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Diagnostic Accuracy Of High-Sensitivity Cardiac Troponin For The Early Detection Of Acute Myocardial Infarction In Emergency Department Patients: A Systematic Review

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Abstract

Background:
High-sensitivity cardiac troponin (hs-cTn) assays have revolutionized the early diagnosis of acute myocardial infarction (AMI) in emergency department (ED) settings. Their ability to detect low troponin concentrations enables rapid clinical decision-making and improved patient outcomes.

Objective:
This systematic review aimed to evaluate the diagnostic accuracy of hs-cTn assays for early detection of AMI in ED patients and to assess the performance of rapid diagnostic algorithms and emerging approaches.

Methods:
A systematic search of PubMed, Scopus, Web of Science, Embase, and Google Scholar was conducted up to December 2025. Twelve studies were included, encompassing prospective, retrospective, and multicenter diagnostic accuracy designs. Data on sensitivity, specificity, predictive values, and area under the curve (AUC) were extracted. A narrative synthesis approach was applied due to heterogeneity.

Results:
High-sensitivity troponin assays demonstrated excellent diagnostic performance, with AUC values ranging from 0.84 to 0.98. Sensitivity and negative predictive value were consistently high (≥96% and ≥99%, respectively), supporting safe rule-out of AMI. Rapid algorithms (0/1-hour and 0/2-hour) effectively classified 50–66% of patients as low risk. Absolute troponin changes outperformed relative changes, while point-of-care testing and machine learning approaches enhanced diagnostic efficiency. However, specificity and positive predictive value were comparatively lower, particularly in early presentations.

Conclusion:
Hs-cTn assays provide highly accurate and reliable tools for early AMI detection in ED settings. Rapid diagnostic strategies significantly improve clinical workflow, although careful interpretation is required to address reduced specificity.

Keywords: High-sensitivity troponin; Acute myocardial infarction; Diagnostic accuracy; Emergency department; Rapid diagnostic algorithms; Point-of-care testing.

Introduction

Acute myocardial infarction (AMI) remains a leading cause of morbidity and mortality worldwide, necessitating rapid and accurate diagnostic strategies in emergency department (ED) settings. Early identification of myocardial injury is critical to initiate timely therapeutic interventions and improve clinical outcomes. Traditional diagnostic approaches, including clinical assessment, electrocardiography, and conventional cardiac biomarkers, often lack sufficient sensitivity during the early hours of symptom onset, which can delay diagnosis and appropriate management (Freund et al., 2011; Zhelev et al., 2015).

Cardiac troponins are highly specific biomarkers of myocardial injury and have become the cornerstone of AMI diagnosis. With the development of high-sensitivity cardiac troponin (hs-cTn) assays, clinicians are now able to detect much lower concentrations of troponin with improved analytical precision. These assays enable earlier detection of myocardial injury compared to conventional assays, significantly enhancing diagnostic performance in patients presenting with chest pain (Kavsak et al., 2009; Lee et al., 2020).

The introduction of hs-cTn assays has led to a paradigm shift in the diagnostic criteria for AMI, as reflected in the universal definition of myocardial infarction. Even minor elevations in troponin concentrations, when interpreted in the appropriate clinical context, can indicate myocardial injury. Furthermore, the assessment of dynamic changes in troponin levels over time has been shown to improve diagnostic accuracy, particularly in distinguishing acute from chronic myocardial injury (Casals et al., 2008; Clerico et al., 2022).

One of the major advantages of hs-cTn assays is their ability to facilitate accelerated diagnostic protocols in the ED. Rapid rule-in and rule-out strategies, often based on serial troponin measurements within 1–2 hours, allow clinicians to make faster and more reliable decisions regarding patient disposition. These protocols have demonstrated high sensitivity and negative predictive value, enabling safe early discharge of low-risk patients while prioritizing high-risk individuals for urgent care (Sandoval et al., 2022; Joyce et al., 2023).

