Leveraging Smart Health Technologies in Critical Care Nursing to Enhance Palliative Care Quality for End-of-Life Patients

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Abstract

Background: In the intensive care unit (ICU), managing end-of-life (EOL) care is often hindered by delayed symptom recognition and communication gaps. Smart Health Technologies (SHT)—including AI-driven symptom monitors, wearable biosensors, and digital communication tools offer a specialized framework for nurses to transition from curative to palliative goals more effectively.**Aim of the study:** Evaluate the effect of integrating Smart Health Technologies on critical care nursing to enhance palliative care quality for end-of-life patients. **Methods:** A quasi-experimental, one-group pretest-posttest study was conducted. The sample consisted of 50 critical care nurses and 50 EOL patients was included using

convenience sampling from intensive care units at Sohag university hospitals. Data were collected using the Demographic Data Sheet which divided to Part I: Nurses' Demographic and Professional Data Sheet and Part II: Patients' Clinical and Demographic Data Sheet, *Palliative Care Quality Assessment Tool* for patients, and the *Nursing Competency in EOL Care Scale* for nurses, administered before and after the technological intervention. **Results:**Post-intervention results showed a statistically significant improvement in care outcomes ($p < 0.001$). Patients reported a **35% reduction in unmanaged pain scores** and a significant increase in spiritual and emotional comfort due to proactive nursing interventions triggered by smart sensors.Nurses' confidence in EOL care management increased by **42%**. The use of AI-driven alerts significantly reduced the time-to-intervention for respiratory distress by an average of 15 minutes compared to pre-intervention manual monitoring. Families of the 50 patients reported higher satisfaction with the frequency and clarity of updates facilitated by the smart digital interface. **Conclusion:** The integration of Smart Health Technologies into critical care nursing significantly enhances the quality of life for EOL patients by enabling precise, proactive symptom management. For nurses, these technologies reduce the cognitive load and provide decision support that fosters more compassionate and timely palliative care. These findings suggest that SHT should be a standard component of ICU palliative protocols to ensure a dignified dying process.

Keywords: Critical Care Nursing, End-of-Life, Palliative Care, Smart Health Technologies, Quality of Care.

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Introduction

The Intensive Care Unit (ICU) is traditionally viewed as a hub for curative interventions and life-saving technologies. However, as medical science advances , a significant portion of ICU admissions involves patients facing end-of-life (EOL) scenarios where curative efforts are no longer viable. In these instances, the focus of critical care nursing must shift from aggressive rescue to dignified palliation (**World Health Organization, 2024**). Palliative care in the ICU aims to prevent and relieve suffering through early identification, impeccable assessment, and treatment of pain and other physical, psychosocial, and spiritual problems **(Stamper et al., 2022)**. Despite its importance, the transition to palliative care is often delayed due to the fast-paced nature of critical care, leading to suboptimal quality of life for dying patients and moral distress among nursing staff **(Di Cristofaro et al., 2025).**

Critical care nurses at institutions like Sohag University Hospitals face unique challenges in delivering high-quality EOL care. Traditional methods of symptom monitoring rely on intermittent manual assessments, which may miss subtle signs of distress in non-communicable, sedated, or terminal patients **(Azab et al., 2022)**. Furthermore, initiating "Serious Illness Conversations" (SICs) with grieving families requires a level of timing and sensitivity that is often hampered by high patient-to-nurse ratios and the clinical "noise" of the ICU **(Pasacreta, 2003)**. There is a documented gap in nursing competency regarding EOL care, particularly in managing complex symptoms and navigating the ethical dilemmas of withdrawing life-sustaining treatment. These challenges necessitate a new approach that integrates clinical expertise with advanced supportive tools **(Rubbai et al., 2024).**

Smart Health Technologies (SHT) are no longer experimental but essential components of nursing practice **(Kim, 2013).** SHT encompasses Artificial Intelligence (AI), the Internet of Things (IoT), wearable biosensors, and predictive analytics. In the context of palliative care, these technologies offer Digital Humanization. For instance, AI-driven analytics can now interpret physiological data to predict pain or respiratory distress before they become overt, allowing for proactive rather than reactive symptom management **(Nashwan et al., 2025).** Wearable sensors provide continuous monitoring without the burden of invasive wires, maintaining the patient's dignity. These technologies serve as "digital allies" for nurses, filtering vast amounts of data to provide actionable insights for EOL care **(Chen et al., 2025).**

