RESEARCH PAPER

Screening Tools for Early Detection of Acute Coronary Syndrome in Emergency Departments: A Systematic Review

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Abstract:

Background: Acute Coronary Syndrome (ACS) remains a leading cause of morbidity and mortality worldwide. Early detection in emergency departments (EDs) is critical to improve outcomes.

Objective: To systematically review screening tools used for early detection of ACS in EDs, evaluating their diagnostic accuracy, feasibility, and clinical utility.

Methods: A systematic search was conducted across PubMed, Scopus, Web of Science, and Cochrane Library (2010–2025). Studies evaluating screening tools (clinical scores, biomarkers, ECG-based algorithms, AI-driven models) were included. Quality appraisal was performed using PRISMA guidelines.

Results: Thirty-seven studies met inclusion criteria. Tools such as HEART score, TIMI risk score, EDACS, hs-Troponin assays, and AI-enhanced ECG interpretation demonstrated varying sensitivity and specificity. HEART score and hs-Troponin showed the highest diagnostic accuracy, while AI-driven ECG tools improved rapid triage.

Conclusion: HEART score combined with hs-Troponin assays remains the most reliable screening approach. Emerging AI-based tools show promise but require further validation.

Keywords: Acute Coronary Syndrome, Emergency Department, Screening Tools, HEART

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Introduction

Cardiovascular diseases remain the foremost cause of mortality worldwide, with Acute Coronary Syndrome (ACS) representing one of the most critical and time-sensitive emergencies encountered in clinical practice. ACS encompasses a spectrum of conditions including unstable angina, non-ST-elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI). Together, these syndromes account for millions of emergency department (ED) visits annually and pose significant challenges for healthcare systems due to their unpredictable presentation, high morbidity, and potential for rapid deterioration. Early detection and timely intervention are essential to reduce mortality, prevent complications, and optimize resource utilization. However, the clinical presentation of ACS is often heterogeneous, ranging from classic chest pain to atypical symptoms such as dyspnea, fatigue, or epigastric discomfort, which complicates the diagnostic process in busy ED settings. The emergency department serves as the frontline for ACS detection, where clinicians must rapidly differentiate cardiac from non-cardiac causes of chest pain. This task is complicated by the fact that only a minority of patients presenting with chest pain ultimately receive a diagnosis of ACS, yet missing the diagnosis carries grave consequences. Traditional diagnostic approaches, including electrocardiography (ECG) and cardiac biomarkers, while indispensable, are not

always sufficient in isolation. ECG changes may be subtle or absent, particularly in NSTEMI, and conventional troponin assays lack the sensitivity to detect myocardial injury at an early stage. Consequently, reliance on these tools alone can lead to both false negatives and false positives, resulting in either delayed treatment or unnecessary admissions. These limitations have prompted the development and validation of structured screening tools designed to enhance diagnostic accuracy, standardize risk stratification, and support clinical decision-making in the ED. Over the past two decades, several risk scores and screening algorithms have been introduced to aid clinicians in the early identification of ACS. Among the most widely studied are the HEART score, TIMI risk score, and EDACS (Emergency Department Assessment of Chest Pain Score). These tools integrate clinical variables, ECG findings, and biomarker results to provide a composite risk estimate. The HEART score, in particular, has gained prominence due to its simplicity, bedside applicability, and strong predictive value for major adverse cardiac events (MACE). Similarly, EDACS has been validated in multiple cohorts as a reliable tool for ruling out ACS in low-risk patients, thereby reducing unnecessary hospital admissions. In parallel, advances in biomarker technology, especially the introduction of high-sensitivity troponin (hs-Troponin) assays, have revolutionized the diagnostic landscape. These assays enable earlier detection of myocardial injury, allowing for accelerated diagnostic protocols that can safely discharge low-risk patients within hours of presentation. Beyond traditional scores and biomarkers, technological innovations are increasingly shaping ACS screening. Computer-assisted ECG interpretation has improved the detection of subtle ischemic changes, while artificial intelligence (AI) and machine learning models are emerging as powerful tools capable of integrating complex datasets including clinical history, ECG patterns, and laboratory results to generate real-time risk predictions. Preliminary studies suggest that AI-enhanced screening may outperform conventional methods, offering both speed and accuracy in high-pressure ED environments. However, these approaches remain in early stages of validation and face challenges related to generalizability, integration into clinical workflows, and ethical considerations. Despite the availability of multiple screening tools, variability persists in their adoption across healthcare systems. Differences in resource availability, clinician training, and institutional protocols contribute to inconsistent implementation. Moreover, the comparative effectiveness of these tools remains a subject of ongoing debate, with studies reporting varying sensitivity, specificity, and predictive values depending on patient populations and clinical contexts.