In addition to laboratory-based assays, point-of-care (POC) troponin testing has emerged as a valuable tool for improving diagnostic efficiency, particularly in resource-limited or high-throughput settings. POC hs-cTn assays provide rapid results with shorter turnaround times, potentially reducing ED overcrowding and improving patient flow. Studies have shown that these assays can achieve diagnostic performance comparable to central laboratory testing when integrated into structured clinical pathways (Mohammadzadeh et al., 2022; Cullen et al., 2024).

Despite these advancements, several challenges remain in the clinical application of hs-cTn testing. Increased sensitivity may come at the expense of reduced specificity, as elevated troponin levels can also be observed in non-ischemic conditions such as heart failure, renal dysfunction, and sepsis. This necessitates careful interpretation of results in conjunction with clinical findings and other diagnostic modalities to avoid misdiagnosis and unnecessary interventions (Clerico et al., 2022; Ledwoch et al., 2022).

Another important consideration is the potential role of single-measurement strategies using hs-cTn for rapid exclusion of AMI. Recent evidence suggests that, in selected low-risk patients, a single low hs-cTn value at presentation may be sufficient to rule out myocardial infarction with high safety. This approach has the potential to further streamline ED workflows, although its applicability depends on assay characteristics and patient selection criteria (Zhelev et al., 2015; Sandoval et al., 2022).

Overall, the integration of high-sensitivity troponin assays into clinical practice has significantly improved the early detection and risk stratification of patients with suspected AMI. Ongoing research continues to refine diagnostic algorithms and explore novel

approaches, including POC testing and optimized sampling strategies, to further enhance accuracy and efficiency in emergency care settings (Lee et al., 2020; Joyce et al., 2023).

Methodology

Study Design

This study employed a systematic review methodology following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological transparency, rigor, and reproducibility. The primary objective was to synthesize and critically evaluate the available evidence regarding the diagnostic accuracy of high-sensitivity cardiac troponin (hs-cTn) assays for the early detection of acute myocardial infarction (AMI) in emergency department (ED) patients.

The review focused on studies assessing the diagnostic performance of hs-cTn assays, including sensitivity, specificity, predictive values, and area under the receiver operating characteristic curve (AUC), as well as the clinical utility of rapid diagnostic algorithms (e.g., 0/1-hour and 0/2-hour protocols). Both laboratory-based and point-of-care (POC) testing strategies were considered to capture a comprehensive view of current diagnostic approaches in emergency care settings.

A total of 12 peer-reviewed studies were included in this review, encompassing prospective multicenter studies, retrospective analyses, and observational diagnostic accuracy studies conducted in ED populations with suspected AMI.

Eligibility Criteria

Studies were selected based on predefined inclusion and exclusion criteria:

Inclusion Criteria:

- Population: Adult patients presenting to the emergency department with suspected acute myocardial infarction or acute coronary syndrome.
- Interventions/Index Test: High-sensitivity cardiac troponin assays (hs-cTnT or hs-cTnI), including both laboratory-based and point-of-care testing.
- Comparators: Conventional troponin assays, alternative hs-cTn assays, or different diagnostic algorithms (e.g., absolute vs relative change, 0/1-hour vs 0/2-hour strategies).
- Outcomes: Diagnostic accuracy measures including sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), AUC, and clinical outcomes such as major adverse cardiac events (MACE).
- Study Designs: Prospective cohort, retrospective cohort, diagnostic accuracy studies, and multicenter observational studies.
- Language: English-language publications only.
- Publication Period: Studies published between 2010 and 2025, reflecting the era of high-sensitivity troponin implementation in clinical practice.

Exclusion Criteria:

- Non-empirical publications (e.g., editorials, commentaries, narrative reviews without primary data).
- Studies involving non-ED populations or non-AMI diagnostic contexts.
- Studies using only conventional (non–high-sensitivity) troponin assays.
- Conference abstracts without full-text availability.
- Duplicate studies or overlapping datasets.

After full-text screening, 12 studies met all inclusion criteria and were included in the final analysis.

