

Assessment of 12-Lead Electrocardiogram Interpretation Competency Among Critical Care Nurses: A Multi-Center Cross-Sectional Study in Public and Private Tertiary Care Hospitals of Peshawar, Pakistan

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Abstract

Cardiovascular disease (CVD) is the leading cause of death globally and timely ECG interpretation by critical care nurses is vital for lowering mortality rates in clinical settings. In Pakistan, no evidence of a multi-center study exists that has comprehensively assessed nurses' competency in ECG interpretation. The aim of this study is to assess the ECG interpretation competency among critical care nurses, to identify association between nurses' demographics and their ECG interpretation skills, and to compare the competency level scores of nurses of public and private hospitals. A multi-center quantitative descriptive cross-sectional study was conducted across six tertiary care hospitals in Peshawar. A stratified sample of 155 critical care nurses (ICU, CCU, Emergency) was recruited from a total population of 258 nurses. Data was collected through a validated 12-lead ECG interpretation competency questionnaire (ICC = 0.869 and CVI = 0.87) comprising 12 scenario-based multiple-choice questions. Most nurses had 1–5 years of critical care experience, and 62.6% had not attained formal ECG training. Moderate competence was observed in 62.6% of participants, high competence in 34.2%, and low competence in 3.2%. One-way ANOVA revealed that working experience significantly influenced ECG competence ($p < 0.001$), while chi-square analysis showed a significant association between ECG training and interpretation score ($p = 0.041$). No significant difference was observed between nurses in public and private hospitals ($p = 0.215$). This study provides multi-center evidence of ECG interpretation competency among critical care nurses in Pakistan, informing targeted educational interventions and hospital policies.

Keywords: Electrocardiogram Interpretation; Critical Care Nurses; Competency Assessment; Multi-Center Study; Peshawar

Introduction

Cardiovascular disease (CVD) is the leading cause of death globally, accounting for around 20.5 million fatalities in 2021 about one in every three deaths worldwide.(1) Statistical reports from the World Health Organization and Saudi Arabia's Ministry of Health indicate that cardiovascular diseases accounted for nearly 42% of deaths from non-communicable diseases in 2010.(2) Timely detection of cardiovascular disorders represents an effective strategy for reducing death rates.(3) As a developing nation with low literacy rates, Pakistan faces significant challenges in public health education, leaving its population particularly vulnerable to chronic conditions such as cardiovascular disease due to limited preventive healthcare knowledge.(4)

The electrocardiogram serves as a fundamental diagnostic instrument for evaluating heart-related conditions.(5) It is designed to monitor and record variations in the heart's electrical

impulses.(6) This procedure is considered the non-invasive gold-standard technique for diagnosing heart attacks, arrhythmias, chest pain syndromes, collapsed lungs, and various other conditions that demand continuous tracking and visualization of the heart's electrical signals.(7) Electrocardiogram interpretation has clinical utility for diverse patient populations presenting with multiple cardiac conditions,(8) offering conclusive detection of active or past heart attacks, with the ability to pinpoint the exact affected cardiac regions and measure the extent of damage.(2) The American College of Cardiology guidelines mandate that patients showing symptoms of acute coronary syndrome receive an electrocardiogram and its interpretation within 10 minutes of initial assessment,(8) and the American Heart Association similarly advises that every patient arriving at the emergency department with chest pain or angina should have an electrocardiogram within the first 10 minutes of arrival.(9)

Nurses play a crucial role in providing hospital care, particularly in critical care environments such as the Intensive Care Unit (ICU), Cardiac Care Unit (CCU), and Emergency Department, where continuous electrocardiogram monitoring is essential for patient management.(2) As frontline healthcare providers, nurses typically review electrocardiogram tracings first, recognizing critical abnormalities that demand prompt action.(2) Nurses' constant presence at patients' bedsides makes their capability to differentiate between regular and irregular electrocardiogram tracings fundamentally crucial.(10) Mastering this skill allows nursing staff to effectively interpret electrocardiogram patterns and associated clinical changes, ensuring the implementation of correct and immediate therapeutic measures.(10) In emergency and critical care settings, registered nurses play a vital role in conducting electrocardiogram assessments, interpreting results, and relaying critical findings to the healthcare team.(4) Nurses' primary responsibility in initial electrocardiogram interpretation is vital for lowering mortality rates and enhancing patient survival in clinical settings.(6) Importantly, evidence confirms that this competency gap is addressable, as structured educational interventions have proven effective in significantly improving both the knowledge and practical skills of nurses.(11)

