. Consequently, the widespread adoption of telemetry monitoring remains limited, resulting in a paucity of research examining arrhythmia detection through these modalities in Thai healthcare settings. Thailand has not formally adopted these standardized criteria into routine clinical practice. Current decisions regarding initiation and discontinuation of inpatient cardiac telemetry monitoring remain predominantly dependent upon individual physician clinical judgment and hospital-specific protocols.

At Ramathibodi Hospital, a leading tertiary medical hospital in Thailand, the American College of Cardiology guideline remain unimplemented. Current practice involves monitoring some patients until discharge or device reallocation to higher-priority cases, potentially creating equipment shortages during the high-demand period. The absence of standardized telemetry protocol presents several challenges in the current clinical practice. These include potential overutilization of telemetry resources for low-risk patients, suboptimal resource allocation during the high-demand periods, and lack of evidence-based criteria for initiation and discontinuation of the ECG monitoring. Such practices may result in an inefficient healthcare resource utilization and potentially compromise optimal patient care delivery.

Ramathibodi Hospital operates 3 centralized telemetry monitoring centers, providing surveillance services for medical, surgical, and pediatric patients admitted to general wards requiring arrhythmia monitoring. Hospital utilization statistics demonstrate increasing trends in telemetry monitoring service demand, with 732, 814, and 809 patients utilizing these services in 2019, 2020, and 2021, respectively. In developed healthcare systems, data on telemetry monitoring, including detected arrhythmias, undergoes systematic analysis to develop evidence-based protocols for enhancing patient management accuracy and timeliness, facilitating appropriate therapeutic interventions and optimizing clinical outcomes.¹⁵⁻¹⁷ Currently, standardized protocols and criteria for initiation of telemetry monitoring remain absent from the hospital practice. Existing workflow requires cardiology consultation prior to the device discontinuation. Duration of the monitoring often extends until the patient discharge regardless of clinical necessity, with device discontinuation primarily driven by equipment demand for newly admitted patients rather than evidence-based clinical indication. ECG interpretation and clinical communication protocols are contingent upon the operational context of individual service units and the experiential competency of the nursing personnel.

However, limited research has examined the prevalence and characteristics of arrhythmias detected through telemetry monitoring in Thai healthcare settings. This knowledge gap is particularly significant given the resource-intensive nature of telemetry systems and the need for evidence-based utilization criteria in resource-limited environment. The absence of local data regarding arrhythmia incidence and patterns detected through telemetry surveillance impedes the development of appropriate clinical protocols and resource allocation strategies. Therefore, this study aimed to investigate the incidence and characteristics of cardiac arrhythmias detected through telemetry monitoring in hospitalized patients at a tertiary care medical hospital in Thailand. The findings will provide fundamental epidemiological data to support evidence-based development of service models, clinical protocols, and resource management strategies for telemetry monitoring systems, ultimately optimizing patient care delivery and organizational efficiency in resource-sensitive healthcare environments.

Methods

Participants

A cross-sectional study design was implemented at Ramathibodi Hospital, a tertiary care medical hospital. The study population comprised hospitalized patients receiving telemetry monitoring as prescribed by their attending physicians. Sample size determination was conducted utilizing the n4studies statistical software platform, with population data derived from hospital electronic health records spanning 2019 to 2021, revealing 2355 patients who underwent telemetry monitoring during this period. Employing a proportion of 0.50, a margin of error of 5%, and a significance level of .05, the requisite sample size was calculated to be 331 participants. Participant selection was executed through a purposive sampling method.

The inclusion criteria were patients aged 18 years or older. Patients who were prescribed telemetry monitoring between 1 June 2023 and 31 December 2023. Patients diagnosed with at least 1 type of cardiac arrhythmia, confirmed by a physician.

The exclusion criteria were patients with a history of confusion or dementia during hospitalization, rendering them unable to cooperate with telemetry monitoring, and severe skin lesions at the chest wall that prevented the proper placement of electrodes.

Data Collection

The data collection instrument comprised 3 distinct forms and was developed by the principal investigator through a systematic review of pertinent literature. Content validity was established using content validity index (CVI), assessed by 3 experts: a cardiologist, a critical care nursing specialist, and a cardiovascular nursing faculty member. The scale-CVI/average (S-CVI/Ave) was 0.80, meeting the acceptable criterion (≥ 0.80).

Section 1: personal information form – included demographic such as age, sex, marital status, educational level, healthcare entitlement, and clinical data including underlying diseases, smoking and alcohol consumption, cardiac surgeries or procedures, medications, and initial diagnosis.

Section 2: AHA classification form – that classified patients based on the American Heart Association (AHA) guideline for cardiac monitoring indications in hospitalized patients into 3 risk categories: class I, high risk for immediate life-threatening arrhythmias, requiring continuous telemetry; class II, moderate risk, for whom telemetry may be beneficial in selected cases; and class III, low risk, where telemetry is generally not indicated but may assist in clinical decisions.

Section 3: arrhythmia event recording form – included initial ECG findings, types of arrhythmias detected, time (in days) from telemetry initiation to detection, clinical management strategies, and reasons for discontinuing the telemetry monitoring.

Following an ethics approval, formal authorization was obtained from the director of Ramathibodi Hospital to access patient data via hospital's electronic medical record system. The principal investigator and research team executed data collection and documentation procedures utilizing Excel version 2019 (Microsoft Corp). Data access was restricted exclusively to designated members of the research team.

Statistical Analysis

Descriptive statistical analyses were performed using Excel version 2019. Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as mean (SD).

Results

A total of 331 patients were included in the study, with a mean (SD) age of 63.67 (19.73) years (median [range], 64.5 [23-97] years). Most patients were male (55.29%), aged 70 years and over (58.31%) with government insurance coverage (61.33%). Educational levels included bachelor's degree or equivalent in 32.02%, primary education in 29.91%, and secondary education in 21.15%. Regarding occupation, most patients were retired or unemployed (62.13%), followed by government employees/civil servants (10.44%), company employees (6.96%), traders/business owners (17.30%), farmers (3.18%), and other occupations (32.50%). Most patients were nonsmokers (323 patients, 97.58%) and nondrinkers or former drinkers (98.79%). Preexisting comorbidities were present in 90.33%, predominantly hypertension (66.16%), dyslipidemia (53.17%), and coronary artery disease (22.66%). Diabetes mellitus, heart failure, and atrial fibrillation affected 33.53%, 12.69%, and 29.91%, respectively. Previous cardiac interventions occurred in 57.70%, mainly coronary angiography/percutaneous coronary intervention in 89.53%.

Most patients were on regular medications (92.75%). Among these patients, lipid-lowering agents were most frequently prescribed (72.31%), followed by proton pump inhibitors (61.24%), beta-blockers (57.0%), and antiplatelet agents (54.07%). Cardiovascular system-related medications were also prevalent, including anticoagulants (37.46%), diuretics (36.81%), angiotensin-converting enzyme inhibitors/angiotensin II receptor blockers (24.1%), and calcium channel blockers (21.82%). Antiarrhythmic agents included amiodarone (12.70%) and digoxin (4.56%). Additional medications comprised antianxiety agents (36.81%), hypoglycemic agents (25.08%), and antidepressants (9.45%).

Primary admission diagnoses included acute coronary syndrome (9.06%), cardiac arrhythmias (11.48%), and congestive heart failure (12.39%). Mean (SD) hospital length of stay was 19.46 (31.49) days (median [range], 35.5 [1-276] days), with mean (SD) duration of cardiac telemetry monitoring of 154.1 (166.8) hours (median [range], 336 [24-1656] hours). Time-to-detection data, the mean (SD) time from telemetry initiation to detection was 58.8 (67.2) hours (median [range], 24 [24-720] hours). Most events were identified early: 200 events (51.7%) within the first 24 hours and 315 events (81.4%) within the first 72 hours. Only 17 events (4.4%) required more than 168 hours for detection.

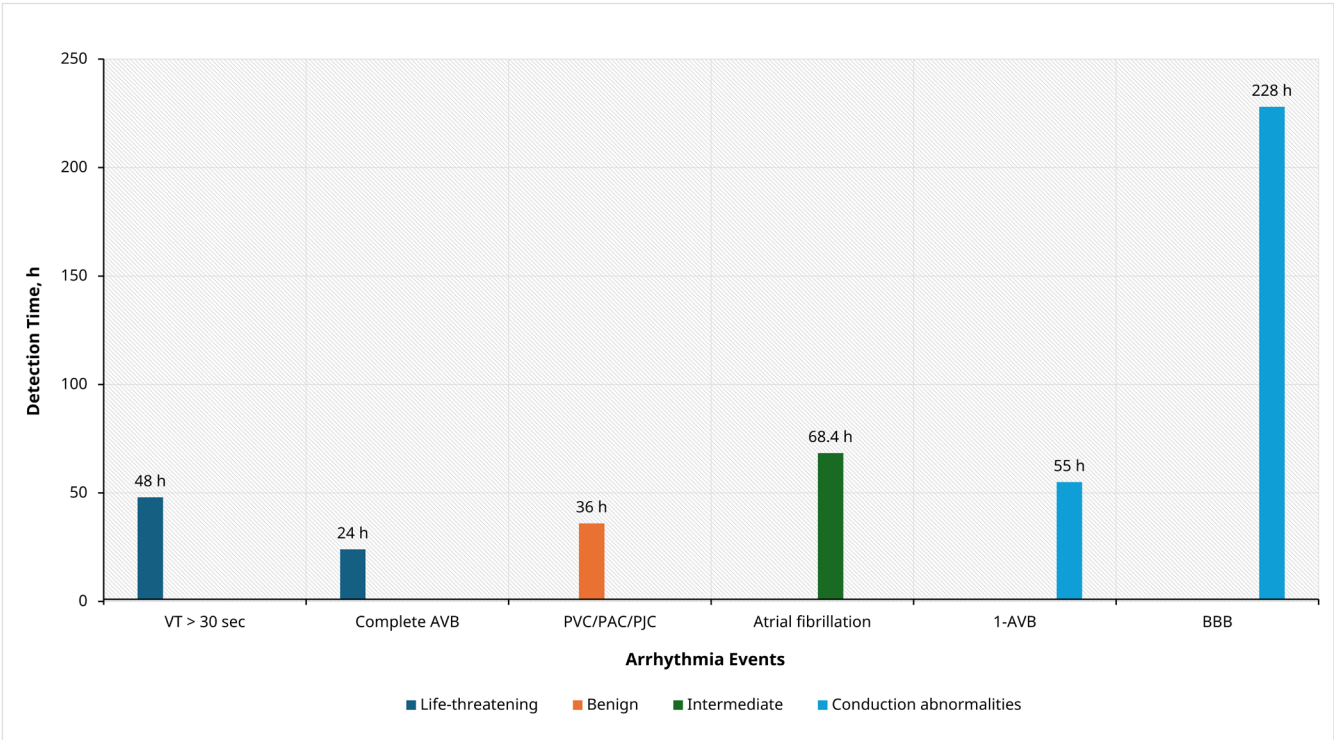
Life-threatening arrhythmias demonstrated early detection (complete atrioventricular block: 24 hours; ventricular tachycardia > 30 seconds: 48 hours). Benign arrhythmias were also detected relatively early, with 90% to 100% of premature contractions (premature ventricular contraction [PVC], premature atrial contraction [PAC], premature junctional contraction [PJC]) identified within 72 hours. Atrial fibrillation showed intermediate detection timing (mean [SD], 68.4 [50.4] hours), with 75.4% detected within 72 hours. Conduction abnormalities varied considerably, from first-degree atrioventricular block (mean [SD], 55.0 [45.6] hours) to bundle branch blocks requiring extended monitoring (mean [SD], 228 [153.6] hours). These findings suggest that 72-hour monitoring captures most clinically significant arrhythmic events (Figure 1).