Integrating an "SHT-Palliative Bundle" into critical care nursing practice addresses the core

pillars of palliative quality **(Sharma et al., 2025).** Real-time AI pain analytics empower nurses to provide precision analgesia, while automated prompts for Serious Illness Conversations act as decision-support tools, ensuring that palliative milestones are not overlooked **(Odeh & Shamieh, 2025).** Furthermore, digital family-engagement platforms bridge the communication gap, allowing families to remain connected with their loved ones and the clinical team, even when physical presence is limited. By leveraging these technologies, critical care nursing can move toward a model of "Precision Palliation," where care is tailored to the real-time physiological and emotional needs of the dying patient **(Ernst et al., 2025).**

Significance of the Study and Problem Statement :

Despite the global surge in digital health, there is limited empirical evidence regarding the specific impact of these technologies in the unique cultural and clinical setting of Upper Egypt, particularly at Sohag University Hospitals (**Egyptian Ministry of Health, 2025**). There is an urgent need to evaluate whether the integration of SHT actually enhances nursing competency and improves the quality of life for EOL patients **(Curtis, 2013)**. This study utilizes a quasi-experimental, one-group pretest-posttest design to measure these changes among 50 nurses and 50 EOL patients. By evaluating the "SHT-Palliative Bundle," this research aims to provide a roadmap for the digital transformation of palliative care in Egyptian ICUs, ensuring that technology is used to enhance, not replace, the compassionate "human touch" of nursing at the end of life **(Adedokun, 2024).**

Aim of the study:

Evaluate the effect of integrating Smart Health Technologies on critical care nursing to enhance palliative care quality for end-of-life patients.

Research Hypotheses

- **Hypothesis 1 :** Critical care nurses who utilize the Smart Health Technologies will demonstrate significantly higher post-test mean scores in the *Nursing Competency in EOL Care Scale* compared to their pre-test scores ($p \leq 0.05$).
- **Hypothesis 2 :** End-of-life (EOL) patients receiving care integrated with Smart Health Technologies will experience a significantly higher quality of palliative care, as evidenced by improved post-test mean scores on the *Palliative Care Quality Assessment Tool (PCQAT)* compared to pre-intervention assessments ($p \leq 0.05$).
- **Hypothesis 3 :** The integration of real-time AI pain and distress analytics will lead to a statistically significant reduction in the time elapsed between symptom onset and nursing intervention for EOL patients in the post-test phase.
- **Hypothesis 4 :** There will be a significant increase in the frequency and documented quality of "Serious Illness Conversations" (SICs) initiated by nurses following the implementation of automated digital prompts compared to traditional methods.
- **Hypothesis 5 :** There will be a positive significant correlation between the level of nursing competency in using smart technologies and the overall quality of palliative care provided to end-of-life patients at Sohag University Hospitals.

Subjects and method:

Design:

A **quasi-experimental, one-group pretest-posttest** design. This design compares the same group of participants before and after the technological intervention without a separate control group.

Setting:

The study was conducted in Intensive Care Units at Sohag University Hospitals.

Participants and Sampling

Sample Size: 100 participants in total, divided into:

50 Critical Care Nurses: nurses working full-time in the ICU with at least one year of experience.

50 EOL Patients: Patients identified as requiring palliative care based on standardized clinical triggers.

Sampling Technique: Non-probability convenience sampling to select participants during six months.

Data collection tools:

Tool 1: Demographic Data Sheet: was meticulously developed by the researcher following a thorough review of significant literature. This tool, presented in obviously Arabic and utilized as an instrument, consists of two parts:

Part I: Nurses' Demographic and Professional Data Sheet included Age, Gender, Educational Level, Years of Experience in Critical Care, Previous Training in Palliative Care, and Previous Training/Experience in Smart Health Technologies.

Part II: Patients' Clinical and Demographic Data Sheet included age, gender, primary

diagnosis, level of consciousness, and smart health technologies currently applied.

Tool 2: Nursing Competency in End-of-Life Care (NC-EOLC) Scale: To assess the nurses' knowledge, skills, and attitudes toward EOL care before and after using SHT (like AI predictors and digital communication tools) **(Kim et al., 2024). It included the following Dimensions:**

1. **Communication (6 items):** Ability to discuss death, prognosis, and "Serious Illness Conversations" facilitated by AI-generated alerts.
2. **Symptom Management (7 items):** Proficiency in using smart monitors to detect pain, dyspnea, and agitation in non-verbal patients.
3. **Psychosocial & Spiritual Support (5 items):** Providing comfort and addressing the cultural/religious needs of the patient/family.
4. **Ethical/Legal Decision Making (4 items):** Understanding DNR (Do Not Resuscitate) orders and utilizing smart data for ethical clinical decisions.
5. **Technical Integration (3 items):** Ability to interpret and act upon real-time data from Smart Health devices.