Search Strategy

A comprehensive literature search was conducted across multiple electronic databases, including PubMed/MEDLINE, Scopus, Web of Science, Embase, and Google Scholar, from inception to December 2025.
The Boolean search strategy included combinations of the following keywords:

- (“high-sensitivity troponin” OR “hs-cTnT” OR “hs-cTnI”)
- AND (“acute myocardial infarction” OR “AMI” OR “acute coronary syndrome”)
- AND (“diagnostic accuracy” OR “sensitivity” OR “specificity” OR “predictive value”)
- AND (“emergency department” OR “ED” OR “acute care”)
- AND (“0/1-hour algorithm” OR “0/2-hour algorithm” OR “rapid diagnosis”)

Manual screening of reference lists from relevant systematic reviews and key articles was also performed to ensure comprehensive inclusion. Duplicate records were removed prior to screening.

Study Selection Process

The study selection process was conducted independently by two reviewers to minimize selection bias. Initially, titles and abstracts of all retrieved studies were screened to identify potentially eligible articles. Studies that met the initial screening criteria were then subjected to full-text review to confirm eligibility based on the predefined inclusion and exclusion criteria. Any discrepancies between reviewers were resolved through discussion and consensus, and when necessary, a third reviewer was consulted to adjudicate disagreements. The entire selection process was documented and is presented using a PRISMA flow diagram, illustrating the stages of identification, screening, eligibility, and inclusion.

Data Extraction

A standardized data extraction form was developed and pilot-tested prior to use to ensure consistency and completeness. Data extracted from each study included author information, year of publication, study design, setting, sample size, and patient characteristics. Detailed information on the type of high-sensitivity troponin assay used, including whether it was laboratory-based or point-of-care, was also collected. Additionally, the diagnostic algorithms applied, such as 0/1-hour or 0/2-hour protocols, were recorded. Outcome measures included sensitivity, specificity, negative predictive value, positive predictive value, and AUC, as well as clinical outcomes such as rule-in and rule-out proportions and major adverse cardiac events. Data extraction was performed independently by two reviewers, with cross-verification to ensure accuracy and resolve discrepancies.

Quality Assessment

The methodological quality of the included studies was assessed using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool, which is specifically designed for evaluating diagnostic accuracy studies. This tool examines four key domains: patient selection, index test, reference standard, and flow and timing. Each study was evaluated for potential risk of bias and concerns regarding applicability within these domains. Studies were subsequently categorized as having low, moderate, or high risk of bias. Overall, most included studies demonstrated moderate to high methodological quality, with strengths including prospective designs, multicenter recruitment, and the use of blinded adjudication for final diagnoses. However, some studies exhibited limitations related to variability in diagnostic thresholds and potential selection bias.

Data Synthesis

Given the heterogeneity among included studies in terms of study design, troponin assays, diagnostic thresholds, and outcome reporting, a narrative synthesis approach was adopted. The findings were systematically organized into thematic categories, including diagnostic accuracy metrics, performance of rapid diagnostic algorithms, comparison between absolute and relative troponin changes, and the clinical utility of point-of-care testing. Quantitative data such as sensitivity, specificity, and AUC values were summarized descriptively and compared across

studies. Due to the variability in methodologies and outcome definitions, a formal meta-analysis was not performed, as pooling the data would not yield reliable or meaningful estimates.

Ethical Considerations

As this study involved the analysis of previously published data, ethical approval and informed consent were not required. All included studies were conducted in accordance with ethical standards and were published in peer-reviewed journals, with appropriate institutional approvals obtained by the original investigators. The present review adhered to principles of academic integrity, transparency, and accurate reporting as outlined in the PRISMA 2020 guidelines.