Of the 331 patients undergoing cardiac telemetry monitoring, arrhythmias were detected in 212 patients (64.05%). Most arrhythmias were detected in AHA class II in 118 patients (55.60%), managed primarily through observation in 138 patients (65.09%) or medication adjustment in 36 patients (16.98%). Most patients were discharged home upon monitoring completion (196 patients, 59.21%) (Table 1).

A total of 387 abnormal ECG events were detected among 331 patients. The events were classified according to AHA risk levels for cardiac monitoring indications in

hospitalized patients. PVCs were the most frequent abnormality (34.37%), followed by PACs/nonconducted PACs (19.90%) and atrial fibrillation (15.76%). Nonsustained ventricular tachycardia occurred in 7.24%, while first-degree atrioventricular block was observed in (5.43%) (Table 2). The distribution across risk classes showed that class II events predominated, representing over half of all detected arrhythmias, while class III cases, which were categorized as low-risk, high-risk events were identified in approximately 10% of cases, accounting for 10% of all detected abnormalities (Figure 2).

Figure 1. Mean Detection Time From Telemetry Initiation to Arrhythmia Detection



Abbreviations: AVB, atrioventricular block; BBB, bundle branch block; PAC, premature atrial contraction; PJC, premature junctional contraction; PVC, premature ventricular contraction; VT, ventricular tachycardia.

Table 1. Incidence of Cardiac Arrhythmias Detected by Telemetry Monitoring and Classification by Severity	
Patient Information	No. (%)
Patients classified by ECG findings (n = 331)	
No arrhythmia detected	119 (35.95)
Arrhythmia detected (classified by AHA)	212 (64.05)
AHA class I	74 (35.00)
AHA class II	118 (55.60)
AHA class III	20 (9.40)

Table 1. Incidence of Cardiac Arrhythmias Detected by Telemetry Monitoring and Classification by Severity (Continued)

Patient Information	No. (%)
Clinical management in patients with detected arrhythmia (n = 212)	
Observation	138 (65.09)
Medication adjustment (initiation/titration)	36 (16.98)
Bedside cardioversion	2 (0.94)
Permanent pacemaker/ defibrillator (insertion/revise)	10 (4.72)
Coronary angioplasty/ stent placement	2 (0.94)
Transfer to ICU/CCU	13 (6.13)
Additional diagnostic tests	11 (5.19)
Reasons for telemetry discontinuation (n = 331)	
No further clinical indication	104 (31.42)
Discharge home	196 (59.21)
Transfer to ICU/CCU	31 (9.37)
Due to cardiac arrhythmia, No.	12
Due to respiratory problem, No.	3
Due to sepsis/septic shock, No.	4
Due to hemodynamic instability, No.	10
Other reasons, No.	2

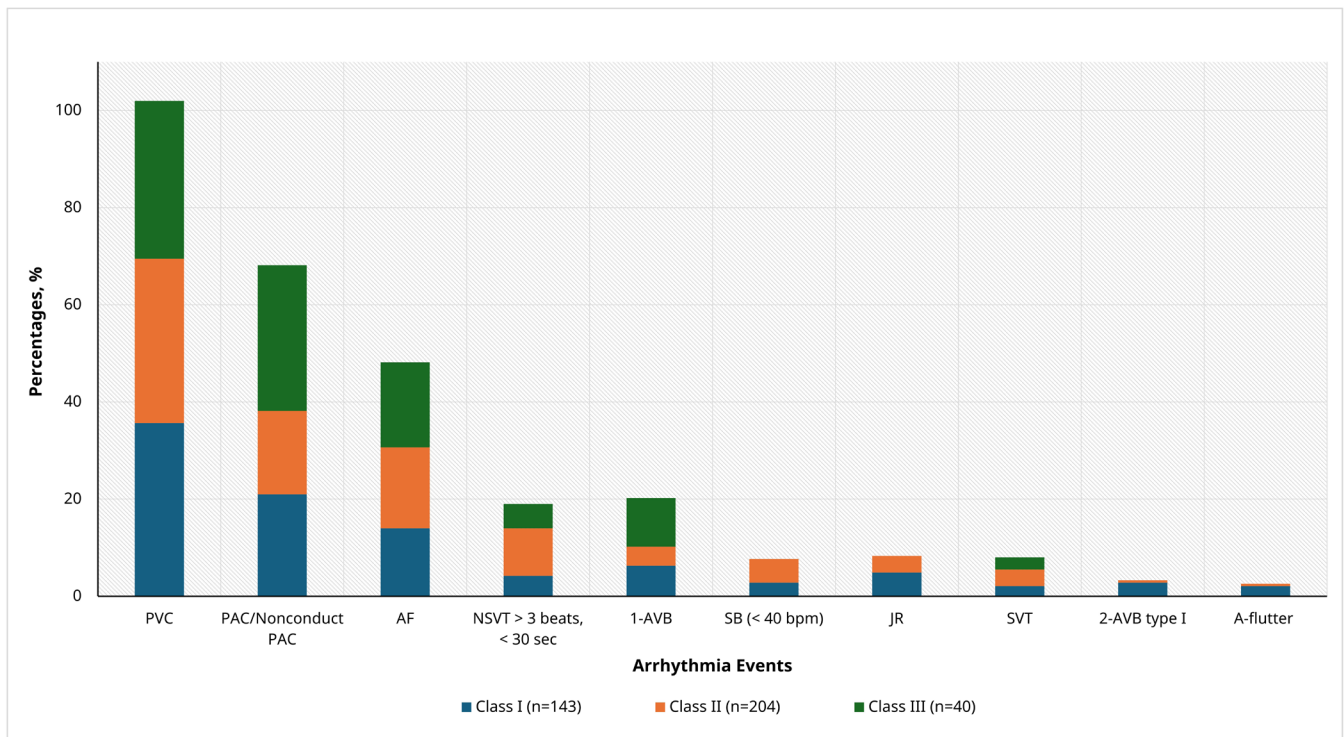
Abbreviations: AHA, American Heart Association; CCU, cardiac care unit; ECG, electrocardiogram; ICU, intensive care unit.

Table 2. Number of Abnormal Electrocardiogram Events Classified by the American Heart Association Indication Risk Levels

Type of Cardiac Arrhythmia*	Total Events (n = 387)	Class I (n = 143)	Class II (n = 204)	Class III (n = 40)
Ventricular tachycardia > 30 sec	1 (0.26)	0	1 (0.49)	0
Nonsustained ventricular tachycardia > 3 beats but < 30 sec	28 (7.24)	6 (4.20)	20 (9.80)	2 (5.00)
Supraventricular tachycardia	11 (2.84)	3 (2.10)	7 (3.43)	1 (2.50)
Atrial fibrillation	61 (15.76)	20 (13.99)	34 (16.67)	7 (17.50)
Atrial-flutter	4 (1.03)	3 (2.10)	1 (0.49)	0
Sinus bradycardia (heart rate < 40 bpm)	14 (3.62)	4 (2.80)	10 (4.90)	0
Pause > 3 sec	6 (1.55)	0	6 (2.94)	0
Junctional rhythm	14 (3.62)	7(4.90)	7 (3.43)	0
Third-degree atrioventricular block	1 (1.55)	1 (0.70)	0	0
Second-degree atrioventricular block type I	5 (1.29)	4 (2.80)	1 (0.49)	0
Second-degree atrioventricular block type II	3 (0.78)	2 (1.40)	1 (0.49)	0
First-degree atrioventricular block	21 (5.43)	9 (6.29)	8 (3.92)	4 (10.00)
Premature atrial contraction/nonconduct premature atrial contraction	77 (19.90)	30 (20.98)	35 (17.16)	12 (30.00)
Premature ventricular contraction	133 (34.37)	51 (35.66)	69 (33.82)	13 (32.50)
Premature junctional contraction	4 (1.03)	2 (1.40)	1 (0.49)	1 (2.50)
ST-segment change	2 (0.52)	1 (0.70)	1 (0.49)	0
Bundle branch blocks	2 (0.52)	0	2 (0.98)	0

* More than 1 arrhythmia type per patient was possible; the total number of events was 387, with 331 patients.

