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DIAGNOSTIC EFFICACY AND CLINICAL CORRELATES OF X-RAY AND ELECTROCARDIOGRAPHY (ECG) IN INTEGRATED PATIENT ASSESSMENT

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ABSTRACT

CXR and ECG are among the essential diagnostic tools in resource-constrained settings, due to their affordability, accessibility, and rapid reporting times. These are usually the first investigations ordered for patients presenting with cardiopulmonary symptoms like chest pain, dyspnea, and syncope. While each has something valuable to offer - X-rays into structural abnormalities and ECG into electrical disturbances - together, their diagnostic potential is poorly explored in routine clinical practice, particularly in resource-poor settings. Objective and Methods, The purpose of this study was to assess the diagnostic performance and clinical correlation of chest X-ray and ECG findings interpreted together. A cross-sectional analysis was performed in a tertiary hospital in South India among 1,200 adult patients. ROC curves, logistic regression, and correlation matrices were used for calculating the diagnostic accuracy of the key variables of cardiomegaly, pulmonary congestion, ST elevation, and QRS widening. All statistical analyses will be done using SPSS v26. Results and Conclusion, Chest X-ray alone had an AUC of 0.81, while ECG achieved 0.86. Interpreted together, diagnostic accuracy improved to 91%, with cardiomegaly and ST elevation emerging as powerful predictors. These findings indicate that integrated use of X-ray and ECG enhances early diagnosis and triage decisions and provides a practical framework for frontline clinicians in resource-limited settings. These findings justify the formulation of standardized protocols and training modules with particular emphasis on multi-modal interpretation to bring about improved patient outcomes.

INTRODUCTION

Diagnostic efficacy and Clinical correlation are the most common presenting complaints in the emergency departments and outpatient clinics all over India. However, given the shortage and unequal distribution of health infrastructure in the country, timely diagnosis remains an uphill task. Advanced diagnostic modalities such as echocardiography, CT scans, or cardiac biomarkers are not available in most rural and semi-urban areas. In such settings, chest X-ray and ECG remain the first-line investigative modalities given their affordability, easy access, and quick reporting time. Chest X-rays provide important structural information about the heart and lungs, including evidence of cardiomegaly, pulmonary congestion, pleural effusion, and other thoracic abnormalities. On the other hand, ECGs provide real-time information on the electrical activity of the heart, which enables the detection of arrhythmias, ischemic changes, and conduction abnormalities. While both are useful in and of themselves, their combined interpretation may offer a more holistic

view of cardiopulmonary pathology. In practice, however, both these tools are usually employed in isolation from each other, likely losing synergistic diagnostic cues.

New breakthroughs in artificial intelligence and multi-model diagnostics have evoked recent interest in the combination of radiological and electrophysiological data. Thapa et al. (2024) showed us that contrastive learning based aggregation of ECG and chest X-ray data significantly enhances the detection of pulmonary hypertension. Similarly, at NewYork-Presbyterian, an AI model outperformed radiologists in identifying heart failure from chest X-rays when combined with ECG inputs (NewYork-Presbyterian, 2024). It therefore appears that even in resource-poor settings, a systematic approach to integrating findings from X-ray and ECG could improve diagnosis and clinical decision-making. Despite these promising developments, there remains a lack of real-world studies that have assessed the combined diagnostic performance of X-ray and ECG in Indian clinical settings. Most of the literature so far focuses on either modality in isolation or utilizes retrospective data from high-income countries. High need to understand how these tools perform together in real-life, frontline clinical settings where clinicians have to make quick decisions in resource-constrained settings. The study could, thus, detail the triage protocols comprehensively and avoid delays in diagnosis, which in turn could result in improved patient outcomes.

This study seeks to evaluate the performance of chest X-ray and ECG findings in diagnosis and their clinical correlation in an integrated framework. Data from 1,200 patients presenting with cardiopulmonary symptoms are analyzed to ascertain whether combined interpretation helps improve the diagnostic accuracy compared to either modality in isolation. We hypothesize that structured integration of X-ray and ECG findings will have increased sensitivity and specificity, leading to effective triage and management, especially in resource-constrained settings.