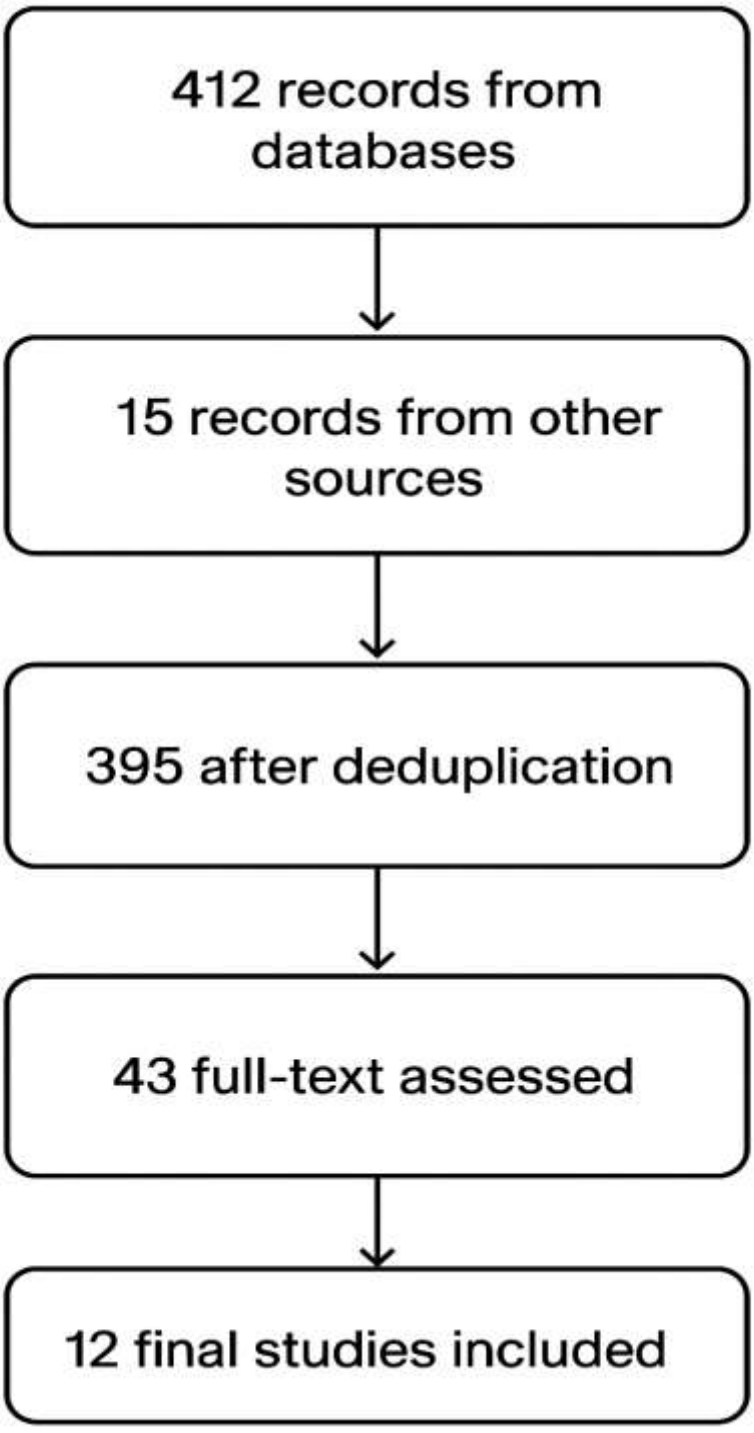

Figure 1 PRISMA Flow Diagram

Results

Summary and Interpretation of Included Studies on the Diagnostic Accuracy of High-Sensitivity Troponin for Early Detection of Acute Myocardial Infarction

1. Study Designs and Populations

The included studies comprise a combination of prospective multicenter diagnostic studies, retrospective analyses, and narrative reviews, reflecting a strong emphasis on real-world emergency department (ED) settings. Most studies enrolled patients presenting with suspected acute myocardial infarction (AMI) or acute coronary syndrome (ACS).