Figure 2. Percentages of Arrhythmia Types Among Patients Stratified by the American Heart Association Telemetry Indication Categories



Abbreviations: A-flutter, atrial-flutter; AF, atrial fibrillation; AVB, atrioventricular block; JR, junctional rhythm; NSVT, nonsustained ventricular tachycardia; PAC, premature atrial contraction; PVC, premature ventricular contraction; SB, sinus bradycardia; SVT, supraventricular tachycardia.

Discussion

This study demonstrated that arrhythmias were detected in 64.05% of patients undergoing telemetry monitoring, substantially exceeding previously reported rates in telemetry monitoring studies.^{12, 14} This discrepancy primarily reflects methodological differences in arrhythmia classification criteria. When excluding benign events (PVCs, PACs, PJs), the incidence was 35.3%, aligning with established literature and validating the reproducibility of clinically significant arrhythmia detection.^{11, 12, 14}

Among 387 abnormal ECG events were predominantly detected in AHA class II (55.60%) and class I (35%), representing largely benign arrhythmias managed conservatively through observation (65.09%). Only 3.77% required permanent pacemaker implantation and 5.66% needed coronary intervention or ICU transfer, indicating minimal immediate clinical impact for most detected events. The most frequent arrhythmias were PVCs (34.37%), PACs (19.90%), and atrial fibrillation (15.76%), reflecting the typical spectrum in hospitalized cardiac patients.^{8, 11, 12}

Clinical Implications and Resource Management

The predominance of benign arrhythmias requiring only observational management, combined with 81.4% of events detected within 72 hours (mean [SD], 58.8 [67.2] hours), indicates significant opportunities for optimizing telemetry resource allocation. Life-threatening

arrhythmias demonstrated early detection (24-48 hours), while benign arrhythmias were also identified early within 72 hours. Given the current mean (SD) monitoring duration of 154.1 (166.8) hours (approximately 6.4 days), these temporal patterns suggest that most clinically relevant events were detectable within a 72-hour period.^{8, 12}

Healthcare systems should consider implementing time-limited monitoring protocols, reducing duration for low-risk patients while prioritizing AHA class I patients for extended monitoring. System-level impacts include optimized bed occupancy, reduced nursing workload, and prevention of telemetry overuse, particularly given that only 4.4% of events required more than 7 days for detection.^{11, 12}

Standardized Notification Protocols

The absence of standardized protocols for arrhythmia notification presents a significant clinical practice gap. Currently, decisions regarding physician notification depend primarily on individual nursing experience and judgment, creating potential for both over-notification of benign events and under-notification of clinically significant arrhythmias. While no adverse incidents have been documented from current practices, the variability in notification approaches may lead to inefficient physician workload distribution and potential delays in appropriate clinical responses.

The development of evidence-based notification guidelines stratified by AHA classification and arrhythmia type could significantly reduce inappropriate alerts while ensuring timely communication of clinically significant events. Such protocols should delineate immediate notification criteria for life-threatening arrhythmias (sustained ventricular tachycardia, complete heart block), routine notification schedules for moderate-risk events (atrial fibrillation, nonsustained ventricular tachycardia), and documentation-only requirements for benign arrhythmias (isolated PVCs, PACs). Implementation of standardized notification protocols could optimize physician-nurse communication efficiency while maintaining patient safety standards.^{8, 12, 13}

Medication-Related and Postoperative Factors

The high prevalence of polypharmacy (92.75%), particularly diuretic administration, highlighting medication-related arrhythmia risk through electrolyte imbalances.^{18, 19} Proactive electrolyte monitoring and correction could reduce clinically insignificant events and optimize telemetry utilization. For patients with previous cardiac interventions (57.70%), standardized postoperative protocols with defined monitoring durations could improve efficiency while maintaining patient safety.^{18, 20-23} The current practice of continuous monitoring until discharge regardless of clinical necessity suggests potential for protocol refinement, such as routine (24-48 hour) telemetry after percutaneous coronary intervention for uncomplicated cases.^{21, 24}

Study Limitations

Key limitations include single-center design, purposive sampling methodology, and cross-sectional design, limiting generalizability and precluding causal inference.⁷ Additional constraints encompass lack of standardized telemetry criteria, absence of long-term outcome assessment, and missing content validity evaluation. These methodological limitations affect applicability to diverse healthcare settings with varying patient populations and monitoring protocols.

Future Research Directions

Prioritized research areas include multicenter validation of refined telemetry criteria, cost-effectiveness analyses of risk-stratified protocols, and prospective guideline implementation evaluations.^{12, 16} Development of predictive models for high-risk patient identification and integration of artificial intelligence for real-time arrhythmia classification represent opportunities for optimizing resource utilization.

Additionally, validation of standardized notification protocols for different arrhythmia types is needed to address current practice variability and optimize physician-nurse communication efficiency. Studies examining optimal monitoring durations for specific patient populations and post-procedural requirements would support more targeted telemetry utilization strategies.

These findings support development of protocols distinguishing patients requiring continuous surveillance from patients that can be managed with less intensive monitoring. Study limitations include single-center design, purposive sampling, and cross-sectional study limiting generalizability. Future research should focus on multicenter validation, predictive model development, and cost-effectiveness analyses to inform evidence-based guidelines for resource optimization of cardiac monitoring.^{12, 16}

Conclusions

This study identified arrhythmias in 64.05% of telemetry-monitored patients, with predominantly benign events (55.60% of AHA class II) and can be managed conservatively (65.09%). The high detection rate of clinically insignificant arrhythmias emphasizes the need for standardized, risk-stratified telemetry criteria to optimize resource utilization while maintaining patient safety.

Additional Information

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Ethics Approval: This study was approved by the Human Research Ethics Committee of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University (MURA2023/154 on 3 March 2023). The study strictly adhered to ethical principles involving human participants. Patient confidentiality was protected by using anonymized ID codes instead of names, and the results were presented in aggregate form to ensure data privacy.

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Author Contributions:

Conceptualization: Urasri Imsomboon, Krissada Meemook, Naline Niyomthai, Sopita Areerob, Rungaroon Phuengyaem

Formal Analysis: Chaiwat Wanchuay, Urasri Imsomboon

Funding Acquisition: Sopita Areerob

Investigation: Sopita Areerob, Urasri Imsomboon, Rungaroon Phuengyaem

Methodology: Urasri Imsomboon

Writing – Original Draft: Sopita Areerob, Urasri Imsomboon, Chaiwat Wanchuay

Writing – Review & Editing: Urasri Imsomboon, Krissada Meemook

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Intraoperative Anxiety and Its Associated Factors Among Patients Undergoing Conscious Surgery for Closed-Leg Fracture

Xue Zhang^{1, 2}, Niphawan Samartkit^{3*} , Khemaradee Masingboon³ 

¹ Nursing Science Program, Faculty of Nursing, Burapha University, Chon Buri, Thailand

² Department of Operating Room, The Second Affiliated Hospital and Yuying Children's Hospital, Wenzhou Medical University, Wenzhou, China

³ Department of Adult Nursing, Faculty of Nursing, Burapha University, Chon Buri, Thailand

Abstract

Background: Patients undergoing open reduction and internal fixation surgery frequently opt for spinal anesthesia, which preserves intraoperative consciousness. This conscious state may trigger significant anxiety during surgical procedures. Despite the clinical relevance of this phenomenon, intraoperative anxiety among conscious patients remains under-recognized in Chinese surgical populations. Many scholars have conducted extensive research on preoperative and postoperative anxiety levels. However, a study on the level of intraoperative anxiety and its' related factors is still lacking. This knowledge gap motivated the current investigation.

Objectives: To examine the level of intraoperative anxiety and the relationship between gender, age, waiting time, surgical time and intraoperative anxiety among patients with closed-leg fracture undergoing conscious surgery.

Methods: A total of 112 participants were recruited during February 2025 to April 2025 by selecting samples as per the inclusion criteria and using random sampling. Research instruments include the demographic questionnaire and the Visual Analog Scale for Anxiety (VAS-A). Data were analyzed using descriptive statistics, the independent *t* test, and the Pearson correlation coefficient.

Results: The mean (SD) intraoperative anxiety was 6.3 (2.2), which indicates a clinically-relevant level of anxiety. There was a significant difference in the experience of intraoperative anxiety between female and male patients ($t = -3.92$, $P < .001$). Age, waiting time, and surgical time had a positive correlation with intraoperative anxiety among the patients undergoing conscious surgery ($r = 0.221$, $P < .05$; $r = 0.307$, $r = 0.346$, $P < .001$, respectively).

Conclusions: The findings provide a reference for healthcare providers to better understand the factors contributing to intraoperative anxiety of patients with closed-leg fracture undergoing conscious surgery, allowing for early identification of high-risk individuals, and targeted interventions, thereby preventing and alleviating intraoperative anxiety, reducing anxiety-related physiological response, minimizing complication risk, and promoting postoperative recovery.

