Review Article

High-Sensitivity Cardiac Troponin I for Exploring the Importance of Diagnostic Myocardial Infarction

Zinah Abbass Ali [1,*], Samar Hasan Shammar [1], Sheerin Hamza Abbas [2]

[1] Department of Clinical Biochemistry, College of Medicine, University of Babylon, Hillah 51002, Iraq.

[2] Department of Biochemistry, College of science of women, University of Babylon, Hillah 51002, Iraq.

[*] Corresponding author: Zenaabbass1980@gmail.com

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Abstract

Myocardial infarction (MI) ranks among the top injuries in morbidity and mortality globally, demanding prompt and efficient methods for diagnosis. Using high-sensitive cardiac troponin I (hs-cTnI) assays" has greatly improved the MI diagnosis by identifying myocardial injury much earlier than standard assays. The purpose of the review was to investigate the diagnostic value of hs-cTnI in MI and its benefits over ordinary troponin assays, clinical applications, challenges, and prospects in cardiovascular diagnostics. A thorough analysis of the literature dealing with hs-cTnI assays, as well as their clinical effectiveness, sensitivity, specificity, and use in diverse patient populations was performed. The focus of the analysis is on comparative studies, biomarker performance evaluation, and new diagnostic protocol development. Hs-cTnI assays enhance the diagnosis of MI by detecting cardiac troponin at lower concentrations, which allows for timely intervention and risk stratification. This distinguishes MI from other cardiac and non-cardiac problems and is very useful in special populations like the elderly, women, and patients with chronic kidney disease. hs-cTnI tests have shown considerable challenges like the degree of standardization of the assay and false positive results in non-ischemic circumstances. Because it permits more accurate and timely MI notifications, the integration of hs-cTnI assays into clinical practice aids in the accurate and timely detection of troponin myocardial injury. Clinical cut-off diagnostic values as well as AI-based predictive analysis and quantities interpretation-dependent variability need more optimized values in future research.

Keyword: Troponin assays, risk stratification, sensitivity, specificity - Cardiac biomarkers, Myocardial Infarction (MI)

Introduction

Myocardial Infarction (MI) is listed among the top causes of death in most regions of the world making it necessary to accurately and quickly be diagnosed [1]. High sensitivity and specificity [2, 3] of cardiac biomarkers ensures they are preferred the world over for MI, especially for the cardiac troponins. The detection of myocardial injury has been aided by the introduction of high sensitivity cardiac troponin I (hs-cTnI) assay which allows earlier diagnosis and better patient outcome [4, 5]. This review will look at the role of hs-cTnI in MI diagnosis as well as its advantages and disadvantages relative to the other conventional troponin assays both in the clinical setting and other applications, challenges and future perspectives [6, 7]

Pathophysiology of Myocardial Infarction and Biomarkers

MI is the pathological blockage of one or more coronaries systems for avascular regions which results in the ischemia followed by necrosis of the magic muscle [8, 9]. The more of muscle involved the greater the release of the cellular markers of myocardial injury and necrosis like the troponins [10, 11]. The markers of heart

muscle injury (cardiac troponin I and troponin T) always have specificity for the heart and hence are the most preferred genes [12, 13] The emergence of high-sensitivity tests facilitates the identification of troponin at markedly lower doses, hence enhancing early diagnosis [14,15]. In addition to troponins, several biomarkers like creatine kinase-MB (CK-MB), myoglobin, and heart-type fatty acid-binding protein (H-FABP) have been investigated for myocardial infarction identification. Nonetheless, these indicators do not possess the specificity and diagnostic precision offered by hs-cTnI [16,17].

Biological Function of Cardiac Troponin-I

Cardiac Troponin-I (cTnI), a regulatory protein within the troponin complex, is specific to cardiomyocytes. Its release is directly associated with the severity of myocardial damage, establishing it as a gold-standard biomarker. In contrast to cTnT, cTnI has minimal expression in skeletal muscle, hence increasing specificity for cardiac disorders [18,19].

High-Sensitivity Cardiac Troponin I Assays

High-sensitivity cardiac troponin assays can detect troponin levels in more than 50% of healthy individuals, hence improving cardiovascular risk evaluation [20,21]. These assays exhibit a high negative predictive value for ruling out myocardial infarction in emergency situations [22,23]. The 4th Universal Definition of Myocardial Infarction emphasizes the importance of hs-cTnI in differentiating type 1 MI (resulting from atherosclerotic plaque rupture) and type 2 MI (attributable to oxygen supply-demand imbalance) [24,25].

Clinical Adoption and Guidelines

Since 2018, the Fourth Universal Definition of MI has endorses hs-cTnI for diagnosis, emphasizing serial measurements and absolute URL thresholds. Major cardiology societies, including the European Society of Cardiology (ESC), advocate hs-cTnI integration into accelerated diagnostic protocols (ADPs).

Diagnostic Performance of hs-cTnI

Sensitivity and Specificity

A multicenter prospective cohort study (n= 1,200) demonstrated hs-cTnI's superior sensitivity (94% vs. 78%) and specificity (85-90%) compared to conventional assays within the first hour of presentation. This aligns with meta-analyses showing hs-cTnI's negative predictive value (NPV) of 97–99%, effectively excluding MI in low-risk patients.

