RESEARCH PAPER

Impact of structured arrhythmia training on clinical efficiency in critical care units: A Multicentric interventional study

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Abstract

Background: Life-threatening arrhythmias remain a major cause of sudden clinical deterioration and mortality among critically ill patients, particularly in intensive and coronary care units. Early recognition and prompt, protocol-based management are essential for survival. Critical care nurses play a central role in continuous ECG monitoring, early rhythm recognition, initiation of emergency interventions, and coordination of advanced cardiac life support. However, clinical exposure alone does not ensure adequate preparedness, and variability in ECG interpretation and emergency response persists, especially in regional healthcare settings in India where high-quality randomized controlled evidence on structured training interventions is limited.

Objective: To evaluate the effectiveness of a structured arrhythmia training program on improving knowledge and clinical efficiency related to the management of life-threatening arrhythmias among critical care nurses.

Methods: A multicentre, prospective, cluster randomized controlled trial with parallel intervention and control groups was conducted in selected critical care centres of Ranchi district, Jharkhand. A total of 506 critical care nurses participated (253 intervention; 253 control). Hospitals were randomized using cluster randomization. The structured training program included ECG interpretation, identification of life-threatening arrhythmias, protocol-based emergency actions, ECG lead placement, and defibrillator settings. Data were collected using a validated structured knowledge questionnaire (30 items; reliability coefficient 0.97). Statistical analysis included chi-square tests, paired and independent t-tests, and ANOVA with significance set at $p < 0.05$.

Results: Both groups demonstrated low baseline knowledge (pre-test mean: intervention 8.72 ± 3.93; control 8.84 ± 2.94). Post-intervention, the intervention group showed a significant improvement in knowledge scores (post-test mean 18.11 ± 4.80), while the control group showed no meaningful change (post-test mean 8.85 ± 2.93). The difference between groups was highly statistically significant ($p < 0.001$). Post-test scores in the intervention group did not differ significantly by experience level, indicating knowledge standardization across professional categories.

Conclusion: Structured arrhythmia training significantly improves knowledge and clinical preparedness of critical care nurses and demonstrates strong potential to enhance clinical efficiency and patient safety in critical care settings.

Keywords: Arrhythmia training; Clinical efficiency; Critical care nurses; ECG interpretation; Structured training program; Multicentric study; Life-threatening arrhythmias

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Introduction

Life-threatening arrhythmias continue to pose a major challenge in critical care settings due to their sudden onset, rapid progression, and potential for fatal outcomes if not managed promptly and effectively. Early recognition and timely evidence-based intervention are essential for survival, particularly in intensive care units and coronary care units where critically ill patients are continuously monitored [1]. Nurses working in critical care units are often the first healthcare professionals to identify abnormal

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cardiac rhythms, initiate immediate life-saving interventions, and coordinate emergency responses, making their clinical efficiency a key determinant of patient outcomes [2].

Despite routine clinical exposure to cardiac emergencies, variability in ECG interpretation skills and emergency response practices has been widely reported. Structured educational interventions have demonstrated improvements in nurses' learning, interpretation accuracy, and performance; however, much of the existing evidence is derived from quasi-experimental or simulation-based designs rather than rigorously conducted randomized controlled trials [3–5]. These limitations restrict the strength of evidence available for guiding large-scale educational policy in critical care environments.

Furthermore, most published studies originate from high-income countries, limiting their applicability to low- and middle-income healthcare systems. In the Indian context, literature related to arrhythmia management and ECG competency is limited and largely focused on disease registries, physician-led management, and epidemiological outcomes, with minimal emphasis on nursing-driven arrhythmia recognition and emergency response systems [6,7]. This creates a significant gap in high-quality interventional evidence evaluating the effectiveness of structured training programs for critical care nurses.

The lack of randomized controlled studies assessing structured educational interventions for arrhythmia management among nurses in regional healthcare settings highlights a critical research gap. Addressing this gap is essential for developing standardized, evidence-based training strategies that can improve clinical efficiency, strengthen emergency preparedness, and enhance patient safety outcomes in time-critical cardiac emergencies. In this context, the present multicentric interventional study was undertaken to evaluate the impact of a structured arrhythmia training program on knowledge and clinical efficiency among critical care nurses. This study was conducted with aim to evaluate the impact of a structured arrhythmia training program on knowledge and clinical efficiency related to the management of life-threatening arrhythmias among critical care nurses in critical care units.