Keywords: Age, Conscious surgery, Gender, Intraoperative anxiety, Surgical time, Waiting time

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* Corresponding Author:
nsamartkit@gmail.com

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Introduction

Bone fractures are a public health problem worldwide, and may cause serious disease and economic burden.¹ According to the National Bureau of Statistics of China, more than 250 000 people were injured in traffic accidents in 2020.² Moreover, electric scooters are popular in urban areas of China, which are associated with many orthopedic injuries.³ Closed-leg fractures were a prevalent clinical condition, which accounted for just over 1 in 4 trauma fracture patients.⁴ Meanwhile, fractures often lead to loss of basic functional capabilities, requiring patients to need extensive support for daily living activities.⁵ A fracture frequently imposes significant practical demands, emotional distress, and potential safety risks. These consequences may lead to a remarkable psychological burden, as 4 out of 5 traumatic fracture patients experience psychological disorders (anxiety, depression, fear), severely undermining recovery.⁶

Early surgical intervention is an effective treatment for most closed-leg fractures.⁷ The procedure aims to provide anatomical restoration and immediate stability, thereby facilitating earlier mobilization for leg fractures.^{8, 9} However, surgery is also a strong stimulus, which can affect the physical and mental health of the patient.¹⁰ More than 80% of traumatic fracture patients have different degrees of psychological disorder, manifested as anxiety, depression, fear, and other negative emotions.⁶ Anxiety has been reported in 60%-80% of adult patients who undergo surgery.¹¹ Mitchell¹² reported that approximately three-quarters of patients experienced anxiety during surgery. Anxiety is experienced at different levels of severity during the intraoperative period. Haugen et al¹³ reported that 1 in 3 patients felt anxiety in the intraoperative period. Developments in anesthesiology have led to the increased use of local anesthesia, whereby the patient is conscious during the surgery.

In this research study 'conscious surgery' refers to the use of local anesthesia technology to cause reversible loss of sensation and muscle contraction in a limited area of the body without changing the patient's level of consciousness. The benefits of conscious surgery include decreased operative time, less postoperative opioid use, decreased recovery time, and better patient satisfaction.¹⁴ A growing number of published studies have highlighted the advantages of conscious sedation over general anesthesia, including decreased blood loss, fewer medical complications, and better postoperative pain control.¹⁵ Most of these studies have suggested that local anesthesia is associated with improved perioperative outcome, and they make the case that local anesthesia is superior to general anesthesia (other factors being equal) since there tends to be a lower risk of perioperative complications, rates of nausea and vomiting, reduced blood loss, and reduced length of hospital stay, thereby reducing the hospital-related cost and caseload burden.¹⁶⁻¹⁸

However, conscious surgery can cause a range of fear and anxiety.¹⁹ Usually, undergoing conscious surgery, the patient is alert, and can experience everything that is perceptible or imagined during the procedure.²⁰ Patients who have undergone surgery with spinal anesthesia have often described the operating room as a scary, bizarre, and frightening place. Those patients reported feeling agitated, anxious, and concerned while in the operating room.²¹ The unfamiliar environment of the operating room, the alarms of the monitoring devices, and the noises related to surgical instruments are important causes of intraoperative anxiety.^{13, 22} Additionally, external interventions such as wound dressings, traction, and patient restrained to restricted mobility may further exacerbate discomfort.²³ Many patients undergoing conscious surgery have reported anxiety related to the narrow operating table, low light conditions, and unsettling noises

from drilling, sawing, and/or cutting.²⁴ In addition, excessive anxiety in the surgery patient can have negative consequences on anesthesia.

Anxiety may lead to an increase in the levels of stress hormones, resulting in increased arterial blood pressure, heart rate, and high systemic catecholamine levels.²⁵ Physiological effects of anxiety can require higher dosages of medication during anesthesia.²⁶ Intraoperative anxiety may exacerbate pain perception and decrease the tolerance to pain.²⁷ Furthermore, empirical evidence has confirmed that anxiety adversely affects wound healing, and the associated physiological changes may cause an increased risk of infection and prolonged wound-healing time.²⁸ Therefore, interventions to reduce intraoperative anxiety can help maintain normal blood pressure, heart rate, and respiratory rate, and decrease the need for post-surgery sedative drugs.²⁹ In addition, alleviating the intraoperative anxiety of patients may reduce the occurrence of postoperative complications and even shorten the postoperative recovery time.¹⁸

Among orthopedic and trauma patients, intraoperative anxiety was associated with multiple factors. Evidence has demonstrated that gender differences may significantly influence a patient's anxiety level during the intraoperative period. Studies have found that female patients exhibit higher anxiety scores than their male counterparts.^{5, 22, 30} Studies have found a significant relationship between age and intraoperative anxiety; young adults typically exhibit heightened fear of the unknown due to limited experience in managing major stressful events. The actual anxiety level depends on individual psychological resilience, social support, financial status, and occupational characteristics.³¹ Some studies have found that the greater life experience and coping strategies of older patients helped to moderate the anxiety effects.³² By contrast, other studies have found that elderly patients had the highest anxiety level among patients. Moreover, lengthy preanesthetic waiting time induced a higher level of intraoperative anxiety.³³ As surgery time increases, anxiety increases in patients undergoing orthopedic surgeries under spinal anesthesia.³⁴ Consequently, enhancing operative efficiency and minimizing waiting time and surgical time should be effective strategies to mitigate a patient's anxiety level during surgery.^{11, 35}

Many scholars have conducted extensive research on the preoperative and postoperative anxiety levels of different surgical populations. However, the research on the related factors of intraoperative anxiety and the degree of anxiety of patients is still lacking. Healthcare professionals need to understand patient anxiety, and should be able to implement strategies to reduce the anxiety, including techniques that improve the patient's overall surgical experience and ensure a smooth procedure. This study examined conscious patient intraoperative anxiety and its related factors as a basis for developing effective interventions to relieve anxiety and promote postoperative recovery of patients undergoing conscious surgery.

This study aimed to describe the level of intraoperative anxiety in patients with closed-leg fracture undergoing conscious surgery, and examine the relationships between gender, age, waiting time, and surgical time with intraoperative anxiety in patients with closed-leg fracture undergoing conscious surgery.

Methods

Study Design, Setting, and Participants

A descriptive-comparative correlational research design was used in this study, conducted at the Second Affiliated Hospital of Wenzhou Medical University in Wenzhou, China. The study sample comprised the patients who had a closed-leg fracture, and were admitted

in the orthopedic ward. In addition, participants were scheduled for open reduction and internal fixation surgery in an awake state, at the Second Affiliated Hospital of Wenzhou Medical University in Wenzhou, China. The sample was recruited by random sampling, using the following inclusion criteria: 1) age at least 18 years; 2) diagnosed with one leg fracture, including fracture femur, fracture tibia, fracture fibula, or fracture both bones; 3) no injury in other organs; 4) no history of anesthesia and surgery; and 5) normal hearing and writing skills. Patients requiring intraoperative conversion to general anesthesia or deep sedation were excluded. The sample size in this study was calculated by using the G*Power 3.0.10 program for correlational research design. The researchers specified a medium-effect size ($d = 0.30$), a power of 0.90, and $\alpha = .05$, which generated a prescribed sample size of at least 112 participants. The researchers added 10% for incomplete questionnaires, thus yielding a total sample size of 123 participants.

Instruments

Two questionnaires were used for collecting data: 1) the demographic questionnaire (developed by the researchers) included general information (gender, age, highest educational level, marital status, religion, occupation, annual family income, living place, and healthcare payment scheme), and health information (surgical history, disease history, fracture site, surgery type, anesthesia method, waiting time, and surgical time); and 2) the Visual Analog Scale for Anxiety (VAS-A) was used to measure the intraoperative anxiety level. VAS-A is easy for the average patient to understand, and can be a valid method for measuring subjective feelings that yield interval-level data.³⁶ VAS-A comprises a 10-cm line, on which the participants mark their current degree of anxiety, with the left end of the line being labelled 0 (no anxiety), and the right end being labelled 10 (maximum anxiety). The participants were asked to indicate how anxious they were feeling by marking the appropriate place on the line.³⁷ VAS-A is routinely employed for anxiety assessment in China, with validated and extensive application in measuring intraoperative anxiety.^{38, 39} VAS-A was validated by comparing it with Corah's Dental Anxiety Scale (CDAS) and Spielberger's State Trait Anxiety Inventory (STAI). The result showed that VAS-A score was significantly correlated to CDAS ($P < .0001$), STAI-Y1 ($P < .0001$), and STAI-Y2 ($P < .002$), which confirmed that VAS-A is a reliable indicator of preoperative anxiety and may detect patients with depressive symptoms also. VAS-A scores around 5 cm are effective indicators of the threshold for a clinically meaningful level of preoperative anxiety.⁴⁰

Data Collection

The information for this research was collected from the orthopedic ward and operating theatre. The orthopedic ward nurse searched the registration information to identify patients who met the inclusion criteria. Patients with closed-leg fracture were asked for their verbal consent to participate in the study. Those who agreed were referred to the researchers. The researchers met and informed participants (and any accompanying family members) of the purpose of the study, ethical issues, and human protections of the study. A signed written consent form was then obtained. On average, the study site has a daily caseload of 10 closed-leg fracture patients who are scheduled for open reduction and internal fixation surgery. The data for this study were collected from February 2025 to April 2025.

Statistical Analysis

This study used IBM SPSS 26.0 software (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp; 2019) to analyze the data. Descriptive statistics were used to describe

the demographic data. A *t* test was used to examine the relationship between gender and intraoperative anxiety. Pearson product moment correlation was used to examine the relationship between age, waiting time, surgical time, and intraoperative anxiety.

Results

Demographic Characteristics

More than half of the participants were male (56.9%), while 43.1% were female. The mean (SD) age of the participants was 54.1 (12.2) (range 22-76 years). The largest proportion of participants (56.1%) fell within the 41-59 years age group. Among these participants, nearly half had completed junior/senior high school (48.0%), followed by a bachelor's degree or higher (19.5%). Almost all the participants were married (96.8%), and nearly three-quarters of the participants were employed (73.2%) (Table 1).

Health Information

The most common site of fracture among the participants was tibial fracture (65.1%), while 1 in 5 patients presented with a femoral fracture (19.5%). The method in all cases was intraspinal anesthesia, and nearly all had combined spinal and epidural anesthesia (95.9%). The mean (SD) wait time was 37.4 (15.2) minutes (range 9-60 minutes), with over half waiting more than half an hour (56.9%). The mean (SD) of surgical time was 102 (36.8) minutes. The surgery time for one-third of cases was between 91-120 minutes (35.0%), and 61-90 minutes for one-fourth of cases (26.8%). The majority (71.5%) of the participants were otherwise healthy at the time of surgery, while 28.5% had comorbidities (hypertension, diabetes, hyperlipidemia, hepatitis B, osteoporosis) (Table 2).