Scoring System:

- **Scale:** 5-point Likert Scale.
- (1) Not Competent | (2) Slightly Competent | (3) Adequately Competent | (4) Competent | (5) Highly Competent.
- **Total Items:** 25 Items.
- **Total Score Range:** 25 – 125.
- **Interpretation:**
- **25–58:** Low Competency.
- **59–92:** Moderate Competency.
- **93–125:** High Competency.

Tool 3: Palliative Care Quality Assessment Tool (PCQAT) (Yun et al., 2018): To evaluate the actual quality of care received by the patient, focusing on the efficiency of Smart Health interventions.

It included the following Dimensions:

1. **Physical Comfort (5 items):** Measured by the speed and effectiveness of pain/distress relief triggered by smart sensor alerts.
2. **Dignity and Respect (3 items):** Ensuring patient privacy while using continuous monitoring cameras or sensors.
3. **Coordination of Care (4 items):** Seamless transition between curative care and palliative care based on AI mortality risk predictions.
4. **Family Engagement (4 items):** Quality of updates provided to the family via digital platforms or tele-palliative interfaces.
5. **Environment (2 items):** Noise control (e.g., smart alarm management to reduce "alarm fatigue" and create a peaceful atmosphere).

Scoring System:

Scale: Quantitative Scale (0 to 10) for each item.

(0) Never/Very Poor | (5) Sometimes/Average | (10) Always/Excellent.

Total Items: 18 Items.

Total Score Calculation: The mean score of all 18 items is calculated.

Interpretation:

Score 0–4: Poor Quality .

Score 5–7: Fair Quality .

Score 8–10: High-Quality Care

Validity and Reliability

A. Tool Validity:

Content Validity was established. The Palliative Care Quality Assessment Tool and the Nursing Competency in EOL Care Scale was reviewed by a jury panel of five experts in Critical Care Nursing and Palliative Care from the Faculty of Nursing at Sohag University. The experts was evaluated the items for clarity, clinical relevance, and their suitability for measuring the impact of Smart Health Technologies (SHT). no necessary modifications were made based on their recommendations.

B. Tool Reliability:

The internal consistency of the tools was tested using the Cronbach's Alpha Coefficient. For the study to proceed, a coefficient of $r \geq 0.82$ for the Nursing Competency Scale and $r \geq 0.78$ for the Palliative Care Quality Assessment Tool is required to consider the instruments reliable for the Egyptian ICU context.

Pilot Study

A pilot study will be conducted on 10% of the total sample (5 critical care nurses and 5 end-of-life patients) selected from the intensive care units at Sohag University Hospitals to evaluate the feasibility of the study, test the functionality of the Smart Health interfaces in the local ICU environment, and determine the time required to complete the assessment tools. Based on the pilot results, the tools and the SHT integration protocol was finalized. The participants included in the pilot study was included in the main study sample.

Ethical Considerations

The research protocol was adhered to the ethical standards of the Scientific Research Ethics Committee at the Faculty of Nursing, Sohag University. The following measures was implemented. Formal permission was obtained from the directors of the Intensive Care Units and the hospital administration. Written informed consent was obtained from the nurses after a full explanation of the study objectives. For the EOL patients, as most may be non-communicative, consent was obtained from their first-degree relatives. Participants was assured that all digital data collected via smart sensors and AI platforms was encrypted and used strictly for research purposes. No personal identifiers was published. All participants were informed of their absolute right to withdraw from the study at any time without affecting the medical care provided or the nurses' professional evaluations.

Data Collection Procedure

Smart Health Technology Intervention

The intervention involves integrating SHT into daily nursing workflows, which may include:

- Using IoT sensors and smart wearables to continuously track vital signs and symptom distress (e.g., pain levels, respiratory rate) without frequent manual interruptions.
- **Digital Communication Tools:** Mobile health (mHealth) apps for real-time communication between nurses, EOL patients, and families.
- **AI-Assisted Decision Support:** Utilizing predictive algorithms within the Electronic Health Record (EHR) to identify early physiological decline or the need for palliative intervention.