However, existing literature provides limited investigation into nurses' competency in analyzing electrocardiographic changes. Empirical evidence underscores this gap, as a study in India found that over 80% of staff nurses demonstrated low competency in ECG interpretation.(12) This gap is widespread; for example, a study in Saudi Arabia revealed that only 30% of critical care nurses had adequate knowledge.(2) Furthermore, this deficit is particularly dangerous in specific areas; research indicates that while nurses may identify life-threatening arrest rhythms, a significant majority struggle to recognize acute ischemic changes, such as ST-elevation myocardial infarction, on an ECG.(13) According to research conducted by Dogan and Melek, a significant proportion (60.5%) of nurses demonstrated insufficient understanding of electrocardiogram monitoring protocols and failed to correctly classify arrhythmia types.(14) Another study conducted in a Baghdad healthcare facility on early intervention for patients with ventricular tachycardia revealed that nurses had insufficient knowledge.(14) Registered nurses often report difficulty in interpreting electrocardiograms due to insufficient knowledge,(9) and misinterpretation leads to higher healthcare costs and slower admissions, placing an unnecessary burden on hospitals and patients alike.(14) An additional barrier is attitudinal; a study in China found that a majority of ICU nurses believed they should rely on a physician's opinion for ECG interpretation, highlighting a need for educational programs that also address professional role perception.(15)

Few studies have assessed nurses' competency in electrocardiogram interpretation, and no evidence of a multi-center study exists in Pakistan that has comprehensively assessed this competency. This study aims to bridge that gap by assessing the 12-lead electrocardiogram interpretation competency among critical care nurses in public and private hospitals of Peshawar. By identifying knowledge gaps, this study provides actionable insight to improve electrocardiogram training programs and ultimately enhance patient outcomes in Pakistan's healthcare system.

Materials and Methods

Study Design

A quantitative, descriptive, cross-sectional study design was used to evaluate critical care nurses' competency in the interpretation of 12-lead electrocardiograms (ECGs) in public and private hospitals. The descriptive design characterized the current competence level of critical care nurses, while the cross-sectional design was used to evaluate and compare participants' competency levels across settings.

Study Setting

The study was conducted in public hospitals (Lady Reading Hospital, Hayatabad Medical Complex, Khyber Teaching Hospital) and private hospitals (Northwest General Hospital, Rehman Medical Institute, and Kuwait Teaching Hospital) in Peshawar. These are tertiary care hospitals with intensive care unit (ICU), cardiac care unit (CCU), and emergency department (ED) facilities.

Population and Sample Size

The population comprised all registered critical care nurses working in the ICU, CCU, and ED of the participating public and private hospitals in Peshawar. The target population consisted of registered nurses who regularly perform or interpret 12-lead ECGs as part of their professional duties and who were actively involved in the treatment and monitoring of critically ill patients. The sample size was 155, calculated from a total population of 258 nurses via Raosoft software with a 95% confidence level, 5% margin of error, and 50% response distribution. A stratified sampling technique was used: the total population of critical care nurses was divided into two strata (public and private hospitals), and within each stratum participants were selected using proportionate allocation to ensure equal representation. This technique was chosen because it improves the representativeness of the sample and allows comparison between nurses working in different healthcare settings.

Inclusion and Exclusion Criteria

Registered nurses with a minimum of three months' experience who were present at the time of data collection and voluntarily participated, providing written informed consent, were eligible for the study. Nurses who were unwilling to participate, and questionnaires that were not returned or were returned incomplete, were excluded from the study.