Table 1. Demographic Characteristics of the Patients With Closed-Leg Fracture Undergoing Conscious Surgery	
Characteristic	No. (%)
Gender	
Male	70 (56.9)
Female	53 (43.1)
Age, y	
20-40 (early adulthood)	16 (13.0)
41-60 (middle adulthood)	69 (56.1)
> 60 (elderly)	38 (30.9)
Educational attainment	
None	22 (17.9)
Primary school	18 (14.6)
Junior/senior high school	59 (48.0)
Bachelor's degree or higher	24 (19.5)
Marital status	
Single	1 (0.8)
Married	119 (96.8)
Widowed	3 (2.4)

Table 1. Demographic Characteristics of the Patients With Closed-Leg Fracture Undergoing Conscious Surgery (Continued)

Characteristic	No. (%)
Occupation	
Unemployed	33 (26.8)
No occupation	7 (5.7)
Retired	26 (21.1)
Employed	90 (73.2)
Government staff	7 (5.7)
Healthcare personnel	2 (1.6)
Commercial staff	36 (29.3)
Farmer	7 (5.7)
Laborer	38 (30.9)

Table 2. Health Information of the Patients With Closed-Leg Fracture Undergoing Conscious Surgery

Characteristic	No. (%)
Fracture site	
Femoral fracture	24 (19.5)
Tibial fracture	80 (65.1)
Fracture in both bones (tibia and fibula)	19 (15.4)
Anesthesia method	
Combined spinal and epidural anesthesia	118 (95.9)
Spinal Anesthesia	2 (1.6)
Epidural Anesthesia	3 (2.4)
Waiting time, min	
≤ 30	53 (43.1)
> 30	70 (56.9)
Surgical time, min	
50-60	13 (10.6)
61-90	33 (26.8)
91-120	43 (35.0)
121-150	25 (20.3)
151-180	4 (3.2)
> 180	5 (4.1)
Comorbidities	
No comorbidity	88 (71.5)
Had comorbidities*	35 (28.5)

* Hypertension, diabetes, hyperlipidemia, hepatitis B, osteoporosis.

The VAS-A scores of the participants, which ranged from 0 to 10, were a mean (SD) of 6.3 (2.2). This mean score indicated a clinically-relevant level of anxiety.

The mean (SD) score of intraoperative anxiety of male patients with closed-leg fracture undergoing conscious surgery was 5.6 (2.2). For female patients, the mean (SD) score was 7.1 (1.9). The mean of intraoperative anxiety was different among age groups of the patients with closed-leg fracture undergoing conscious surgery. For those aged 20-40 years, the mean (SD) score was 6.1 (2.4); 41-60 years had a mean (SD) score of 6.0 (2.3), and for those age over 60 years, the mean (SD) score was 6.6 (1.9). Moreover, the mean (SD) score of intraoperative anxiety was 5.4 (2.2) when the waiting time was less than 30 minutes, which was much lower compared to those with a wait time exceeding 30 minutes (mean [SD], 6.8 [1.9] minutes). Based on the analysis of the surgical time, the mean (SD) score of intraoperative anxiety was 5.1 (2.3) at 50-60 minutes, 5.4 (1.9) at 61-90 minutes, 6.2 (2.1) at 91-120 minutes, 8.0 (1.4) at 121-150 minutes, 7.3 (0.9) at 151-180 minutes, and 6.2 (2.9) at more than 180 minutes (Table 3).

The analysis indicated that intraoperative anxiety was significantly higher in female patients compared with their male counterparts (mean [SD], 7.1 [1.9] vs 5.6 [2.2]; ($P < .001$).

This study found that age had a positive correlation with intraoperative anxiety among the patients with closed-leg fracture undergoing conscious surgery ($r = 0.221$, $P < .05$). Waiting time and surgical time had a moderate positive correlation with intraoperative anxiety among the patients with closed-leg fracture undergoing conscious surgery ($r = 0.307$, $P < .001$; $r = 0.346$, $P < .001$) respectively (Table 4).

Table 3. Intraoperative Anxiety Scores for Patients With Closed-Leg Fracture Undergoing Conscious Surgery by Gender, Age, Wait Time, and Surgical Time

Variable	No. (%)	Intraoperative Anxiety Score, Mean (SD)
Gender		
Male	70 (56.9)	5.6 (2.2)
Female	53 (43.1)	7.1 (1.9)
Age, y		
20-40	16 (13.0)	6.1 (2.4)
41-60	69 (56.1)	6.0 (2.2)
> 60	38 (30.9)	6.6 (1.9)
Waiting time, min		
≤ 30	53 (43.1)	5.4 (2.2)
> 30	70 (56.9)	6.8 (1.9)
Surgical time, min		
50-60	13 (10.6)	5.1 (2.3)
61-90	33 (26.8)	5.4 (1.9)
91-120	43 (35.0)	6.2 (2.1)
121-150	25 (20.3)	8 (1.4)
151-180	4 (3.2)	7.3 (0.9)
> 180	5 (4.1)	6.2 (2.9)

Table 4. Correlation Coefficients Between Age, Waiting Time, Surgical Time and Intraoperative Anxiety Among the Patients With Closed-Leg Fracture Undergoing Conscious Surgery

Variable	Correlation Coefficients	P Value
Age	0.221	< .050
Waiting time	0.307	< .001
Surgical time	0.346	< .001

Discussion

The present study found a significant positive correlation between age and intraoperative anxiety, and the mean of the participants' age was 54.1 years, with their mean (SD) score of the level of intraoperative anxiety of 6.3 (2.2). This was comparable with Turan et al,³⁹ which found the mean score of participants' age was 43.8 years and mean (SD) score of the level of intraoperative anxiety was 5.2 (1.64). These results aligned with the finding of greater intraoperative anxiety among elderly patients compared with middle-age and younger adults.^{36, 37} Potential contributing factors include the decline in physiological function and greater concern regarding postoperative care compared to younger people.⁴¹ There is also an age-related decline in decision-making capacity and reduced ability to acquire and process health information.^{42, 43} In addition, the higher anxiety level among elderly patients may be due to progressive cognitive decline, heightened concern about anesthesia risks (particularly for those with multiple comorbidities), difficulty in functional recovery (such as fear of losing independence, becoming care-dependent, and requiring nursing home admission), and mortality-related apprehension.^{42, 43} These compounding factors create a unique anxiety profile that differs substantially from younger patient populations.

Furthermore, the level of intraoperative anxiety in this study was higher than the studies by Turan et al.³⁹ That discrepancy could be explained by the fact that gender is a significant determinant of intraoperative anxiety. In the present study, females constituted 43.1% of participants, which was distinctly higher than the proportions reported in the studies by Turan et al³⁹ (10.6%). This differential distribution might partially account for the observed elevation in intraoperative anxiety scores.^{41, 42}

Moreover, this research found a significant difference in the intraoperative anxiety score between males and females, in that females had more intraoperative anxiety than their male counterparts. This finding was highly consistent with previous research, which found a significant difference in intraoperative anxiety between males and females, ie, that female patients reported a significantly higher intraoperative anxiety level when undergoing conscious surgery, compared with males.^{5, 44} This finding could be explained by differing norms for emotional expression, ie, which might lead females to report anxiety more candidly or to be more susceptible to the influence of health threat information.⁴⁵

The elevated intraoperative anxiety observed in female patients could be explained through Lazarus and Folkman's transactional model of stress. For example, female patients predominantly appraise surgery as dually threatening. This threat perception intensifies as fracture-induced limitations in activities of daily living (ADL) trigger systemic household care breakdown, with depleting coping resources as well as role realignment deficits during

the critical 3-month postfracture rehabilitation window.⁴⁶ These dynamics culminate in heightened intraoperative anxiety.

This gender disparity may correlate with both biological and psychosocial mechanisms. Biologically, hormonal modulation of the hypothalamic-pituitary-adrenal (HPA) axis and neurobiological dimorphism in pain processing potentially heighten a female patient's sensitivity to surgical stress and anticipatory pain. Psychosocially, gender-specific emotional expression norms may facilitate greater openness in reporting anxiety among women, alongside heightened vulnerability to health-threatening information.

This study found that waiting time had a positive and moderate correlation with intraoperative anxiety ($r = 0.307$, $P < .001$). This result was consistent with the study by Putri et al,⁴⁷ which investigated the relationship between waiting time and anxiety level in patients receiving spinal anesthesia prior to cesarean section. That study found that patients with a waiting time exceeding 30 minutes exhibited significantly higher anxiety.⁴⁷ In addition, it has been found that the longer the waiting time in the operating room, the higher the level of patient anxiety.⁴⁸ Some studies have found that the environment of the preoperative waiting area could exacerbate patient anxiety. Accordingly, some hospitals have modified the healthcare environment to reduce stress, eg, by playing relaxing music or popular television programs in waiting rooms.⁴⁹

Moreover, this study found a positive correlation between surgical time and intraoperative anxiety, which indicates that prolonged surgical time may significantly impact patient intraoperative anxiety. This result aligned conclusively with the established literature: Häggström et al,⁴³ empirically validated that extended surgical time significantly amplifies intraoperative anxiety, particularly during regional anesthesia. Comparing with other studies in orthopedic surgery patients, the mean surgical time in this study (mean [SD], 102 [36.8] minutes), was somewhat longer than the finding in the studies by Turan et al³⁹ of 45 minutes (SD 33.0) and Kaur et al³⁴ of 79 minutes (SD 12.9). Consequently the participants' level of intraoperative anxiety in this study (mean [SD], 6.8 [1.4]) was higher than Turan et al³⁹ (mean [SD], 5.2 [1.6]) and Kaur et al³⁴ in which VAS-A was 4-5. This has suggested that prolonged surgical time is a contributing factor to intraoperative anxiety. Furthermore, this study found that patients with a surgical time ranging from 121 to 150 minutes had the highest level of intraoperative anxiety (mean [SD], 8.0 [1.4]). This result was consistent with the study by Novy et al,⁴⁹ which found that 71.4% of patients whose surgery lasted more than 2 hours showed medium-to-high anxiety during surgery.