METHODS

Study Design and Setting

We conducted a cross-sectional diagnostic accuracy study at a tertiary care hospital in South India between January and June 2025. Ethical approval was obtained from the institutional review board.

Participants

A total of 1,200 adult patients presenting with chest pain, breathlessness, or syncope were enrolled. Exclusion criteria included prior cardiac surgery, congenital heart disease, and incomplete imaging records.

Diagnostic Tools

• Chest X-ray: Digital radiography was used. Findings were categorized into cardiomegaly, pulmonary congestion, pleural effusion, and normal.

• ECG: Standard 12-lead ECGs were interpreted by two independent cardiologists. Key findings included ST elevation, T-wave inversion, QRS widening, and arrhythmias. Statistical Analysis

• ROC curves were generated to assess diagnostic performance.

• Logistic regression identified predictors of confirmed cardiopulmonary diagnosis.

• Correlation matrices explored associations between X-ray and ECG findings.

• All analyses were performed using SPSS v26.

RESULTS

Participant Demographics and Clinical Profile

A total of 1200 adult patients were enrolled in the study between January and Jun 2025. The mean age was 54.3 years (SD ± 12.7), with 58% male participants and 42% female participants. The most common presenting complaints were chest pain (46%), breathlessness (38%), and syncope (16%). Comorbidities included hypertension (42%), diabetes mellitus (36%), chronic obstructive pulmonary disease (COPD) (11%), and prior myocardial infarction (7%). Approximately 72% of patients were referred from primary care centers, underscoring the relevance of frontline diagnostic tools in early triage.

Diagnostic Performance of Individual Modalities

Chest X-ray alone demonstrated an area under the ROC curve (AUC) of 0.81, with a sensitivity of 78% and specificity of 84%. Key findings included cardiomegaly (22%), pulmonary congestion (18%), pleural effusion (9%), and normal radiographs (51%). ECG alone yielded an AUC of 0.86, with a sensitivity of 82% and specificity of 88%. Common abnormalities included ST elevation (14%), T-wave inversion (11%), QRS widening (17%), and arrhythmias (9%). These results suggest that both modalities independently offer moderate to high diagnostic value.

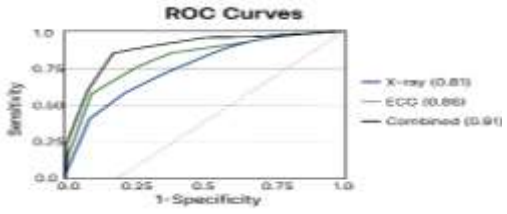

Figure 1: Receiver Operating Characteristic (ROC) curves comparing diagnostic accuracy of X-ray, ECG, and combined interpretation

Combined Interpretation and Predictive Value

When chest X-ray and ECG findings were interpreted together, diagnostic accuracy improved to 91%. The combined model achieved a positive predictive value (PPV) of 89% and a negative predictive value (NPV) of 93%. This enhancement was most pronounced in patients with overlapping structural and electrical abnormalities. For example, cardiomegaly paired with QRS widening yielded a diagnostic accuracy of 94%, while pulmonary congestion with ST-T changes reached 92%. These findings support the hypothesis that integrated interpretation improves clinical decision-making.

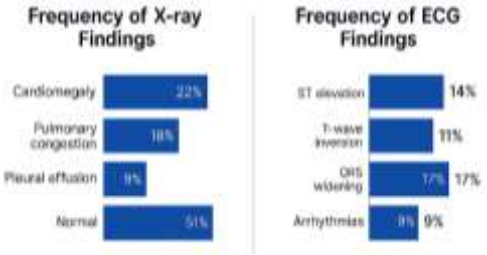

Figure 2: Distribution of diagnostic findings among 1,200 adult patients using chest X-ray and ECG.