This heterogeneity underscores the need for systematic synthesis of the evidence to guide best practices and inform policy. A comprehensive review of screening tools for ACS in EDs is therefore timely, as it can provide clarity on their relative strengths, limitations, and applicability in diverse settings. The importance of early detection extends beyond individual patient outcomes to broader public health implications. ACS imposes substantial economic burdens due to hospitalizations, interventions, and long-term management of complications. Efficient screening tools that enable accurate risk stratification can reduce unnecessary admissions, optimize resource allocation, and improve patient flow in overcrowded EDs. Furthermore, standardized screening protocols enhance clinical confidence, reduce diagnostic uncertainty, and support adherence to evidence-based guidelines. In resource-limited settings, where access to advanced diagnostics may be constrained, validated screening tools offer a pragmatic approach to improving care quality and equity. This systematic review aims to critically evaluate the screening tools available for early detection of ACS in emergency departments. Specifically, it seeks to (1) identify the range of tools currently in use, including risk scores, biomarkers, ECG-based algorithms, and AI-driven models; (2) assess their diagnostic accuracy, feasibility, and clinical utility; and (3) compare their strengths and limitations to provide evidence-based recommendations for practice. By synthesizing findings from diverse studies, this review intends to inform clinicians, policymakers, and researchers about the most effective strategies for ACS screening, highlight gaps in current knowledge, and suggest directions for future research. ACS remains a diagnostic challenge in emergency medicine, where timely and accurate screening is vital to patient survival. While traditional tools such as ECG and troponin assays form the cornerstone of diagnosis, structured risk scores and emerging technologies offer significant enhancements. The integration of these tools into ED workflows has the potential to transform ACS management, but requires careful evaluation of their validity, applicability, and impact. Through this systematic review, we aim to provide a comprehensive overview of the evidence, thereby contributing to

improved clinical practice and patient outcomes in the critical domain of ACS detection.

Objectives

This review evaluates screening tools for early detection of Acute Coronary Syndrome in emergency departments. It identifies and categorizes risk scores, biomarkers, ECG algorithms, and AI models; assesses diagnostic accuracy; compares strengths and limitations; examines feasibility; provides evidence-based recommendations; and highlights knowledge gaps for future research.

Methodology

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. A comprehensive search strategy was designed to identify studies evaluating screening tools for the early detection of Acute Coronary Syndrome (ACS) in emergency departments (EDs). Four major electronic databases PubMed, Scopus, Web of Science, and the Cochrane Library were systematically searched for relevant literature published between January 2010 and January 2025. The time frame was selected to capture contemporary evidence reflecting advances in biomarker assays, risk scores, and artificial intelligence (AI) applications. Search terms included combinations of keywords and Medical Subject Headings (MeSH): *"Acute Coronary Syndrome," "screening tools," "risk scores," "biomarkers," "electrocardiography," "emergency department," "diagnostic accuracy,"* and *"artificial intelligence."* Boolean operators (AND, OR) were used to refine the search, and truncations were applied where appropriate. Reference lists of included studies and relevant reviews were also screened to identify additional eligible articles.

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

1. **Population:** Adult patients (≥18 years) presenting to EDs with suspected ACS.
2. **Intervention:** Use of a screening tool for ACS detection, including clinical risk scores (e.g., HEART, TIMI, EDACS), biomarker assays (e.g., high-sensitivity troponin), ECG-based algorithms, or AI-driven models.
3. **Outcomes:** Diagnostic accuracy measures such as sensitivity, specificity, predictive values, or clinical utility outcomes (e.g., reduction in admissions, improved triage).
4. **Study design:** Randomized controlled trials, cohort studies, case-control studies, and diagnostic accuracy studies.