Clinical Applications of hs-cTnI in MI Diagnosis

Early Detection and Risk Stratification

Hs-cTnI assays enable the detection of myocardial injury within hours of symptom onset, reducing the time to diagnosis compared to conventional assays [26,27]. This is especially vital in emergency rooms, where swift triage of patients presenting with chest discomfort is essential [28,29]. Moreover, hs-cTnI aids in the risk classification of patients with suspected acute coronary syndrome (ACS) [30,31].

Differentiating MI from Non-Ischemic Causes

Hs-cTnI assays help differentiate MI from other causes of troponin elevation, such as myocarditis, heart failure, and renal disease [32,33]. Serial measurements of hs-cTnI over a short duration provide valuable insight into the dynamic changes associated with acute myocardial injury [34,35]. Moreover, hs-cTnI plays a role in identifying patients with stable ischemic heart disease at higher risk of future cardiovascular events [36,37].

Use in Special Populations

Elderly patients, women, and individuals with chronic kidney disease often present with atypical MI symptoms, making hs-cTnI an essential diagnostic tool in these populations (38,39). The ability to detect minute elevations enhances clinical decision-making [40,41].

Recent studies also suggest the use of hs-cTnI in pediatric populations for the assessment of congenital heart disease and myocardial involvement in systemic conditions [42,43].

Comparison with Conventional Troponin Assays

Conventional troponin assays have limitations in detecting low levels of troponin, particularly in early-stage MI [44,45]. High-sensitivity assays provide improved precision and earlier diagnosis, reducing the risk of missed MI cases [46,47]. Several studies have demonstrated that hs-cTnI assays reduce the need for prolonged observation in emergency settings, leading to cost savings and better resource utilization. Furthermore, hs-cTnI has been incorporated into rapid rule-out algorithms, improving patient flow and reducing overcrowding in emergency departments [48]. Clinical Feature listed in Table (1) showed difference in the Conventional Troponin Assays compared to High-Sensitivity-Troponin Assays (hs-cTnI)

Table 1: showed difference in the Conventional Troponin Assays compared to High-Sensitivity-Troponin Assays (hs-cTnI)

Feature	Conventional Troponin Assays	High-Sensitivity-Troponin Assays (hs-cTnI)
Sensitivity	Lower sensitivity, may miss early MI cases	Detects very low troponin levels, allowing early diagnosis
Detection Time	Detectable 6–12 hours after MI onset	Detectable within 1–3 hours after MI onset
Specificity	Moderate specificity for cardiac injury	High specificity, but requires careful interpretation
Diagnostic Accuracy	Less accurate in ruling out MI in early stages	High negative predictive value for MI exclusion
Clinical Application	Mainly used for MI confirmation	Used for MI rule-in and rule-out algorithms
Impact on Emergency Care	Requires multiple tests and longer observation	Reduces length of hospital stay and improves patient flow

Challenges and Limitations of hs-cTnI Testing

Despite its advantages, hs-cTnI testing has challenges, including variability in assay results due to differences in laboratory standards. Additionally, false-positive results can occur due to non-ischemic conditions, necessitating careful interpretation in clinical contexts. Standardization of cutoff values across different assays remains a critical issue. Another challenge is the impact of preanalytical variables such as sample handling, storage conditions, and assay interference from heterophile antibodies [49].

Future Directions and Innovations

Ongoing research aims to refine hs-cTnI assay technology to enhance specificity while maintaining high sensitivity. The integration of hs-cTnI with artificial intelligence (AI) and machine learning models holds promise for improving diagnostic accuracy. Furthermore, multi-biomarker approaches combining hs-cTnI with inflammatory or metabolic markers may further enhance MI detection. Efforts to develop point-of-care hs-cTnI testing devices may enable rapid diagnostics in remote and resource-limited settings [50].

Conclusion

"High-sensitivity cardiac troponin I (hs-cTnI)" assays have adically changed the approach towards the diagnosis and treatment of myocardial infarction (MI). In this review, we demonstrate how hs-cTnI has markedly improved the accuracy of diagnostics and facilitated the earlier recognition of myocardial injury relative to conventional troponin assays. The identification of low-level troponin increases by hs-cTnI facilitates prompt risk classification and action to enhance patient outcomes. The integration of hs-cTnI into clinical practice presents several challenges. Significant concerns persist regarding variability in test performance, false-positive results in non-ischemic situations, and the absence of standardized cutoff values among laboratories. Additionally, understanding hs-cTnI levels in certain populations, the elderly, women, and those with chronic kidney disease,

requires more thought to avoid misdiagnosis. Future studies must aim towards increasing specificity of hs-cTnI assay technologies while retaining high sensitivity. Incorporating artificial intelligence (AI) and machine learning with hs-cTnI testing is one of the best routes for improving accuracy and efficiency in the diagnostic process. The implementation of multi-biomarker strategies that integrate hs-cTnI and other inflammatory and metabolic markers may also enhance the evaluation of cardiovascular risk. To sum up, the hs-cTnI assays are still a great deal of progress in the detection of myocardial infarction; however, additional work is necessary in the areas of standardization of test methods, improvement of clinical processes, as well as the devising of new methodologies to attend to the markers of cardiovascular disease. With the progression of biomarker research, the clinical application of hs-cTnI will be amplified, which will improve the management and outcomes associated with myocardial infarction.

Conflict of interest

None

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