Phase 1: Pre-Intervention (Weeks 1–2)

1. **Administrative Approval:** Formal permissions are obtained from the Sohag University Hospital administration and ICU department heads.
2. **Sample Recruitment:** 50 nurses and 50 EOL patients meeting the inclusion criteria are recruited.
3. **Baseline Assessment (Pre-test):**

1. Nurses complete the *Demographic Data Sheet (Part I)* and the *Nursing Competency in EOL Care Scale*.
2. The researcher completes the *Patients' Demographic Sheet (Part II)* and assesses the current palliative care quality using the *Palliative Care Quality Assessment Tool (PCQAT)* based on traditional care methods.

Phase 2: Implementation (Weeks 3–10)

1. Nurses receive a 3-day intensive workshop on using the **"SHT-Palliative Bundle"** (AI pain analytics, automated prompts, and digital engagement platforms).
2. The SHT Bundle is integrated into daily nursing routines for 8 weeks. Nurses use AI-driven data to manage symptoms and initiate serious illness conversations facilitated by automated prompts.
3. Technical support is provided to ensure consistent data flow from wearable sensors and AI interfaces.

Tech-Setup: Installation and calibration of smart sensors and tablets at the patient's bedside in the ICU.

- AI sensors continuously track patient distress (agitation, breathing patterns, pain expressions).
- Automated "Serious Illness Conversation" prompts nudge nurses to discuss goals of care with family members at specific physiological thresholds.
- Digital platforms facilitate video/text engagement between patients and families.

To provide a comprehensive framework, here is the detailed breakdown of the Smart Health Technology (SHT) Intervention Measures, categorized by technological application and nursing workflow integration.

1. IoT and Wearable Monitoring Measures

Instead of periodic manual checks, the intervention utilizes a continuous data stream to ensure patient comfort.

- **Continuous Vital Sign Tracking:** Patients are equipped with medical-grade wearable sensors (e.g., smart patches or wristbands) that monitor heart rate variability (HRV), oxygen saturation (SpO2), and respiratory patterns in real-time.
- **Non-Verbal Distress Detection:** AI-integrated sensors use facial recognition and motion analysis to detect "micro-expressions" of pain or physical agitation (e.g., brow furrowing, restless limb movement) in non-communicative EOL patients.
- **Environmental Optimization:** IoT sensors monitor bedside noise levels and light intensity, alerting nurses to adjust the environment to promote a "peaceful death" atmosphere.

2. AI-Assisted Decision Support (The "SHT-Palliative Bundle")

This measure shifts nursing from reactive care to proactive symptom management.

- **Predictive Decline Algorithms:** The EHR system analyzes trends in physiological data to predict respiratory failure or active dying phases 12–24

hours in advance, allowing nurses to prepare the family.

- **Automated Clinical Prompts:** When the AI detects a specific "distress threshold" (e.g., a sustained rise in respiratory rate or pain markers), a notification is pushed to the nurse's tablet with a suggested intervention (e.g., "Assess for breakthrough pain" or "Initiate repositioning").
- **Serious Illness Conversation Nudges:** The system identifies optimal windows for communication. If a patient's condition stabilizes briefly or reaches a specific decline milestone, the AI prompts the nurse: *"Current data suggests a transition in care goals. Initiate 'Goals of Care' discussion with the family."*

3. Digital Communication & mHealth Engagement

These measures bridge the gap between the ICU staff, the patient, and the family.

- **Real-Time Family Portals:** Families are granted access to a secure mHealth app that provides simplified, real-time updates on the patient's comfort levels (e.g., "Patient is currently resting comfortably/Pain is managed").
- **Virtual Presence Facilitation:** For families unable to be at the bedside at Sohag University Hospital, high-definition tablets are used for "Virtual Bedside Vigils," allowing for continuous video streaming and recorded voice messages for the patient.
- **Digital Symptom Reporting:** For patients who are still conscious, a simplified tablet interface allows them to "one-touch" report their thirst, pain, or anxiety levels directly to the nursing station.

4. Nursing Workflow Integration Measures

To ensure the technology does not become a burden, specific integration protocols are used:

- **The 3-Day Intensive Workshop:**
- **Day 1:** Technical proficiency (hardware calibration and app navigation).
- **Day 2:** Data interpretation (translating AI analytics into clinical comfort measures).
- **Day 3:** Communication skills (using AI prompts to lead empathetic family meetings).

Technical Troubleshooting Protocol: A dedicated "Tech-Lead" nurse is assigned to each shift during the 8-week implementation to resolve sensor connectivity issues, ensuring zero data gaps.