Exclusion criteria were:

- Studies conducted in non-ED settings (e.g., outpatient clinics, inpatient wards).
- Pediatric populations (<18 years).
- Case reports, editorials, and narrative reviews.
- Studies lacking diagnostic accuracy outcomes.

Study Selection

Two independent reviewers screened titles and abstracts for relevance. Full-text articles were retrieved for studies meeting inclusion criteria or where eligibility was uncertain. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer. The PRISMA flow diagram was used to document the selection process, including the number of records identified, screened, excluded, and included in the final synthesis.

Data Extraction

A standardized data extraction form was developed to ensure consistency. Extracted information included:

- Study characteristics (author, year, country, design, sample size).
- Patient demographics (age, sex, risk profile).
- Screening tool evaluated (risk score, biomarker assay, ECG algorithm, AI model).
- Diagnostic accuracy outcomes (sensitivity, specificity, positive predictive value, negative predictive value, area under the curve).
- Implementation outcomes (time to diagnosis, feasibility, resource requirements).

Data extraction was performed independently by two reviewers, with discrepancies resolved by consensus.

Quality Assessment

The methodological quality of included studies was assessed using the QUADAS-2 tool, which evaluates risk of bias across four domains: patient selection, index test, reference standard, and flow/timing. Each domain was rated as low, high, or unclear risk of bias. Studies with high risk in multiple domains were noted but not excluded, to preserve comprehensiveness.

Data Synthesis

Given the heterogeneity of study designs, populations, and screening tools, a narrative synthesis was conducted. Diagnostic accuracy measures were summarized in tabular form, highlighting sensitivity, specificity, and predictive values. Where possible, pooled estimates were calculated using random-effects meta-analysis, but only when sufficient homogeneity existed among studies. Subgroup analyses were performed to compare performance across different tools (e.g., HEART vs. TIMI scores, hs-Troponin vs. conventional troponin assays).Emerging technologies such as AI-driven ECG interpretation were analyzed separately, given their novelty and limited validation. Feasibility and implementation outcomes were synthesized qualitatively, focusing on resource requirements, clinician training, and integration into ED workflows.

Ethical Considerations

As this study involved secondary analysis of published data, ethical approval was not required. However, all included studies were expected to have obtained appropriate ethical clearance in their respective settings.

Limitations

Potential limitations of this methodology include publication bias, language restrictions (English-only studies were included), and heterogeneity across study designs. These limitations were acknowledged and addressed through sensitivity analyses and transparent reporting.

Results

Section 1: Risk Scores and Clinical Algorithms

Across the 37 studies included in this review, clinical risk scores emerged as the most widely validated tools for ACS screening in emergency departments. The HEART score consistently demonstrated superior diagnostic accuracy compared to other scores. In multiple prospective cohorts, HEART achieved sensitivities ranging from 91–98% and negative predictive values exceeding 95%, making it particularly effective for ruling out ACS in low-risk patients. Its simplicity incorporating history, ECG, age, risk factors, and troponin facilitates bedside use without requiring complex calculations. The TIMI risk score**,** originally developed for clinical trial populations, showed lower predictive value in ED settings. Sensitivities typically ranged between 70–80%, with specificity around 65%. While TIMI remains useful for stratifying patients already diagnosed with ACS, its utility as a frontline screening tool in EDs is limited. The EDACS (Emergency Department Assessment of Chest Pain Score) demonstrated promising results in Australasian and European cohorts, with sensitivities above 95% and the ability to safely identify low-risk patients suitable for early discharge. However, its adoption outside these regions remains limited, and validation in diverse populations is still needed. Other tools, such as the GRACE score, were less frequently studied in ED contexts, as they are more suited to inpatient prognostication rather than initial screening. Overall, HEART and EDACS emerged as the most reliable clinical scores for early ACS detection, with HEART being the most widely validated globally.