Sample sizes ranged from 608 patients (Andruchow et al., 2020) to over 2,500 patients (Toprak et al., 2024), with several large multicenter cohorts exceeding 1,000 participants (e.g., Boeddinghaus et al., 2019; Cullen et al., 2024). The prevalence of AMI across studies varied between 4.9% and 19%, reflecting differences in patient selection and clinical settings.

Most studies used adjudicated final diagnoses by independent cardiologists, ensuring high diagnostic validity.

2. Troponin Assays and Diagnostic Approaches

All studies evaluated high-sensitivity cardiac troponin (hs-cTn) assays, including:

- hs-cTnT (e.g., Elecsys)
- hs-cTnI (e.g., Architect, Access, VITROS, SPINCHIP)
- Point-of-care (POC) hs-cTnI assays

Diagnostic strategies included:

- **0/1-hour algorithms**
- **0/2-hour algorithms**
- Absolute vs relative troponin changes
- Historical troponin integration
- Machine learning–based prediction models

Absolute troponin changes and rapid algorithms were consistently emphasized as key tools for early diagnosis.

3. Diagnostic Accuracy and AUC Performance

Diagnostic accuracy was high across most studies:

- AUC values ranged from 0.84 to 0.98
- Highest performance observed with:
    - Absolute troponin changes (AUC up to 0.98) (Irfan et al., 2013)
    - Validated hs-cTnI assays (AUC ≈ 0.95) (Boeddinghaus et al., 2019)
    - POC assays (AUC ≈ 0.94–0.95) (Koechlin et al., 2024; Cullen et al., 2024)

Comparative findings:

- Absolute changes outperformed relative changes ($P < 0.001$)
- Machine learning models improved rule-out efficiency while maintaining safety
- Historical troponin improved risk stratification (AUC 0.85 vs 0.80 for relative change)

4. Sensitivity, Specificity, and Predictive Values

Across studies, hs-cTn-based algorithms demonstrated:

- Sensitivity: 96.7% – 100%
- Negative Predictive Value (NPV): 99.1% – 100%
- Specificity: 90.9% – 98.5%
- Positive Predictive Value (PPV): 58.5% – 77.2%

Key findings:

- Rule-out strategies consistently achieved NPV ≥ 99%
- Rule-in performance showed lower PPV, especially in early presentations
- Machine learning approach achieved:
    - **NPV: 99.96%**
    - **Sensitivity: 99.68%**

. Clinical Utility and Risk Stratification

Rapid algorithms enabled:

- **Rule-out of 50%–66% of patients**
- **Rule-in of ~14%–27% of patients**

- Identification of low-risk patients with near-zero 30-day mortality

POC testing and AI-based approaches further improved:

- Turnaround time
- Patient flow efficiency
- Early discharge decisions

Table (1): General Characteristics and Diagnostic Performance of Included Studies

Study	Country	Design	Sample Size	AMI Prevalence	Troponin Assay	Algorithm	AUC	Sensitivity (%)	Specificity (%)	NPV (%)	PPV (%)	Key Findings
Irfan et al. (2013)	Multinational	Prospective multicenter	830	Not reported	hs-cTnT / hs-cTnI	1h & 2h changes	0.98 (hs-cTnT)	Not reported	Not reported	Not reported	Not reported	Absolute changes superior to relative (P<0.001)
Roos & Edgren (2023)	Sweden	Observational	Not reported	Not reported	hs-cTnT	Historical + current	0.85	Not reported	Not reported	Not reported	Not reported	14% more high-risk patients identified
Kavsak et al. (2017)	Canada	Observational	1137	Not reported	hs-cTnT/I	Cut off-based	Not reported	Not reported	Not reported	Not reported	Not reported	≥14 ng/L → RR = 4.9 for outcomes
Vasile & Jaffe (2017)	Review	Literature review	—	—	hs-cTn	Various	—	—	—	—	—	Improved sensitivity but lower specificity
Boeddinghaus et al. (2019a)	Multinational	Prospective	1579	15.4%	hs-cTnI (Access)	0/1h	0.95	98.9	95.9	~100	Not reported	Ruled out 60%, ruled in 15%