Data Collection Tool and Procedure

Data were collected using an adapted 12-lead electrocardiogram interpretation competency questionnaire developed by Coll Badell M. The questionnaire comprised two sections: Section 1 captured sociodemographic details (gender, age, years of experience, hospital), and Section 2 assessed clinical ECG interpretation competence through 12 scenario-based multiple-choice questions covering rhythm identification, myocardial infarction diagnosis, and prioritization of urgent action. Each correct response was scored 1 point and incorrect answers 0 points, giving a possible range of 0–12. The cut-off value for ECG interpretation competence was a minimum of 9 out of 12. Competency levels were stratified into three tiers: scores of 0–4 indicate low competence, 5–8 moderate competence, and 9–12 high competence. A pilot study on 20 participants assessed questionnaire reliability and clarity; all items were valid, requiring no modifications, and Cronbach's alpha for the 12-item tool was 0.718, indicating acceptable reliability. The pilot sample was included in the final analysis. Following approval from the Ethical Review Board of Peshawar Medical College and formal permission from participating organizations, data were collected. Written consent was obtained from participants, and participants were given adequate time to complete the questionnaire.

Data Analysis

Data were verified for accuracy and completeness prior to entry and analysis. Statistical Package for the Social Sciences (SPSS) version 31.0 was used for all analyses. Descriptive statistics frequency, percentage, mean, and standard deviation were used to summarize participant demographics and ECG interpretation competency. Inferential statistics (one-way ANOVA, chi-square test, and independent-samples t-test) were used to examine the relationship between demographic variables and ECG interpretation competency, and to compare competency scores between nurses working in public and private hospitals.

Ethical Considerations

The study protocol was approved by the Institutional Review Board (IRB) of Peshawar Medical College. Formal authorization was secured from all participating institutions prior to data collection. All participants received a comprehensive overview of the research objectives, and written informed consent was obtained in each instance. Participation was entirely voluntary, with participants retaining the right to withdraw at any stage without penalty. Data were handled with strict confidentiality and anonymity, and all collected information was used exclusively for the intended research purpose.

Results

This section presents the findings of the study assessing critical care nurses' competency in interpreting 12-lead electrocardiograms across six tertiary care hospitals (three public and three private) in Peshawar. Data were analyzed using SPSS and are presented as one combined summary table, one composite figure, and one summary table of inferential statistics.

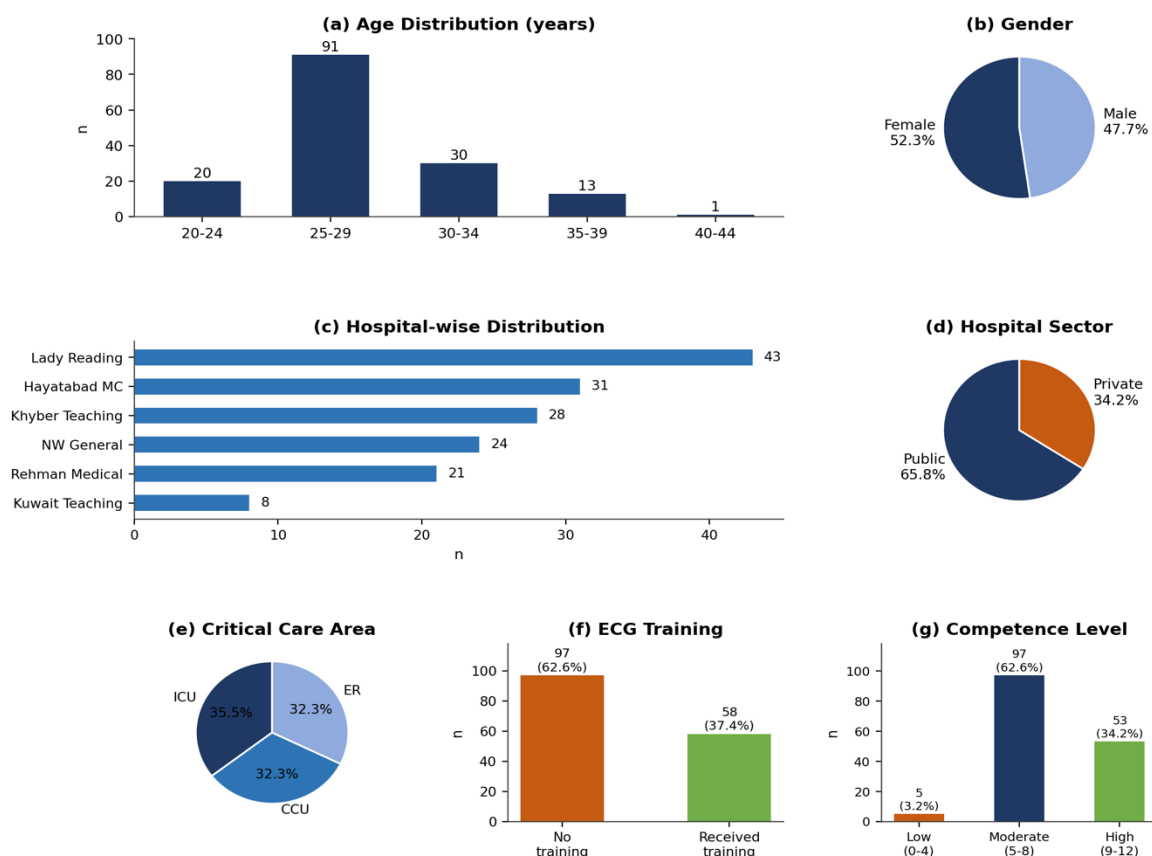
Table 1 summarizes the sociodemographic and study characteristics of the 155 participants, and Figure 1 presents the same characteristics graphically. Most participants were aged 25–29 years (58.7%) and female (52.3%). Lady Reading Hospital contributed the largest share of participants (27.7%), and nearly two-thirds of the sample worked in public-sector hospitals (65.8%), distributed fairly evenly across the ICU, CCU, and ER. Almost two-thirds of nurses (62.6%) had received no formal ECG training, and a similar proportion (62.6%) demonstrated moderate ECG interpretation competence, with 34.2% classified as high and only 3.2% as low. Separately, most participants had 1–5 years of critical care experience (the largest single category), followed by those with less than one year; the proportion with 6–10 years was considerably lower, and only a small number reported 11–20 or more years no exact frequencies for this variable were tabulated in the source data.