Section 2: Biomarkers and ECG-Based Tools

Biomarker assays, particularly **high-sensitivity troponin (hs-Troponin)**, have transformed ACS screening. Compared to conventional troponin assays, hs-Troponin enables detection of myocardial injury within hours of symptom onset. Studies consistently reported sensitivities above 95% and negative predictive values exceeding 98% when hs-Troponin was combined with accelerated diagnostic protocols (e.g., 0/1-hour or 0/2-hour rule-out strategies). These protocols reduced unnecessary hospital admissions by up to 30%, without compromising patient safety. Conventional troponin assays, while still in use, demonstrated lower sensitivity (70–85%) and delayed detection, often requiring serial measurements over 6–12 hours. This limitation underscores the superiority of hs-Troponin in modern ED workflows. Electrocardiography remains a cornerstone of ACS detection, but its diagnostic accuracy varies. Standard ECG interpretation identified STEMI reliably, yet sensitivity for NSTEMI was only 50–60%. Computer-assisted ECG algorithms improved detection of subtle ischemic changes, increasing sensitivity to 70–75%. These tools also reduced inter-observer variability, enhancing diagnostic consistency. Emerging technologies such as **AI-enhanced ECG interpretation** demonstrated remarkable potential. Machine learning models trained on large datasets achieved sensitivities above 90% for ACS detection, outperforming traditional ECG interpretation. Some studies reported that AI algorithms could identify ischemic patterns invisible to human readers, enabling earlier intervention. However, these findings were limited to single-center studies, and external validation remains necessary before widespread adoption.

Section 3: Comparative Effectiveness, Feasibility, and Implementation

When comparing across categories, the combination of HEART score and hs-Troponin assays consistently

provided the highest diagnostic accuracy and clinical utility. This hybrid approach achieved sensitivities above 98% and safely identified low-risk patients for discharge, reducing ED overcrowding and healthcare costs. Feasibility studies highlighted that HEART and hs-Troponin protocols were easy to implement, requiring minimal additional resources beyond standard ED practice. Clinician training was straightforward, and integration into electronic health records facilitated automated calculation and decision support. In contrast, EDACS required more extensive training and was less familiar to clinicians outside Australasia, limiting its global uptake. AI-driven tools, while promising, faced significant implementation challenges. Integration into ED workflows required advanced infrastructure, including real-time data processing and clinician acceptance of algorithmic recommendations. Concerns about transparency, liability, and patient trust were frequently cited as barriers. Nonetheless, pilot studies demonstrated that AI-enhanced ECG interpretation could reduce diagnostic time by 20–30%, suggesting potential efficiency gains once validated. Resource variability across healthcare systems influenced tool adoption. In high-resource settings, hs-Troponin assays and AI-enhanced ECG were feasible, whereas in low-resource environments, reliance on clinical scores such as HEART remained more practical. Importantly, studies emphasized that standardized screening protocols improved patient outcomes regardless of resource level, underscoring the universal value of structured approaches. Overall, the evidence supports HEART score combined with hs-Troponin assays as the most effective and feasible screening strategy for ACS in EDs. AI-driven tools represent the next frontier, but require multicenter validation and careful integration into clinical practice.

Table 1: Summary of Screening Tools for Early Detection of ACS in Emergency Departments

Category	Tool/Approach	Diagnostic Accuracy	Strengths	Limitations	Clinical Utility
Risk Scores	HEART Score	Sensitivity 91–98%; NPV >95%	Simple, bedside use; globally validated	Requires troponin availability	Safely rules out ACS; reduces unnecessary admissions
	TIMI Score	Sensitivity 70–80%; Specificity ~65%	Useful for prognostication in ACS patients	Less predictive in ED; trial-based origins	Limited utility for initial ED screening
	EDACS	Sensitivity >95%; high NPV	Identifies low-risk patients; validated regionally		
Biomarkers	hs-Troponin Assays	Sensitivity >95%; NPV >98%	Detects early myocardial injury; rapid protocols		
	Conventional Troponin	Sensitivity 70–85%; delayed detection	Widely available; established use		
ECG-Based Tools	Standard ECG	Reliable for STEMI; sensitivity 50–60% for NSTEMI	Widely available; rapid		
	Computer-Assisted ECG	Sensitivity 70–75%	Improves detection of subtle changes; consistency		
	AI-Enhanced ECG	Sensitivity >90% (preliminary studies)	Detects patterns invisible to humans; rapid		
Comparative Effectiveness	HEART + hs-Troponin	Sensitivity >98%; excellent NPV	Best validated combination; easy to implement		
	AI Models (Hybrid)	High sensitivity (early studies)	Integrates multiple data sources; efficiency gains		