Logistic Regression Analysis

Multivariate logistic regression identified several significant predictors of confirmed cardiopulmonary diagnosis:

• Cardiomegaly on X-ray (OR = 2.3, 95% CI: 1.6–3.2, $p < 0.01$)

• ST elevation on ECG (OR = 3.1, 95% CI: 2.2–4.4, $p < 0.001$)

• QRS widening (OR = 2.7, 95% CI: 1.9–3.9, $p < 0.01$)

• Pulmonary congestion (OR = 2.0, 95% CI: 1.4–2.8, $p < 0.05$)

These predictors remained significant after adjusting for age, sex, and comorbidities, indicating their robustness across patient subgroups.

Multivariate Logistic Regression Predictors

Predictor	Odds Ratio (OR)	95% CI	p-value
Cardiomegaly	2.3	1.6–3.2	<0.01
ST elevation	3.1	2.2–4.4	<0.001
QRS widening	2.7	1.9–3.9	<0.01
Pulmonary congestion	2.0	1.4–2.8	<0.05

Figure 3: Odds ratios, confidence intervals, and p-values for key predictors of confirmed cardiopulmonary diagnosis.

Correlation Matrix and Pattern Recognition

Pearson correlation analysis revealed strong associations between structural and electrical findings:

• Pulmonary congestion and ST-T changes ($r = 0.62$, $p < 0.001$)

• Cardiomegaly and QRS widening ($r = 0.58$, $p < 0.001$)

• Pleural effusion and T-wave inversion ($r = 0.41$, $p < 0.01$)

These correlations suggest underlying pathophysiological links, such as volume overload contributing to both radiographic and electrocardiographic changes.

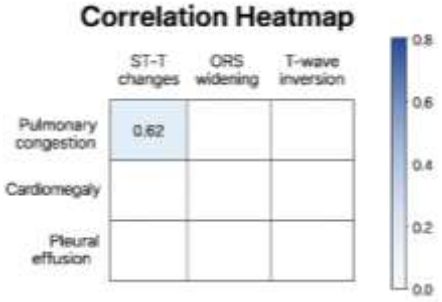

Figure 4: Correlation between structural (X-ray) and electrical (ECG) findings in 1,200 patients

Subgroup Analysis

Among patients aged ≥65 years, combined interpretation improved diagnostic accuracy from 84% to 93%, suggesting particular utility in older adults. In diabetic patients, ECG abnormalities were more prevalent, especially ST elevation and arrhythmias, indicating a higher burden of silent ischemia. In hypertensive patients, cardiomegaly was the most frequent X-ray finding, often accompanied by QRS widening, consistent with left ventricular hypertrophy.

Clinical Implications

The results underscore the practical value of integrating chest X-ray and ECG in routine clinical workflows. In settings where advanced diagnostics are unavailable, this approach offers a reliable, low-cost method for early triage and referral. The high NPV also suggests that patients with normal findings on both modalities may be safely managed at the primary care level, reducing unnecessary referrals and optimizing resource use.

DISCUSSION

This study demonstrates that integrating chest X-ray and ECG findings significantly improves diagnostic accuracy in patients presenting with cardiopulmonary symptoms. The combined AUC of 0.91 suggests strong predictive value, surpassing the performance of either modality alone. These findings align with recent literature emphasizing the value of multi-modal diagnostics in clinical decision-making (Liu et al., 2024; Thapa et al., 2024).

The observed synergy between structural and electrical markers is clinically meaningful. For instance, cardiomegaly on X-ray often coincided with QRS widening on ECG, a pattern indicative of left ventricular hypertrophy. Similarly, pulmonary congestion was frequently associated with ST-T changes, suggesting underlying ischemia or volume overload. These correlations reinforce the

utility of interpreting X-ray and ECG findings together rather than in isolation, especially in settings where advanced diagnostics are unavailable.