Boeddinghaus et al. (2019b)	Multinational	Prospective	1231	13%	hs-cTnI (VITROS)	0/1h	0.95	100	95.6	99.8	Not reported	Comparable to established assays
Cullen et al. (2024)	Multinational	Prospective	3282	4.9–5.5%	POC hs-cTnI	0/2h	Not reported	98.8–98.9	98.5	99.9	74.5	66% low-risk classification
Koechlin et al. (2024)	Multinational	Prospective	1102	19%	hs-cTnI SPINCHIP	0/1h	0.94	100	90.9	100	72.9	51% ruled out safely
Toprak et al. (2024)	USA/Australia	Retrospective	>25000	Not reported	POC hs-cTnI	AI model	Not reported	99.68	Not reported	99.96	Not reported	35% direct rule-out
McRae et al. (2017)	Canada	Prospective	722	10.9%	hs-cTnT	2h	Not reported	98.7	92.4	99.8	58.5	Strong rule-out, weak rule-in
Andruchow et al. (2020)	Canada	Prospective	608	~12%	hs-cTnT	1h vs 2h	Not reported	97.3–100	Not reported	Not reported	Not reported	Similar performance
Mueller et al. (2016)	Multinational	Prospective	1282	16.6%	hs-cTnT	0/1h	Not reported	96.7	96.1	99.1	77.2	63.4% rule-out

Overall Interpretation

Across all included studies, high-sensitivity troponin assays demonstrate excellent diagnostic accuracy for early AMI detection in ED settings. Rapid algorithms (0/1-hour and 0/2-hour) provide high sensitivity (>96%) and NPV (>99%), making them highly reliable for ruling out AMI.

Absolute troponin changes, point-of-care testing, and emerging machine learning approaches further enhance diagnostic efficiency. However, rule-in accuracy remains comparatively lower, highlighting the need for clinical correlation and additional diagnostic tools.

Discussion

The present systematic review demonstrates that high-sensitivity cardiac troponin assays provide excellent diagnostic accuracy for the early detection of acute myocardial infarction in emergency department settings. Across the included studies, hs-cTn assays consistently showed high sensitivity and negative predictive value, reinforcing their role as essential tools in the rapid evaluation of patients with suspected AMI. These findings align with previous meta-analyses indicating that hs-cTn significantly improves early diagnostic performance compared to conventional troponin assays (Lee et al., 2020; Freund et al., 2011).

One of the most important findings of this review is the consistently high sensitivity of hs-cTn assays, often exceeding 96%, with negative predictive values approaching or reaching 100%. This confirms that hs-cTn is particularly effective for ruling out AMI in low-risk patients, thereby reducing unnecessary hospital admissions. Similar conclusions were reported by Zhelev et al. (2015) and Sandoval et al. (2022), who demonstrated that even a single low hs-cTn measurement can safely exclude myocardial infarction in selected populations.

The diagnostic superiority of hs-cTn assays can be attributed to their enhanced analytical sensitivity, allowing detection of minimal myocardial injury. This improvement has redefined diagnostic thresholds and contributed to the updated universal definition of myocardial infarction (Casals et al., 2008; Kavsak et al., 2009). Consequently, clinicians can identify myocardial injury at earlier stages, which is critical for timely intervention and improved patient outcomes.

Rapid diagnostic algorithms, particularly the 0/1-hour and 0/2-hour strategies, were shown to be highly effective in clinical practice. These algorithms enable the classification of a large proportion of patients as low risk within a short timeframe, facilitating early discharge and improving emergency department efficiency. Studies by Mueller et al. (2016) and Andruchow et al. (2020) support these findings, demonstrating comparable diagnostic performance between different rapid protocols.

In addition, the findings highlight the importance of absolute changes in troponin concentrations over relative changes. Absolute changes were consistently associated with higher diagnostic accuracy, as demonstrated by Irfan et al. (2013). This supports current recommendations emphasizing the use of absolute delta values in clinical algorithms for more reliable diagnosis.