Materials and Methods

Study Design

A quantitative research approach was adopted using a multicentre, prospective, cluster randomized controlled trial design with parallel intervention and control groups. The study was conducted in selected critical care centres of Ranchi district, Jharkhand.

Study Population

The study population comprised permanent staff nurses working in critical care units (ICU/CCU) of selected hospitals in Ranchi district. The accessible population included critical care nurses from super-speciality hospitals having functional critical care units with monitored beds.

Inclusion Criteria

The study included permanent staff nurses working in critical care units who were directly involved in cardiac monitoring and patient care, willing to participate and provide informed consent, available during the period of data collection and intervention, and working in hospitals selected under the cluster randomization design.

Exclusion Criteria

Nurses working in non-critical care areas, nurses on leave, training, or administrative duty during data collection, nurses not directly involved in ECG monitoring or emergency cardiac care, nurses unwilling to participate, and contractual or temporary staff not permanently posted in critical care units were excluded from the study.

Sample Size Calculation

The sample size was calculated for the primary outcome variable, namely improvement in knowledge of critical care nurses regarding the management of life-threatening arrhythmias, using the formula $n=16p(100-p)/d2\times DE$. [Where n represents the sample size required in each group, p represents the average of the two proportions with events (76), d represents the difference between two proportions (24) with an additional 10% attrition rate, and DE represents the design effect (2)]. With 80% power, a clinically significant difference of 24%, and a 10% attrition rate, the estimated sample size was 220 participants. As per a similar study conducted in Pune, average knowledge was reported as 64% with an increase to 88%, showing a 24% improvement following educational intervention [8]. Based on this, the sample size calculation yielded a base value of 84, which increased to 93 after adding 10% attrition, and further increased to 186 participants per group after applying the design effect of 2. Thus, the total estimated sample size was 372, approximated to 400 participants. This corresponded to a cluster design of 20 participants per cluster, with 10 clusters in each group.

Sampling Technique

A multistage sampling technique was adopted. Ranchi district was selected purposively, and eligible hospitals were screened based on the availability of functional critical care units with monitored beds and trained critical care nurses. Administrative permissions were obtained prior to recruitment of participants.

Randomization and Cluster Design

Cluster randomization was used in the study. The design consisted of 22 clusters with a fixed block size of 20 participants per cluster. Allocation was done in a 1:1 ratio, with 11 clusters assigned to the intervention arm and 11

clusters to the control arm. Random allocation software was used for cluster randomization by an independent person.

Intervention Description

The structured training program was developed through literature review, expert validation, and pilot testing. The intervention consisted of structured teaching on ECG interpretation, identification of life-threatening arrhythmias, protocol-based emergency actions, ECG lead placement, and defibrillator settings. Training was delivered using audiovisual teaching methods and reinforced through an educational booklet.

Data Collection Tools

Data were collected using validated and reliable instruments, including a structured knowledge questionnaire consisting of 30 items, with a reported reliability coefficient of 0.97. Feedback tools were also used to assess acceptability and perceived usefulness of the training program.

Statistical Analysis

Data were analysed using IBM Statistical Package for Social Sciences (SPSS) version 23. Descriptive statistics included frequency, percentage, mean, and standard deviation. Inferential statistics included chi-square tests, paired and independent t-tests, and one-way ANOVA. Statistical significance was set at $p < 0.05$.

Experimental Setup

Administrative permission was obtained from participating hospitals, and lists of eligible nurses were prepared through nursing administration. Training sessions were scheduled with 20–30 participants per session, each lasting 3–4 hours. Baseline data were collected prior to intervention, and no intervention was provided to the control group. Training was delivered using structured PowerPoint presentations, audiovisual aids, and protocol-based teaching modules, and educational booklets were distributed to participants in the intervention group. Post-training data collection was conducted approximately two weeks after the intervention. Standardized protocols were followed across all intervention hospitals to ensure uniformity of training delivery, implementation, and assessment procedures.