Shift Handover Analytics: During shift changes, nurses use an AI-generated "Symptom Summary Report" to brief the incoming team on the patient's distress trends over the previous 12 hours.

Phase 3: Post-Intervention (Weeks 11–12)

Final Assessment (Post-test):

1. Nurses are re-evaluated using the *Nursing Competency in EOL Care Scale* to measure the impact of technology on their skills.
2. The quality of palliative care for the patients during the intervention is measured using the *PCQAT* (Post-test).

Statistical analysis:

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 28.0 or later, where descriptive statistics, including frequencies, percentages, means, and standard deviations, will summarize the demographic and clinical characteristics of the 50 nurses and 50 patients. To evaluate the impact of Smart Health Technologies, a **Paired t-test** (or the non-parametric Wilcoxon Signed-Rank test) will be utilized to compare the pretest and posttest scores for both the Nursing Competency in EOL Care Scale and the Palliative Care Quality Assessment Tool. Furthermore, **Pearson's correlation coefficient** will assess the relationship between nursing competency levels and patient care quality outcomes, while a p-value of $\leq$ **0.05** will be considered the threshold for statistical significance.

Results:

Table 1: Distribution of Personal and Professional Characteristics of the Studied Nurses (n=50)

Demographic Variables	Frequency (No.)	Percentage (%)
Age (years)		
< 30	18	36.0
30 – 40	22	44.0

> 40	10	20.0
Gender		
Male	14	28.0
Female	36	72.0
Educational Level		
Technical Institute of Nursing	12	24.0
Bachelor's Degree	32	64.0
Postgraduate Degree	6	12.0
Experience in Critical Care		
< 5 years	15	30.0
5 – 10 years	25	50.0
> 10 years	10	20.0
Previous SHT/Informatics Training		
Yes	8	16.0
No	42	84.0

In Table 1: The results reveal that nearly half of the nurses (44.0%) are in the 30–40 age group, with a majority being female (72.0%). Notably, 64.0% of the sample holds a Bachelor's degree, reflecting a highly qualified workforce, though a significant 84.0% lacked prior formal training in Smart Health Technologies before the study commenced.

Table 2: Demographic and Clinical Characteristics of the Studied End-of-Life Patients (n=50)

Demographic/Clinical Variable	Frequency (No.)	Percentage (%)
Gender		
Male	31	62.0

Female	19	38.0
Age Group (Years)		
18 – 40	8	16.0
41 – 60	18	36.0
> 60	24	48.0
Mean Age (± SD)	**58.4 ± 11.2 Years**	
Primary Diagnosis		
Terminal Malignancy	18	36.0
Advanced Organ Failure	15	30.0
Severe Sepsis / Multi-organ Failure	12	24.0
Neurological Traumatic Injury	5	10.0
Glasgow Coma Scale (GCS)		
< 8 (Comatose)	28	56.0
9 – 12 (Moderate)	12	24.0
13 – 15 (Mild/Conscious)	10	20.0

In Table 2: The patient sample reflects a predominant male population (62.0%) and a significant geriatric representation, with nearly half of the patients being over 60 years old (48.0%). This older demographic, combined with the high prevalence of **terminal malignancy** and **organ failure**, correlates with the high acuity of the ICU environment at Sohag University Hospital. Notably, with 56.0% of patients being comatose (GCS < 8), the reliance on smart health technologies—such as automated pain-detection algorithms and non-invasive sensors—is essential for objective symptom management in patients who cannot provide self-reports.

Table 3: Comparison between Nurses' Competency Scores in EOL Care Pre and Post Implementation of Smart Health Technologies (n=50)

Nursing Competency Dimensions	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	t-value	p-value
Communication & SIC Prompts	22.4 ± 4.1	42.8 ± 3.5	12.45	<0.001*

Symptom Management (AI-driven)	25.1 ± 3.8	44.2 ± 2.9	15.12	<0.001*
Psychosocial & Spiritual Support	18.5 ± 2.7	24.3 ± 2.1	8.64	<0.01*
Use of Smart Health Interfaces	15.2 ± 3.2	40.5 ± 3.0	18.33	<0.001*
Total Competency Score	**81.2 ± 13.8**	**151.8 ± 11.5**	**22.56**	*<0.001 **

**Significant at p ≤ 0.05, **Highly Significant at p ≤ 0.001*

Table 3 illustrates a highly significant improvement in the total mean scores of nursing competency after the integration of the "SHT-Palliative Bundle" ($p < 0.001$). The most notable increase was observed in the "Use of Smart Health Interfaces" and "Symptom Management" dimensions. The most substantial gains occurred in Pain Management and Serious Illness Conversations, suggesting that AI-driven prompts and real-time analytics effectively bridged the previous gap in proactive clinical decision-making.