Many researchers have explored the effectiveness of interventions for reducing the occurrence of intraoperative anxiety for patients undergoing conscious surgery. One study found that listening to instrumental music during lower leg fracture surgery caused a reduction in anxiety.⁵¹ Another study found that wearing virtual reality (VR) goggles can create an immersive environment to distract patients from various stress factors.⁵² Investigation found that the use of VR/music on serum cortisol and adrenocorticotrophic hormone (ACTH) levels in knee replacement surgery under combined spinal epidural anesthesia could ameliorate intraoperative anxiety.⁴¹ Although these interventions effectively mitigate anxiety in patients during both the preanesthetic waiting period and intraoperative phases, optimizing workflow efficiency to minimize waiting times and surgical duration should remain a priority.

The findings of this study provide a reference for healthcare providers to better understand the factors contributing to intraoperative anxiety of patients with closed-leg fracture undergoing conscious surgery, allowing for early identification of high-risk

individuals and targeted interventions. Additionally, the results should assist medical staff in tailoring intraoperative nursing strategies based on individual patient differences, thereby preventing and alleviating intraoperative anxiety, reducing anxiety-related physiological responses, minimizing complication risks, and promoting postoperative recovery.

Conclusions

This study found that the patients undergoing conscious surgery for closed-leg fracture had clinically-relevant levels of intraoperative anxiety. In addition, females had higher intraoperative anxiety than their male counterparts. Age, waiting time, and surgical time had a positive correlation with intraoperative anxiety among these participants.

Additional Information

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Ethics Approval: The protocol for this study received ethical approval from the Institutional Review Boards of Burapha University (G-HS129/2567 on 10 January 2025) and the Second Affiliated Hospital of Wenzhou Medical University (2024-K-377-02 on 21 January 2025). Prior to participation, all candidates received comprehensive verbal and written information, including research objectives, study procedures, and voluntary participation rights (including withdrawal without penalty before data collection commencement). Written informed consent was obtained from all participants. Participant confidentiality and anonymity were rigorously maintained throughout the research process, including secure data storage.

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Methodology: Xue Zhang, Niphawan Samartkit

Investigation: Xue Zhang

Writing – Original Draft: Xue Zhang, Niphawan Samartkit

Writing – Review & Editing: Niphawan Samartkit

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The Role and Impact of Artificial Intelligence in Shaping Resident Doctor Education

Witthawin Sae-Lee 

Department of Anesthesiology, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Abstract

Artificial intelligence (AI) holds immense potential to transform resident doctor education by offering personalized, adaptive learning experiences and enhancing clinical skill development. Drawing from a literature search of key academic databases for articles published between 2018 and 2024, this review explores the current applications, benefits, challenges, and future directions of AI integration into residency training programs. AI facilitates structured curriculum design, enabling customized pathways based on individual resident needs and performance data. It enhances mentorship and monitoring through virtual tutors, improved accessibility, and data-rich workplace-based assessments, while complementing traditional human oversight. AI-driven simulations provide safe environments for procedural practice with immediate, objective feedback, showing promise in specialties like radiology, dermatology, and ophthalmology. However, significant challenges remain, including the need for robust validation, addressing risks of over-reliance that may hinder critical thinking, managing medicolegal concerns, ensuring faculty development, and meeting infrastructure requirements. Concerns about AI's impact on the job market also influence residents. Successfully leveraging AI requires addressing these challenges through further research, developing ethical guidelines, and integrating AI literacy throughout medical training to prepare future physicians effectively.

Keywords: Artificial intelligence, Medical education, Residency training, Curriculum design, Clinical simulation

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Corresponding Author:
witthawin.sae@mahidol.ac.th

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Introduction

Artificial intelligence (AI) represents a multidisciplinary domain within computer science, dedicated to creating systems that emulate or surpass human cognitive functions. These systems excel in visual perception, speech recognition, natural language processing, and complex decision-making.¹ The application of AI to medical education, in particular, holds immense potential for transforming resident training and improving patient care. The primary objective of AI research is to develop sophisticated models capable of processing vast datasets, learning from experiences, and adapting to new situations, thereby exceeding traditional human capabilities.²

This transformative impact is already evident across various medical domains. For instance, AI-powered diagnostic tools are enhancing clinical decision support for residents, predicting patient outcomes, and suggesting treatment protocols in real-time. In surgical training, AI-enhanced simulations allow residents to practice complex procedures in a safe and controlled environment, receiving immediate feedback on their technique.³⁻⁵ These applications demonstrate the potential of AI to not only improve patient care but also to revolutionize the way residents learn and develop essential skills. While these

Clinical Decision Support Systems (CDSS) hold great promise, their successful integration into clinical workflows also necessitates careful consideration of factors such as credibility and usability.⁴ Beyond diagnostics, AI is revolutionizing fields like drug discovery and surgical precision.^{6,7}

As AI continues to integrate into medical practice, medical education must evolve. Training programs must prepare future physicians to work effectively and ethically with AI. In particular, AI offers personalized learning experiences tailored to each resident's needs and learning style, accelerating knowledge acquisition and professional development. Current applications of AI in medical education include learning support through individualized feedback and guided learning pathways, which improve educational outcomes while reducing costs. However, challenges remain, such as addressing the technical complexities of developing AI applications and ensuring their effectiveness in sensitive areas like examinations. To meet these challenges, systematic curricular reforms should integrate AI into medical training, enabling future physicians to maximize AI's potential while maintaining a human-centered approach to care.^{8,9}

The integration of AI into medical education raises critical questions about the role of educators, the balance between human and machine input, and ethical considerations. AI offers opportunities for personalized learning, improved simulations, and data-driven assessments, but also necessitates a shift in traditional teaching methods. Educators must acquire a foundational understanding of AI to align their curricula with emerging healthcare demands while addressing challenges such as ethical use and maintaining human oversight in education.¹⁰

Despite the growing adoption of AI in clinical practice, its integration into residency training programs remains in its early stages, with limited consensus on best practices and significant gaps in the literature. This review explores the current state, benefits, challenges, and future directions of AI in medical resident education. It examines successful AI implementations, discusses curriculum design implications, and addresses ethical considerations. By doing so, it aims to contribute to the dialogue on AI's role in shaping the future of medical education and provide insights for educators, administrators, and policymakers.

Methodology

Search Strategy and Data Sources

This review was conducted through a systematic search of prominent academic databases, including PubMed and Scopus, to identify relevant literature. The search was performed between October 2024 and December 2024. The following keywords and their combinations were used: 'Artificial Intelligence', 'Machine Learning', 'Residency Training', 'Graduate Medical Education', 'Curriculum Design', 'Clinical Simulation', and 'Physician Training'. The search was limited to peer-reviewed articles, including original research, reviews, and commentaries, published in English between January 2018 and December 2024 to ensure the review captured the most current research in this rapidly evolving field.

Study Selection and Eligibility Criteria

The study selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Initially, titles and abstracts were screened for relevance. Subsequently, the full texts of potentially eligible articles were

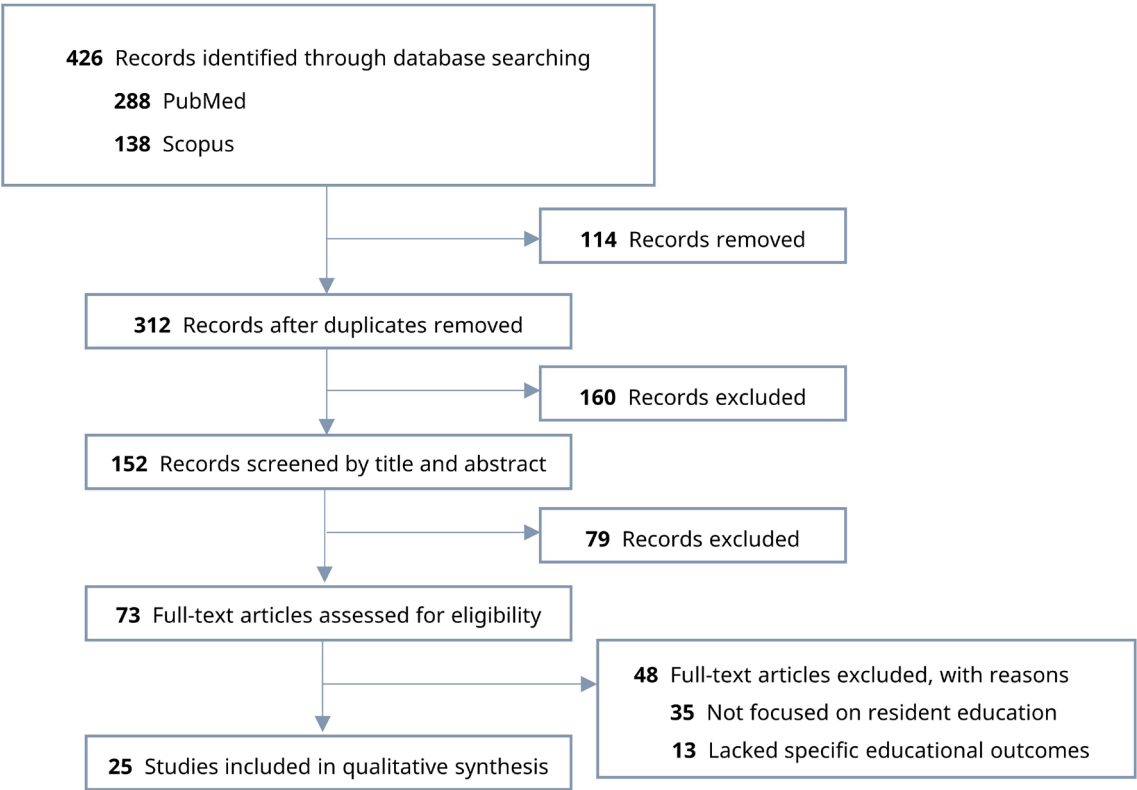
thoroughly reviewed to determine if they met the final inclusion criteria. For the purpose of this review, a resident doctor is defined as a physician who has graduated from medical school and is undergoing a formal, supervised postgraduate training program (ie, residency) to acquire specialized competence in a specific medical field before being licensed for independent practice. The entire selection process is illustrated in the flow diagram (Figure 1).