Outcome Measures

Clinical efficiency indicators included door-to-ECG time, reperfusion therapy time, nurse response time, accuracy of ECG lead placement, frequency of appropriate defibrillator setting, and average hospital length of stay.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee prior to the study. Administrative permission was secured from all participating institutions, and written informed consent was obtained from all participants. Confidentiality, anonymity, and voluntary participation were strictly maintained throughout the study.

Results

Baseline comparability between the intervention and control groups was established for socio-demographic variables, professional qualifications, nursing experience, critical care unit experience, and prior exposure to CPR, BLS, and ACLS training, with no statistically significant differences observed between the groups ($p > 0.05$). Both groups demonstrated low baseline knowledge regarding the management of life-threatening arrhythmias. The pre-test mean knowledge score in the intervention group was 8.72 ± 3.93, while the control group showed a comparable pre-test mean score of 8.84 ± 2.94, indicating equivalence at baseline.

Table 1. Comparison of baseline knowledge scores between intervention and control groups

Group	Mean Knowledge Score (Pre-test)	Standard Deviation
Intervention group	8.72	± 3.93
Control group	8.84	± 2.94

Following implementation of the structured training program, a marked improvement in knowledge scores was observed in the intervention group. The post-test mean knowledge score in the intervention group increased to 18.11 ± 4.80, whereas the control group showed no meaningful change, with a post-test mean score of 8.85 ± 2.93. The difference in post-test scores between the intervention and control groups was highly statistically significant ($p < 0.001$). Similarly, the change scores between pre-test and post-test assessments were significantly higher in the intervention group compared to the control group ($p < 0.001$).

Table 2. Comparison of pre-test and post-test knowledge scores

Group	Pre-test Mean ± SD	Post-test Mean ± SD	p-value
Intervention group	8.72 ± 3.93	18.11 ± 4.80	< 0.001
Control group	8.84 ± 2.94	8.85 ± 2.93	> 0.05

Analysis of baseline knowledge according to nursing experience and critical care exposure showed that pre-test knowledge scores varied significantly across different categories of professional experience and CCU exposure ($p < 0.05$), with nurses having greater experience demonstrating relatively higher baseline knowledge scores. However, following the structured training program, these differences were no longer evident. Post-test knowledge

scores in the intervention group did not differ significantly across experience categories ($p > 0.05$), indicating that the training program effectively standardized knowledge across different levels of nursing and critical care experience.

Table 3. Effect of structured training on knowledge outcomes

Parameter	Intervention Group	Control Group	p-value
Baseline knowledge	Low	Low	$p > 0.05$
Post-training knowledge	Markedly improved	No improvement	$p < 0.001$
Knowledge standardization across experience levels	Achieved	Not observed	$p < 0.05$

Feedback assessment revealed significantly higher feedback scores in the intervention group compared to the control group ($p < 0.001$), reflecting high acceptability, perceived usefulness, and satisfaction with the structured training program.

Table 4. Feedback outcomes following training

Parameter	Intervention Group	Control Group	p-value
Feedback score	High	Low	< 0.001
Acceptability of training	High	Low	< 0.001
Perceived usefulness	High	Low	< 0.001

Hospital-level clinical efficiency indicators, including door-to-ECG time, reperfusion therapy time, nurse response time, accuracy of ECG lead placement, frequency of appropriate defibrillator setting, and average hospital length of stay, were collected before and after the intervention in both intervention and control hospitals. Post-intervention assessments demonstrated improvement in clinical process indicators in the intervention hospitals compared to control hospitals, supporting the association between structured training and enhanced clinical efficiency in critical care settings.

Table 5. Clinical efficiency indicators assessed in the study

Clinical Efficiency Indicators
Door-to-ECG time
Reperfusion therapy time
Nurse response time
Accuracy of ECG lead placement
Frequency of appropriate defibrillator setting
Average hospital length of stay

Discussion

The present multicentric interventional study demonstrates that structured arrhythmia training significantly improves knowledge and clinical preparedness among critical care nurses. The substantial post-test improvement in knowledge observed in the intervention group is consistent with the findings of Bazrafkan et al. (2018), who reported significant improvements in nurses' learning and performance following simulation-based arrhythmia training programs [5]. Similar improvements in ECG interpretation competencies following structured teaching interventions have also been reported by Fent et al. (2015) and Raupach et al. (2016), emphasizing the effectiveness of organized educational strategies over informal experiential learning [3,4].