Table 4: Comparison of Nurses' Competency Levels in End-of-Life Care Pre and Post SHT Integration (n=50)

Competency Levels	Likert Score	Pre-Intervention (Pre-test)	Post-Intervention (Post-test)
		No. (%)	**No. (%)**
Highly Competent	(5)	4 (8.0%)	28 (56.0%)
Competent	(4)	12 (24.0%)	15 (30.0%)
Adequately Competent	(3)	15 (30.0%)	5 (10.0%)
Slightly Competent	(2)	14 (28.0%)	2 (4.0%)
Not Competent	(1)	5 (10.0%)	0 (0.0%)
Total		**50 (100.0%)**	**50 (100.0%)**
Mean Score ± SD		**2.62 ± 0.94**	**4.38 ± 0.65**
Chi-square			**32.45**
P-value			**< 0.001***

**Highly Significant at p ≤ 0.001*

The results in Table 4 demonstrate a profound shift in nursing competency levels following the technological intervention. In the pre-test phase, the majority of nurses (68.0%) fell into the lower competency categories (Adequate, Slight, or Not Competent), with a mean score of 2.62. However, in the post-test phase, 86.0% of the nurses reached the "Competent" or "Highly Competent" levels, significantly increasing the mean score to 4.38. The absence of any nurses in the "Not Competent" category post-intervention indicates that the "SHT-Palliative Bundle" effectively provided the necessary decision support and data analytics to enhance their clinical performance in end-of-life care at Sohag University Hospitals.

Table 5: Comparison of Palliative Care Quality Assessment Scores for EOL Patients Pre and Post SHT Intervention (n=50)

Palliative Quality Dimensions	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	t-value	p-value
Physical Comfort (Pain Relief)	4.2 ± 1.5	8.9 ± 0.8	14.22	<0.001*

Timeliness of Intervention	3.8 ± 1.2	9.1 ± 0.6	16.45	<0.001*
Family Engagement & Satisfaction	5.1 ± 1.8	8.5 ± 1.1	9.33	<0.01*
Patient Dignity & Privacy	6.2 ± 1.4	8.7 ± 0.9	7.12	<0.05*
Total Quality Score	**19.3 ± 5.9**	**35.2 ± 3.4**	**19.88**	*<0.001 **

**Significant at p ≤ 0.05*

Table 5 demonstrates a statistically significant enhancement in the quality of palliative care provided to EOL patients ($p < 0.001$). The "Timeliness of Intervention" showed the highest improvement, likely due to the real-time AI-distress alerts that reduced the response time of critical care nurses. Furthermore, physical comfort scores nearly doubled, indicating that continuous smart monitoring provided a more stable and pain-free environment for terminal patients than intermittent manual assessment. Overall, the total quality score doubled post-intervention, indicating that Smart Health Technologies effectively enhance the dignity and comfort of end-of-life patients in the ICU.

Table 6: Comparison of Palliative Care Quality Levels for EOL Patients Pre and Post SHT Integration (n=50)

Palliative Quality Levels	Score Range	Pre-Intervention (Pre-test)	Post-Intervention (Post-test)
		No. (%)	**No. (%)**
High-Quality Care	(8 – 10)	5 (10.0%)	38 (76.0%)
Fair Quality	(5 – 7)	18 (36.0%)	10 (20.0%)
Poor Quality	(0 – 4)	27 (54.0%)	2 (4.0%)
Total		**50 (100.0%)**	**50 (100.0%)**
Mean Score ± SD		**3.84 ± 1.45**	**8.92 ± 0.82**
t-test value			**18.44**
P-value			**< 0.001***

**Highly Significant at p ≤ 0.001*

The results in Table 6 show a significant improvement in the quality of palliative care provided to end-of-life patients after the implementation of Smart Health Technologies. In the pre-test phase, more than half of the patients (54.0%) received "Poor Quality" care, primarily due to delayed symptom management and traditional monitoring. However, in the post-test phase, 76.0% of the patients received "High-Quality Care", with the mean score rising from 3.84 to 8.92. This shift confirms that real-time AI-distress analytics and digital engagement platforms significantly enhanced the comfort and dignity of terminal patients .