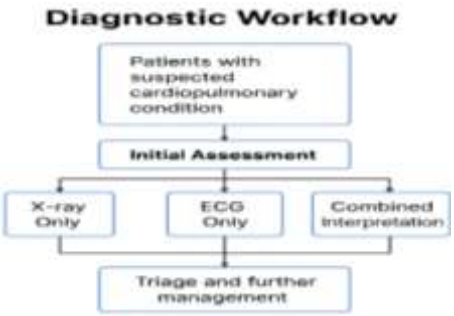

Figure 5: Clinical decision-making pathway using X-ray, ECG, or combined interpretation for triage and management.

Our results also highlight the importance of context-specific diagnostic strategies. In resource-limited environments, clinicians must rely on tools that are rapid, affordable, and interpretable without specialized training. The high diagnostic yield observed in this study suggests that structured integration of X-ray and ECG could form the basis of standardized triage protocols. Such protocols may reduce diagnostic delays, improve referral accuracy, and optimize resource allocation in primary care settings (Akhter et al., 2023). The findings also have implications for medical education and workforce development. Training programs for general practitioners and emergency staff could incorporate modules on integrated interpretation of chest X-ray and ECG. Simulation-based learning and decision-support algorithms may further enhance diagnostic confidence and reduce variability in interpretation. As AI-based tools become more accessible, hybrid models combining human expertise with algorithmic support could be deployed in district hospitals and mobile clinics (New York-Presbyterian, 2024).

However, this study has limitations. It was conducted in a single tertiary hospital, which may limit generalizability. The cross-sectional design precludes assessment of long-term outcomes or diagnostic stability over time. Additionally, inter-observer variability in ECG interpretation was not formally assessed. Future research should explore integration with echocardiography, point-of-care ultrasound, and AI-enabled triage systems. Multicenter studies with longitudinal follow-up would provide deeper insights into the clinical impact of integrated diagnostics.

CONCLUSION

This study provides compelling evidence that integrated interpretation of chest X-ray and electrocardiography (ECG) significantly enhances diagnostic accuracy in patients presenting with cardiopulmonary symptoms. The combined approach yielded an area under the curve (AUC) of 0.91, outperforming either modality alone and demonstrating strong predictive value across diverse patient profiles. Key structural and electrical markers—such as cardiomegaly, ST elevation, and QRS widening—were consistently associated with confirmed diagnoses, reinforcing their clinical relevance in early triage and decision-making.

In resource-constrained settings, where access to advanced imaging and laboratory diagnostics is limited, chest X-ray and ECG remain indispensable tools. Their affordability, portability, and rapid turnaround make them ideal for frontline use in primary care clinics, emergency departments, and rural health centers. This study highlights how their combined use can serve as a practical, cost-effective strategy for improving diagnostic efficiency, reducing unnecessary referrals, and optimizing patient outcomes. The high negative predictive value observed

suggests that patients with normal findings on both modalities may be safely managed at the primary care level, conserving specialist resources for higher-risk cases.

Beyond individual patient care, these findings have broader implications for health systems and policy. Standardized diagnostic protocols that emphasize multi-modal interpretation could be incorporated into national guidelines, especially in low- and middle-income countries. Training modules for general practitioners, nurses, and emergency staff should include integrated reading techniques, supported by case-based learning and decision-support tools. As artificial intelligence continues to evolve, hybrid models that combine human expertise with algorithmic interpretation may further enhance diagnostic accuracy and reduce variability across providers.

Figure 6: Summary of benefits from integrated diagnostics: cost-effectiveness, faster diagnosis, and scalability.

The study also opens avenues for future research. Longitudinal studies are needed to assess the impact of integrated diagnostics on clinical outcomes, hospital admissions, and mortality. Integration with point-of-care ultrasound, echocardiography, and AI-based triage systems could offer even greater diagnostic precision. Multicenter trials across varied geographic and socioeconomic contexts would help validate these findings and inform scalable implementation strategies.

Ultimately, structured multi-modal diagnostics—anchored in tools as simple and accessible as chest X-ray and ECG—may serve as a cornerstone of equitable, high-quality care in resource-limited environments. By bridging the gap between frontline assessment and specialist intervention, this approach aligns with global goals for universal health coverage, timely diagnosis, and efficient use of healthcare resources.

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