Inclusion criteria were 1) peer-reviewed articles published in English; 2) studies focusing on the application, integration, or impact of AI in postgraduate medical education or residency training programs; and 3) articles discussing curriculum design, mentorship, skill development, assessment, or challenges related to AI in resident education.

Exclusion criteria were 1) articles where the primary focus was on undergraduate medical education or continuing medical education for practicing physicians not in a training program; 2) studies centered exclusively on AI in clinical practice without a clear link to resident education or training; 3) editorials, letters, or opinion pieces that did not provide a substantial review of evidence or original data; and 4) articles not available in full-text format.

The final synthesis included 25 articles that met all eligibility criteria. Data from these articles were thematically analyzed to identify key themes, benefits, challenges, and future directions regarding the role of AI in shaping resident doctor education.

Figure 1. PRISMA Flow Diagram Illustrating the Study Selection Process



Review Contents

The literature on the integration of AI into resident education is rapidly expanding, covering several key themes from curriculum design and skill development to assessment and resident perceptions. To provide a clear overview of the foundational evidence discussed in this review, a selection of key, representative studies were presented (Table 1). These articles have been chosen to highlight the most impactful findings and innovative approaches across the primary domains of AI's role in shaping the future of medical training.

Curriculum Design and Educational Frameworks Integration

Integrating AI into residency training is best achieved through a structured approach that maximizes learning outcomes and ensures effective implementation. This framework should include assembling a team of AI experts, assessing the current knowledge level of residents, setting learning objectives, and aligning these with effective teaching strategies. The continuous evaluation and refinement of the curriculum will ensure its relevance and efficacy.¹¹ To illustrate the practical application of such structured curricula, well-constructed programs, like a 3-day intensive curriculum, have demonstrated effectiveness. These programs, featuring didactic lectures, hands-on workshops, and group discussions, have proven to boost residents' understanding and confidence in using AI technologies, particularly in fields like radiology. Similarly, a 3-week AI workshop integrated into academic sessions showed measurable improvement in AI competency.¹²

Building upon the benefits of structured curricula and interactive learning formats, recent studies highlight the transformative potential of AI in enabling personalized, interactive learning experiences.¹³ Through advanced algorithmic analysis of learner data, AI systems can generate pedagogically optimized materials that correspond to individual trainees' cognitive preferences, learning modalities, and competency levels. This evidence-based approach facilitates enhanced comprehension of complex medical concepts while promoting data-driven clinical decision-making. Furthermore, research indicates that AI-enabled adaptive learning platforms can dynamically adjust to residents' developmental progression, thereby improving both diagnostic accuracy and measurable learning outcomes.¹⁴ AI systems can also be adapted to different levels of expertise, offering tailored experiences for both novice and experienced clinicians. This adaptability ensures that residents receive training that is relevant to their current level of proficiency while still challenging them appropriately as they advance.¹⁵

Expanding on the concept of individualized learning, AI education should also be continuous, starting in medical school and extending through residency and professional practice. This continuous approach ensures that residents build upon a solid foundation and stay up to date as AI evolves.¹⁶ Furthermore, beyond individual learning, AI is transforming traditional educational models by enabling a more universal and interconnected approach to learning.¹⁷ AI facilitates this by providing access to vast databases of medical knowledge and connecting learners with experts and peers across geographical boundaries. To solidify these theoretical and broader learning approaches, practical applications are essential. For example, the use of AI tools like computer-aided diagnosis (CAD) systems gives residents the chance to practice interpreting clinical images and other data independently while reinforcing real-world diagnostic skills.¹⁸

AI-Enhanced Monitoring and Mentorship

Addressing the persistent challenges within medical education, particularly in providing consistent and effective mentorship and monitoring, AI offers promising solutions. The traditional paradigms of mentorship and performance monitoring in residency training programs often face limitations, including variations in mentor availability, subjectivity in assessments, and logistical constraints in providing timely feedback. However, the implementation of AI-driven mentorship solutions has emerged as a valuable approach to enhance these critical aspects of resident education. Through the deployment of virtual intelligent tutors and conversational agents, AI systems can provide personalized guidance and support continuous learning development, making mentorship more accessible and responsive to individual needs.¹⁹ These AI-enabled virtual tutors can function as supplementary coaches, delivering real-time feedback during critical training phases, ensuring the maintenance of consistent and constructive feedback mechanisms, particularly when human mentors are unavailable.²⁰ The potential of AI extends beyond virtual tutors, encompassing various tools and approaches to augment and transform mentorship and monitoring in residency training.

Furthermore, AI technology has proven instrumental in addressing longstanding logistical challenges within medical education. By mitigating constraints related to time and geographical limitations, AI systems facilitate seamless mentor-mentee interactions regardless of physical location.¹⁹ This enhanced accessibility has particular significance in contemporary medical education, where distributed learning environments and remote training scenarios have become increasingly prevalent. The literature emphasizes that these technological solutions not only improve the efficiency of mentorship delivery but also contribute to more equitable access to educational resources across diverse training settings.

AI's role in monitoring and assessment has demonstrated particular efficacy through the implementation of workplace-based assessments (WBAs) and diverse evaluation tools. These systems generate rich datasets that facilitate both formative feedback and summative entrustment decisions, ensuring residents meet required competencies while providing valuable insights into their developmental progression.²¹ For example, AI can analyze WBA data to identify specific areas where residents consistently struggle, allowing program directors to tailor teaching modules to address these weaknesses. The systematic collection and analysis of performance data enable educational programs to identify trends, adjust teaching strategies, and optimize learning outcomes more effectively than traditional assessment methods alone.

Recent studies have highlighted the importance of integrating AI-enhanced monitoring systems with traditional educational frameworks. This integration enables a more nuanced understanding of resident performance through multidimensional assessment approaches, combining objective performance metrics with subjective evaluations from human mentors.²⁰ For instance, AI can track a resident's performance on simulated surgeries, providing data on precision and efficiency, while human mentors can assess their communication skills and bedside manner. The synergistic relationship between AI-driven monitoring and human oversight ensures that both quantitative and qualitative aspects of resident development are adequately addressed, leading to more comprehensive and effective educational outcomes.

However, scholars emphasize the importance of maintaining appropriate balance in AI implementation. While AI-enhanced monitoring and mentorship systems offer

substantial benefits, they should complement rather than replace traditional human mentorship roles. The literature suggests that optimal outcomes are achieved when AI systems are strategically deployed to augment existing mentorship structures, providing additional layers of support and assessment while preserving the essential human elements of medical education.¹⁹

Enhanced Learning and Skill Development

Current AI studies in residency training focus largely on simulation settings and the development of technical skills, particularly targeting skill classification and performance assessment. However, larger sample sizes and more balanced data are needed to strengthen these studies.²² AI-driven simulation-based training enables residents to practice and refine their diagnostic capabilities in controlled environments, leading to enhanced diagnostic accuracy and improved preparedness for clinical scenarios.^{14, 23} The technology also provides automated and immediate feedback, which is particularly beneficial as many residents report receiving minimal corrective feedback on their performance. This real-time feedback enhances formative evaluations without entirely replacing traditional feedback mechanisms.²⁴

Recent research demonstrates that AI implementation has shown considerable promise in enhancing diagnostic accuracy across various medical specialties. In dermatology, AI tools provide real-time diagnostic support and simulate rare conditions that are often underrepresented in traditional training settings, while virtual reality integration enables residents to practice technical procedures safely through feedback on crucial metrics such as instrument placement and pressure application.²⁵ This technological integration has particular significance in addressing educational gaps and enhancing surgical skill development through immersive learning experiences.²⁶ Natural language processing and machine learning applications have revolutionized resident assessment by offering more objective evaluations of clinical competencies, analyzing written and verbal responses, and tracking skill development with unprecedented precision.²⁷

In radiation oncology, AI has transformed traditional didactic approaches by supporting flipped learning methodologies and enhancing case-based learning through curated, de-identified clinical vignettes. The technology provides real-time feedback for critical skills such as contouring and treatment planning, helping residents develop intuitive capabilities in patient assessment and procedural accuracy. Notably, AI-powered simulations have become particularly valuable in areas like brachytherapy training, where practical exposure opportunities have declined.^{28, 29}

However, scholars emphasize critical considerations regarding AI integration in clinical practice. The literature cautions that excessive dependence on AI systems could potentially compromise the development of critical thinking and diagnostic capabilities among medical trainees. For example, if residents rely solely on AI-generated diagnoses without independently evaluating patient data, their ability to develop sound clinical judgment may be hindered. The maintenance of AI system efficacy necessitates regular updates and rigorous validation to prevent the perpetuation of incorrect diagnostic patterns. Furthermore, successful implementation requires substantial technological infrastructure investment and continuous system optimization to ensure sustained effectiveness.³⁰ Additionally, logistical challenges and the need for multi-institutional databases must be addressed to optimize AI's impact on medical education. The integration of AI into clinical settings provides realistic healthcare environments that help improve critical thinking

and clinical reasoning skills, especially in fields where trainees encounter a wide range of clinical challenges.³¹ This integration enhances the practical application of theoretical knowledge while maintaining the crucial balance between technological assistance and independent clinical judgment.