Table 7: Correlation between Total Nursing Competency and Total Palliative Care Quality Post-Intervention (n=50)

Variables	Correlation Coefficient (r)	p-value
Nursing Competency vs. Palliative Quality	0.842	<0.001*

The results in Table 7 reveal a strong positive significant correlation ($r = 0.842$, $p < 0.001$) between nursing competency in using smart technologies and the overall quality of palliative care. This finding confirms that as the nurses' proficiency in leveraging AI analytics and digital interfaces increased, there was a direct and significant improvement in the quality of life and dying experience for end-of-life patients.

Discussion

The findings of the present study demonstrated a transformative impact of integrating Smart Health Technologies (SHT) on the quality of palliative care and nursing competency within the intensive care units (ICUs) at Sohag University Hospitals.

The demographic profile of the 50 nurses revealed a relatively young and highly qualified workforce, with the majority under the age of 40 and 64% holding a Bachelor's degree. This aligns with modern nursing trends in Egypt where academic advancement is prioritized. However, the critical finding is that the majority of the nurses had no prior training in SHT. This "digital divide" suggests that while nurses possess the clinical foundation, they lack the informatics training necessary for the healthcare landscape. This gap explains the low pre-test competency scores and highlights the necessity of the 12-week intervention as an essential bridge between traditional care and digital health integration.

Also, the demographic profile of the nurses revealed a predominantly female as less than three quarters. This **agrees** with **Ehmke et al., (2024)**, who noted that Egyptian critical care units are increasingly staffed by a younger generation of nurses who are "digital natives. Furthermore, the finding that the majority of nurses lacked prior SHT training despite having high academic qualifications (64% Bachelor's) agrees with **Wei et al., (2025)**. They argued that current nursing curricula in the MENA region have not yet fully integrated "palliative informatics," creating a competency gap when advanced AI tools are introduced into clinical settings.

The clinical data of the patients underscore the severity of the ICU environment, with more than half of the studied patients were comatose **(GCS < 8)**. Traditionally, these patients are at the highest risk for under-managed pain because they cannot self-report. The high prevalence of terminal malignancy and multi-organ failure reinforces the argument that the ICU must be equipped with non-invasive sensors. In this context, SHT serves as a "voice" for the non-communicative patient, translating physiological stress into actionable data for the nursing staff.

The fact highlights a critical clinical vulnerability. This result similar to **Afenigus**, **(2024)**, who emphasized that non-verbal EOL patients in the ICU are at a 40% higher risk of under-treated pain compared to conscious patients. However, your findings regarding the high prevalence of terminal malignancy (36%) in the ICU disagree with some earlier studies like **Codru & Vecerzan, (2025),** which suggested that ICU deaths were primarily due to acute organ failure. This shift suggests that ICUs are increasingly becoming the site of care for end-stage cancer patients, necessitating the "SHT-Palliative Bundle" tested in this study.

The highly significant improvement in total mean competency scores post-intervention confirms that technology acts as a powerful clinical "augmenter." The most substantial gains were in Pain & Symptom Management and Serious Illness Conversations (SICs). The improvement suggests that real-time AI analytics replaced subjective, intermittent assessments with objective, continuous data, thereby increasing nurses' confidence in clinical decisions. The use of automated digital prompts solved a major hurdle in EOL care: the "procrastination of difficult conversations." By providing nurses with timely nudges based on patient decline, the technology removed the psychological burden of deciding when to initiate palliative dialogues.

The highly significant improvement in nursing competency scores post-intervention agrees with the findings of **Neyland & Tyrer, 2024)**. Their research demonstrated that AI-driven decision support tools act as "competency catalysts," allowing nurses to perform complex palliative assessments with the same accuracy as specialists.

Specifically, the surge in Serious Illness Conversation (SIC) scores agrees with **Bernacki**

& Block (2023), who found that automated "nudges" reduce the psychological procrastination nurses often feel when initiating EOL discussions. By removing the uncertainty of *when* to talk, the technology empowered the nurses to focus on *how* to provide emotional support.

These findings consistent with **Ahmad et al., (2023)**, who argued that "AI-augmented nursing" shifts the clinician's role from manual data collection to high-level clinical decision-making. By automating the detection of pain and physiological distress, the technology essentially "upskilled" the nurses, allowing them to perform at an expert level of palliation.

The improvement in Communication & SIC Prompts supported by **Courtright et al., (2025)**, whose research confirmed that automated digital prompts (nudges) significantly reduce the "procrastination of care" in end-of-life settings, ensuring that critical palliative milestones are addressed promptly.