Table 1. Sociodemographic and Study Characteristics of Participants (N = 155)

Variable	Category	Frequency (n)	Percent (%)
Age (years)	20–24	20	12.9
	25–29	91	58.7
	30–34	30	19.4
	35–39	13	8.4
	40–44	1	0.6
Gender	Female	81	52.3
	Male	74	47.7
Hospital	Lady Reading Hospital	43	27.7
	Hayatabad Medical Complex	31	20.0
	Khyber Teaching Hospital	28	18.1
	Northwest General Hospital	24	15.5
	Rehman Medical Institute	21	13.5
	Kuwait Teaching Hospital	8	5.2
Hospital Sector	Public	102	65.8
	Private	53	34.2

Critical Care Area	ICU	55	35.5
	CCU	50	32.3
	Emergency Room (ER)	50	32.3
ECG Training Course	No	97	62.6
	Yes	58	37.4
ECG Interpretation Competence Level	Low (0–4)	5	3.2
	Moderate (5–8)	97	62.6
	High (9–12)	53	34.2

Figure 1. Sociodemographic Characteristics, ECG Training, and Competence Level of Participants (N=155)



The mean ECG interpretation score for the 155 registered nurses was 7.77 (SD = 1.90), with scores ranging from 2.00 to 12.00 out of a possible 12. Table 2 combines the results of the three inferential tests used to examine associations between this score and working experience, ECG training, and hospital sector. A one-way ANOVA showed a statistically significant difference in ECG scores across experience groups, $F(4, 150) = 5.461$, $p < 0.001$, so the null hypothesis was rejected nurses' ECG interpretation competence is significantly influenced by their working experience in critical care. A chi-square test of independence showed a statistically significant association between ECG training course attendance and interpretation competence, $\chi^2(9, N = 155) = 8.581$, $p = 0.041$, so the null hypothesis was rejected. An independent-samples t-test comparing public and private hospitals showed no statistically significant difference in mean ECG interpretation scores, $t(153) = -1.246$, $p = 0.215$, so the null hypothesis was not rejected nurses in both sectors demonstrated equivalent levels of ECG interpretation competency.