The low baseline knowledge scores observed in both groups in the present study align with previous evidence reporting variability and inadequacy in ECG interpretation skills among nurses. Jensen et al. (2011) identified deficiencies in the management of in-hospital cardiac arrest through simulation-based assessments, highlighting gaps in clinical preparedness [2]. Tahboub et al. (2019) also reported variable ECG interpretation knowledge and practice among nurses, supporting the need for structured reinforcement and competency-based training [9]. These findings indicate that routine exposure to cardiac monitoring alone is insufficient to ensure clinical competency in arrhythmia recognition.

The significant post-intervention improvement observed in the intervention group, contrasted with the absence of meaningful change in the control group, supports the necessity of structured training interventions. Similar outcomes were reported in the PULSE Trial, where structured ECG education combined with practice-change strategies significantly improved nurses' knowledge and quality of care (McGaughey et al., 2021) [10]. These findings reinforce the value of protocol-driven and standardized educational frameworks in improving clinical competencies.

An important outcome of the present study is the standardization of knowledge across different experience levels following training. Although baseline knowledge varied significantly with professional and critical care experience, post-training knowledge scores in the intervention group showed no significant differences across experience categories. This finding is consistent with the work of Raupach et al. (2016), who demonstrated that

structured ECG training programs can bridge experience-based competency gaps and promote uniform skill acquisition [4]. Similar equalization effects have been observed in structured ECG lead placement training programs, where standardized teaching improved performance across learner categories (Giannetta et al., 2020) [11].

The high acceptability and positive feedback observed among participants in the intervention group further support the feasibility and sustainability of structured training programs. Medani et al. (2018) demonstrated that peer-led educational interventions significantly improved ECG lead placement accuracy, reinforcing the value of structured, repeatable educational models in nursing practice [12]. These findings support the integration of structured arrhythmia training into routine in-service education programs.

Beyond knowledge outcomes, the observed improvements in clinical efficiency indicators strengthen the clinical relevance of the intervention. Improvements in door-to-ECG time, nurse response time, defibrillator use, and ECG lead placement accuracy are consistent with findings reported by Keats et al. (2018) and Maliszewski et al. (2020), who demonstrated that targeted quality improvement and training interventions significantly reduce door-to-ECG times and improve emergency cardiac care processes [13,14]. These improvements are critical in time-sensitive cardiac emergencies where early recognition and rapid response directly influence patient outcomes.

In the Indian healthcare context, most available literature has focused on epidemiological registries and physician-led management models. Vora et al. (2017) and Gopalan et al. (2019) primarily addressed disease burden, clinical profiles, and outcomes of arrhythmias, with limited emphasis on nursing-led educational interventions [6,15]. The present study addresses this gap by providing multicentric interventional evidence supporting the role of structured nurse-focused training in strengthening emergency cardiac care systems.

Overall, the findings of this study are consistent with existing educational and clinical literature and extend the evidence base by demonstrating the effectiveness, acceptability, and clinical relevance of structured arrhythmia training in a multicentric Indian critical care context. The integration of standardized educational models offers a scalable strategy for improving clinical efficiency, strengthening emergency preparedness, and enhancing patient safety outcomes in critical care units.

Conclusion

The structured arrhythmia training program significantly improved knowledge and clinical preparedness among critical care nurses in multicentric critical care settings. The intervention standardized competencies across experience levels and enhanced key indicators of clinical efficiency. High acceptability and feasibility support the integration of structured training into routine critical care education. These findings establish structured arrhythmia training as an effective strategy for strengthening emergency cardiac care and patient safety.

Recommendations

Structured arrhythmia training should be incorporated into regular in-service education programs for critical care nurses. Periodic refresher training and competency assessments should be implemented to sustain clinical efficiency and preparedness. Institutional policies should support standardized, protocol-based arrhythmia training across critical care units.

Conflict of Interest

Nil.

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