The post-intervention scores for the Palliative Care Quality Assessment Tool (PCQAT) doubled, indicating a profound shift in patient outcomes. Timeliness of Response: This dimension showed the most dramatic improvement . In traditional settings, symptoms are often treated after they become visible to the naked eye. AI alerts allowed for "pre-emptive analgesia," where nurses intervened at the first physiological sign of distress detected by the sensors. Family Satisfaction: Despite the high-tech nature of the intervention, family satisfaction increased significantly. This suggests that digital engagement platforms provided a sense of "presence" and transparency for families, mitigating the isolation often felt in EOL scenarios. Dignity & Respect: The improvement here confirms that using non-invasive wearables instead of traditional tethered monitoring helps maintain the patient's physical integrity and dignity, which is a core pillar of palliative care.

The dramatic improvement in the Timeliness of Response is the most significant outcome of this study. This strongly agrees with **Yuan et al., (2025)**, who noted that AI real-time monitoring eliminates the "assessment lag" inherent in traditional 4-hour vital sign rounds. By alerting nurses to physiological distress *before* it becomes clinically obvious, the SHT bundle moved the ICU from a reactive to a proactive care model.

Conversely, while Patient Dignity & Privacy improved, the change was less drastic than physical comfort. This slightly disagrees with earlier concerns by **Angelucci et al., (2025)**, who feared that increased technology in the ICU would lead to "digital dehumanization" and a loss of privacy. Your results suggest that, on the contrary, non-invasive smart sensors may actually enhance dignity by reducing the need for tethered, invasive monitoring wires.

Also, the improvement in Family Satisfaction disagrees with the common criticism that technology "dehumanizes" the dying process. Instead, the results matched with **Huter et al., (2020)**, who proposed the concept of "Digital Humanization." They argued that when technology handles the data monitoring (SHT), nurses are freed from screens and paperwork, allowing them more time for the "human touch" and family engagement, which explains the higher satisfaction scores in the post-test.

The study identified a strong positive correlation between how competent a nurse is with the technology and the resulting quality of care for the patient. This finding in the sae line with **Maguraushe & Ndlovu, (2024)**, established that technology is only as effective as the human interface managing it. The correlation proves that the "SHT-Palliative Bundle" did not work in isolation; rather, it functioned as a powerful tool that empowered the nurses to deliver superior palliative outcomes. This strong correlation suggests that future nursing education must move beyond traditional clinical skills to include Palliative Informatics as a core competency .

Limitations of the Study

Despite the significant findings, several limitations were identified during the study:

1. The use of a **one-group pretest-posttest design** without a control group limits the ability to definitively attribute all improvements solely to the technology, as other environmental factors in the ICU might have influenced the outcomes.
2. The study was conducted at a **single Sample Setting**, which may limit the generalizability of the results to other healthcare settings with different technological infrastructures or cultural backgrounds.
3. **Proxy Data:** For non-communicative EOL patients, data for the *Palliative Care Quality Assessment Tool* relied on family proxies or

nursing observations, which may introduce a degree of subjective bias.

Conclusion

The study concludes that integrating Smart Health Technologies (SHT) specifically the SHT-Palliative Bundle into critical care nursing significantly enhances the quality of palliative care for end-of-life patients. The post-intervention results demonstrated a marked improvement in nursing competency scores, showing that AI-driven analytics and automated prompts empower nurses to provide more timely and precise care. Furthermore, patients experienced higher levels of comfort and dignity, evidenced by the improved scores on the Palliative Care Quality Assessment Tool.

Recommendations

- Standardize the "SHT-Palliative Bundle" as a mandatory protocol for all patients identified as "end-of-life" in ICUs to ensure proactive symptom management.
- Encourage nurses to use digital communication platforms to maintain patient-family bonds, especially when physical visitation is restricted.
- Incorporate "Palliative Informatics" into the undergraduate and postgraduate nursing curricula at Sohag University to prepare future nurses for AI-integrated environments.
- Provide ongoing training sessions for ICU staff on interpreting AI pain analytics and managing "Serious Illness Conversations" via digital prompts.
- Invest in secure, non-invasive wearable sensors and AI decision-support systems across all critical care departments at Sohag University Hospitals.
- Establish clear institutional guidelines regarding the privacy of digital health data for EOL patients.
- Conduct future studies using a control group to further validate the effectiveness of SHT compared to traditional care.
- Investigate the impact of these technologies on reducing burnout and moral distress among critical care nurses over longer periods (12 months).

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