Table 2. Summary of Inferential Statistics for ECG Interpretation Score

Variable Tested	Test	Statistic	df	p-value	Decision
Working experience	One-way ANOVA	$F = 5.461$	4, 150	$<.001$	Significant
ECG training course	Chi-square	$\chi^2 = 8.581$	9	0.041	Significant
Hospital sector (Public vs. Private)	Independent t-test	$t = -1.246$	153	0.215	Not significant

Discussion

This study evaluated critical care nurses' competence in 12-lead electrocardiogram interpretation across public and private tertiary care hospitals in Peshawar. The majority of critical care nurses exhibited a moderate level of proficiency in ECG interpretation: 34.2% ($n = 53$) of participants exhibited high competence, 62.6% ($n = 97$) were classified as having moderate competence, and only 3.2% ($n = 5$) were classified as having low competence. The mean ECG interpretation score was 7.77 ± 1.90 , out of a maximum possible score of 12. These results indicate that, despite the majority of nurses demonstrating a satisfactory level of proficiency in ECG interpretation, there remains significant opportunity for advancement in the identification and interpretation of complex electrocardiographic abnormalities.

The results of the present study are consistent with those reported in numerous prior investigations conducted across a variety of healthcare environments. Several international studies have similarly demonstrated that nurses exhibit a moderate level of ECG interpretation competency. In Italy, Giannetta et al. reported comparable findings, with participants achieving a mean knowledge score of 6.9 out of 10, indicating moderate proficiency in ECG knowledge.(7) Similarly, a mean score of 6.68 out of 10 has been reported elsewhere, meaning that around half of nurses did not meet the minimal competency requirement.(9) These results are also consistent with research carried out in Saudi Arabia, where only 30% of nurses showed adequate understanding of ECG interpretation and 49% had intermediate knowledge.(2) Likewise, just 38.8% of emergency nurses in a Palestinian study had outstanding skill levels, with a mean competency score of 60.7%.(16) Similarly, Rahimpour et al. found that the majority of emergency nurses were classified as having poor competency, with only 38.1% achieving high competency levels; these findings lend credence to the idea that, despite repeated exposure to cardiac patients, many nurses still struggle with ECG interpretation.(8) The results are also consistent with research conducted in Asia: in China, Buluba et al. reported an average ECG knowledge score of 5.95 ± 2.14 , with 70.9% of ICU nurses showing low knowledge.(15) Similarly, a study at Al-Hussein Teaching Hospital in Iraq reported 80% of nurses having inadequate ECG interpretation skills.(17) In Ethiopia, Chamiso et al. reported that 91% of nurses demonstrated poor ECG interpretation skills.(18) These results highlight a considerable disparity in ECG proficiency among different healthcare systems.

Studies carried out in highly specialized cardiac institutes, on the other hand, have revealed much higher levels of expertise. A study found that 88.2% of nurses at the National Heart Institute showed good practice and 93.7% had strong ECG knowledge a disparity that may be explained by the increased exposure to cardiac patients, ongoing professional development opportunities, and specialized training offered in cardiac facilities. (6) Numerous studies have indicated that certain ECG principles are frequently challenging for nurses to master. For instance, nurses have reported difficulty with abnormalities of QT intervals, myocardial infarction, atrial fibrillation, supraventricular tachycardia, and pathological Q waves. Similar shortcomings were observed in the current study, indicating that ischemic changes and advanced rhythm analysis remain areas that need more focus in education.(14) The current results further support evidence that professional experience and training have a considerable impact on ECG expertise: higher competency ratings have consistently been linked to educational background, years of experience, ECG training courses, employment in cardiac

units, and exposure to ECG interpretation, according to studies conducted in Saudi Arabia, Iran, Ethiopia, and Malaysia. Overall, the findings of this study and earlier research indicate that nurses' competency in interpreting ECGs remains below optimal levels in many healthcare settings, with deficits more apparent when identifying complex arrhythmias, conduction abnormalities, and ischemic ECG changes.

Conclusion and Recommendations

The study found that critical care nurses had a moderate level of 12-lead ECG interpretation competency (mean score: 7.77 ± 1.90). Greater critical care experience and participation in ECG training were significantly associated with better ECG interpretation skills, while no significant difference was found between nurses working in public and private hospitals. The findings highlight the need for regular in-service ECG training, competency assessments, refresher courses, and clinical mentorship, particularly focusing on complex arrhythmias, advanced ECG abnormalities, and myocardial infarction patterns. Future studies should evaluate the effectiveness of structured educational interventions using experimental or quasi-experimental designs.

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