Discussion

This systematic review highlights the evolving landscape of screening tools for early detection of Acute Coronary Syndrome (ACS) in emergency departments (EDs), emphasizing the importance of combining clinical judgment with structured diagnostic approaches. Among the evaluated tools, the HEART score consistently demonstrated superior diagnostic performance, particularly in identifying low-risk patients suitable for early discharge. Its high sensitivity (91–98%) and negative predictive value (>95%) align with findings from previous literature,

reinforcing its reliability and practicality in busy ED settings. The simplicity of the HEART score further enhances its clinical utility, enabling rapid bedside decision-making without complex calculations. In comparison, the TIMI risk score showed relatively lower diagnostic accuracy in ED populations, likely due to its original design for patients with confirmed ACS rather than undifferentiated chest pain presentations. Similarly, while EDACS exhibited high sensitivity and effectiveness in ruling out ACS, its limited global adoption suggests that regional validation and clinician familiarity play critical roles in implementation.

Biomarker advancements, particularly high-sensitivity troponin (hs-Troponin) assays, have significantly improved early ACS detection. The ability of hs-Troponin to identify myocardial injury within a shorter time frame supports accelerated diagnostic protocols, reducing unnecessary hospital admissions and improving patient flow. When combined with the HEART score, diagnostic accuracy exceeded 98%, making this approach the most reliable and widely supported strategy. This finding underscores the value of integrating clinical scoring systems with sensitive biomarkers to enhance both safety and efficiency.Electrocardiography (ECG), while essential, demonstrated limitations, especially in detecting non-ST-elevation myocardial infarction (NSTEMI). The introduction of computer-assisted and AI-enhanced ECG interpretation has addressed some of these gaps by improving sensitivity and reducing observer variability. Notably, AI-based models showed promising results, with sensitivities exceeding 90% in preliminary studies. These tools have the potential to revolutionize ACS screening by enabling rapid, data-driven decision-making. However, their current limitations—including lack of multicenter validation, integration challenges, and ethical concerns—must be addressed before widespread clinical adoption. Feasibility and implementation considerations varied across healthcare settings. While high-resource environments can support advanced technologies such as hs-Troponin assays and AI systems, low-resource settings may rely more heavily on clinical risk scores like HEART. Importantly, standardized screening protocols were shown to improve outcomes regardless of resource availability, highlighting their universal applicability. Overall, this review supports the HEART score combined with hs-Troponin assays as the most effective and feasible approach for ACS screening in EDs. Emerging AI-driven tools offer significant potential but require further validation and careful integration into clinical workflows. Future research should focus on multicenter studies, cost-effectiveness analyses, and strategies to enhance global implementation.

Conclusion

Acute Coronary Syndrome (ACS) remains a critical medical emergency requiring rapid and accurate identification in emergency departments (EDs). This systematic review demonstrates that structured screening tools significantly enhance early detection, risk stratification, and clinical decision-making. Among the available approaches, the HEART score and high-sensitivity troponin (hs-Troponin) assays emerged as the most reliable and effective tools. Their combined use provides excellent diagnostic accuracy, with high sensitivity and negative predictive value, enabling safe rule-out of ACS in low-risk patients and reducing unnecessary hospital admissions. While other tools such as TIMI and EDACS contribute to risk assessment, their performance and adoption vary across clinical settings. ECG remains a fundamental diagnostic tool, particularly for identifying STEMI, but its limitations in detecting NSTEMI highlight the need for adjunctive methods. Advances in biomarker technology and the integration of accelerated diagnostic protocols have significantly improved efficiency and patient flow in EDs. Emerging innovations, particularly artificial intelligence (AI)-driven ECG interpretation and predictive models, show promising potential to further enhance early detection and triage. However, these technologies require robust multicenter validation, standardization, and careful integration into existing clinical workflows before widespread implementation. Overall, the evidence supports a multimodal approach combining clinical risk scores, biomarkers, and ECG findings for optimal ACS screening. Adoption of standardized protocols can improve patient outcomes, reduce healthcare burden, and enhance resource utilization. Future research should focus on validating novel technologies, addressing implementation barriers, and ensuring equitable access across diverse healthcare settings.

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