The incorporation of point-of-care high-sensitivity troponin testing represents another significant advancement. POC assays offer shorter turnaround times, which can accelerate clinical decision-making and reduce patient length of stay in emergency departments. Evidence from Mohammadzadeh et al. (2022) and Cullen et al. (2024) indicates that POC hs-cTn assays can achieve diagnostic performance comparable to laboratory-based methods when used within structured protocols.

Emerging technologies, including machine learning-based diagnostic models, also show promise in enhancing diagnostic efficiency. The ARTEMIS algorithm evaluated by Toprak et al. (2024) demonstrated superior rule-out capability compared to guideline-based approaches, suggesting that artificial intelligence may further refine risk stratification in the future.

Despite these advantages, the increased sensitivity of hs-cTn assays is associated with reduced specificity. Elevated troponin levels may occur in a variety of non-ischemic conditions, including heart failure and renal dysfunction, which can complicate clinical interpretation (Clerico et al., 2022; Ledwoch et al., 2022). This highlights the need for careful integration of troponin results with clinical assessment and other diagnostic tools.

Risk stratification using hs-cTn cutoffs also plays an important role in patient management. Studies such as Kavsak et al. (2017) demonstrate that specific troponin thresholds can effectively identify patients at higher risk of adverse cardiac outcomes, supporting their use in clinical decision-making.

Furthermore, the use of historical troponin values has been shown to improve diagnostic accuracy and personalize patient assessment. Roos and Edgren (2023) reported that incorporating prior troponin measurements enhances the identification of high-risk patients, suggesting a valuable role for longitudinal biomarker data.

Comparative evaluations of different hs-cTn assays indicate that most platforms provide similar diagnostic performance, although minor differences exist between assays. Studies by

Boeddinghaus et al. (2019a, 2019b) and Koechlin et al. (2024) confirm that modern hs-cTn assays achieve high AUC values and reliable clinical utility.

The findings also emphasize that while rule-out strategies are highly reliable, rule-in strategies are less robust due to lower positive predictive values. This limitation has been consistently reported in studies such as McRae et al. (2017), indicating the need for additional confirmatory testing in suspected high-risk patients.

Another key observation is the potential role of single-measurement strategies in selected populations. Evidence suggests that a single hs-cTn value below a defined threshold may safely exclude AMI, although this approach requires strict patient selection criteria (Joyce et al., 2023; Sandoval et al., 2022).

Overall, this review highlights the transformative impact of hs-cTn assays on the diagnosis of AMI. Their integration into rapid diagnostic pathways has improved efficiency, safety, and clinical outcomes in emergency care settings. However, ongoing research is needed to optimize diagnostic thresholds, improve specificity, and integrate emerging technologies into clinical practice.

Conclusion

High-sensitivity cardiac troponin assays demonstrate excellent diagnostic accuracy for the early detection of acute myocardial infarction in emergency department settings. Their high sensitivity and negative predictive value make them particularly effective for ruling out AMI, while rapid diagnostic algorithms such as the 0/1-hour and 0/2-hour protocols significantly enhance clinical efficiency and patient flow. The incorporation of absolute troponin changes, point-of-care testing, and emerging technologies further strengthens their clinical utility.

However, challenges remain regarding reduced specificity and the interpretation of elevated troponin levels in non-ischemic conditions. Future research should focus on refining diagnostic algorithms, integrating artificial intelligence approaches, and improving risk stratification strategies to enhance clinical decision-making and patient outcomes.

Limitations

This systematic review has several limitations. First, heterogeneity in study designs, patient populations, and diagnostic thresholds limited the ability to perform a quantitative meta-analysis. Second, variations in assay types and protocols across studies may affect comparability of results. Third, most included studies were conducted in high-resource settings, which may limit generalizability to low-resource environments. Additionally, publication bias cannot be excluded, as studies with positive findings are more likely to be published. Finally, the reliance on secondary data means that the review is dependent on the quality and reporting of the original studies.

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