Empirical evidence supports the effectiveness of AI-integrated learning approaches in specialty training. In ophthalmology, AI-assisted training systems have demonstrated significant improvements in residents' diagnostic capabilities, with studies showing higher post-lecture test scores compared to traditional learning methods, particularly in specialized areas such as pathologic myopia identification and classification.³² Furthermore, structured AI curricula like AI-RADS have proven effective in building residents' confidence and competence in understanding and applying AI technologies in clinical practice. These programs successfully bridge the gap between theoretical knowledge and practical application through a combination of didactic lectures and interactive learning experiences.³³

Challenges and Considerations

Integrating AI into residency training presents several significant challenges and considerations that must be addressed to ensure successful implementation. One notable issue is the reliance on small sample sizes and the focus on senior residents in pilot studies, since AI applications in residency programs are still in their infancy. There is currently no consensus on the optimal timing for introducing AI decision support systems (AI-DSS) into the curriculum, highlighting the need for further research to guide these critical decisions.¹⁶

Additionally, the use of AI in surgical training raises important medicolegal concerns, particularly regarding high-stakes decision-making and the risk of patient harm stemming from erroneous AI recommendations. It is essential to examine how flawed algorithms might impact residents' careers and their progression through training, as these implications could have lasting effects on both individual practitioners and patient safety.³⁴

Moreover, there is a pressing need for specialized AI educational content within residency programs. Residents must be equipped with the skills to interpret imaging studies and understand AI tools before they can effectively apply them in clinical practice. Hands-on laboratories and structured lecture series have been identified as effective educational formats for this purpose.^{18, 35} Despite many residents expressing support for AI and machine learning (ML) education, continuous courses throughout residency are necessary to ensure proficiency in utilizing these tools effectively.³⁵

Furthermore, the potential impact of AI on job markets is influencing residency selection. Medical students are increasingly concerned that advancements in AI may render certain specialties, such as diagnostic radiology, obsolete, which can affect their career decisions.³⁶ Addressing these concerns through transparent discussions about the evolving role of AI in medicine will be crucial for attracting future talent to all specialties.

Table 1. Summary of Representative Studies on AI in Resident Education

Author, Year	Specialty/Domain	AI Application/Tool	Key Findings/Outcomes
Curriculum Design and Educational Frameworks			
Hu et al, ¹² 2023	Diagnostic Radiology	AI Training Workshop	Demonstrates that a short, intensive workshop format can measurably improve residents' confidence and understanding of AI concepts.
Lindqwister et al, ³³ 2021	Radiology	AI-RADS Curriculum	Proposes a structured, standardized curriculum (AI-RADS) that successfully enhances residents' competence in applying AI technologies.
Skill Development and Simulation			
Bilgic et al, ²² 2022	Surgical Education	Scoping Review	Found that AI in surgery primarily focuses on skill classification and performance assessment, providing objective metrics for technical skills.
Desseauve et al, ¹⁴ 2024	Obstetrics	ChatGPT	Evaluated how residents interact with large language models, highlighting the need to develop skills for effectively and safely using AI in clinical queries.
Fang et al, ³² 2022	Ophthalmology	Pathologic Myopia ID System	Showed that an AI-assisted training system was significantly more effective than traditional lectures for improving residents' diagnostic accuracy.
Kwon et al, ²⁸ 2023	Radiation Oncology	AI-Empowered Education	AI tools can provide real-time, objective feedback for critical skills like tumor contouring and treatment planning, enhancing procedural accuracy.
Challenges and Resident Perceptions			
Atalay et al, ³⁶ 2023	Diagnostic Radiology	Survey	Showed that medical students' career decisions are being influenced by concerns over AI's potential impact on the job market in certain specialties.
Salastekar et al, ³⁵ 2023	Radiology	Multi-institutional Survey	Revealed that a majority of residents are supportive of AI education and desire continuous training integrated throughout their residency.

Abbreviation: AI, artificial intelligence.

Discussion

The integration of AI in residency training programs represents a significant paradigm shift in medical education, with growing evidence supporting its effectiveness across multiple specialties. This literature review reveals several key themes and implications that warrant careful consideration for future development and implementation.

Educational Effectiveness and Innovation

Recent studies provide compelling evidence of the superior effectiveness of AI-integrated learning approaches compared to traditional methods. For instance, in ophthalmology residency programs, AI-assisted training systems have demonstrated statistically significant improvements in diagnostic accuracy and skill development, demonstrated by higher post-lecture test scores in specialized areas such as pathologic myopia identification and classification.³² Similarly, structured AI curricula like AI-RADS have successfully enhanced residents' confidence and competency in utilizing AI technologies in radiology, bridging the gap between theoretical knowledge and practical application.³³ These findings strongly suggest that AI integration, when properly designed and implemented, can accelerate the learning curve, improve educational outcomes, and better prepare residents for the demands of modern medical practice.

Adaptability and Implementation Challenges

The experiences documented during the COVID-19 pandemic, particularly in the Toronto neurology residency program, highlight the critical importance of adaptability in medical education systems.³⁷ While this adaptation was driven by necessity, it clearly demonstrates the latent potential for technological integration, including AI, in residency training. However, the implementation of AI systems faces several challenges that must be addressed proactively. These include substantial infrastructure requirements, significant cost considerations related to software and hardware, and the imperative for comprehensive faculty development to ensure educators are equipped to effectively integrate AI into their teaching. The successful integration of AI in radiology residency programs, which has involved dedicated resources and faculty training, provides a valuable model for addressing these challenges while simultaneously maintaining and enhancing educational quality.³⁸

Ethical Considerations of Data Privacy and Algorithmic Bias

A crucial aspect of integrating AI into resident education involves navigating the complex ethical landscape, particularly concerning data privacy and algorithmic bias. The use of AI tools necessitates the collection and analysis of vast amounts of sensitive data, including patient information and resident performance metrics, raising significant data privacy and security concerns.³⁹ It is imperative that robust safeguards and clear protocols are established to govern data handling, ensuring compliance with regulations like the Health Insurance Portability and Accountability Act (HIPAA) and maintaining patient and resident confidentiality.^{39, 40} Furthermore, the issue of algorithmic bias poses a substantial threat to equitable medical education.⁴¹ Since AI systems learn from existing data, they are susceptible to inheriting and amplifying biases present in that data, which can lead to disparities in resident assessments. For instance, if an AI is trained on data that disproportionately represents certain demographics, it may develop biases that disadvantage underrepresented groups.⁴¹ This can manifest as skewed performance evaluations or the perpetuation of stereotypes in diagnostic training modules.⁴² Addressing this requires a multi-faceted approach, including the use of diverse and representative datasets, regular audits of AI algorithms for bias, and the development of transparent, explainable AI systems. By prioritizing data privacy and actively mitigating algorithmic bias, medical education programs can foster a more just and effective learning environment for all residents.

Implications of the Study

The findings of this review carry significant implications for various stakeholders within the medical education ecosystem. For educators and program directors, the integration of AI necessitates a paradigm shift from traditional teaching models to a more dynamic, data-driven approach. Curricula must be redesigned to not only include AI literacy but also to leverage AI tools for personalized learning pathways and objective assessments. This requires substantial investment in faculty development to equip educators with the skills to guide residents in a technologically advanced environment.

For policymakers and healthcare institutions, this review underscores the need for strategic planning and resource allocation. The successful implementation of AI in residency training is contingent upon robust technological infrastructure, the development of ethical guidelines, and the establishment of standards for the validation and oversight of AI tools. Proactive policies are required to address medicolegal concerns and ensure that the use of AI enhances, rather than compromises, patient safety and quality of care.

Finally, for resident doctors, the message is clear: AI is poised to become an integral component of medical practice. Rather than a threat to their future roles, it should be viewed as a powerful tool that can augment their skills and improve efficiency. Early and continuous exposure to AI technologies during training is crucial for developing the competence and critical appraisal skills necessary to work effectively alongside these systems, ensuring they can harness the benefits while being mindful of the potential pitfalls.

Limitations of the Study

This review has several limitations. Its findings are constrained by the rapid pace of AI development, a potential publication bias towards positive results, and significant heterogeneity among the included studies. Our search restrictions to English-language databases may have also excluded relevant research. A primary limitation is the literature's focus on short-term educational metrics over long-term clinical competency and patient outcomes. Finally, this review's scope intentionally focused on direct clinical training, excluding the significant roles of AI in resident research and administrative management. Future longitudinal, multi-institutional studies are needed to address these gaps.

Conclusions

This review highlights AI's potential to transform resident education through personalized learning and enhanced skills. However, challenges remain. Studies often have small sample sizes. Medicolegal concerns exist, especially in surgical training. Residency programs need specialized AI content and continuous training. Medical students worry about AI's impact on job markets. Moving forward, larger studies, ethical guidelines, and proactive discussions about AI's role in medicine are needed to ensure it benefits both residents and patients.

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Author Contributions:

Conceptualization: Witthawin Sae-Lee

Formal Analysis: Witthawin Sae-Lee

Methodology: Witthawin Sae-Lee

Visualization: Witthawin Sae-Lee

Writing – Original Draft: Witthawin Sae-Lee

Writing – Review & Editing: Witthawin Sae-Lee

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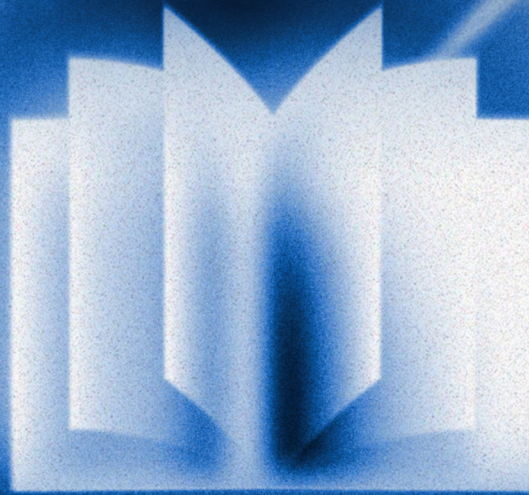
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