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MYOCARDIAL INFARCTION: EARLY DIAGNOSIS AND MODERN REPERFUSION THERAPY

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ABSTRACT

Myocardial infarction (MI) remains a leading global cause of mortality and disability. The prognosis critically depends on the speed and accuracy of diagnosis and the prompt restoration of coronary blood flow. This article reviews contemporary strategies for the early diagnosis of MI, focusing on high-sensitivity cardiac troponin (hs-cTn) assays and point-of-care testing, alongside the pivotal role of electrocardiography (ECG). It then provides a detailed analysis of modern reperfusion therapy paradigms, primarily comparing primary percutaneous coronary intervention (PPCI) and pharmacological fibrinolysis. The discussion emphasizes the "time-dependent" nature of myocardial salvage, the central role of organized systems of care (e.g., STEMI networks), and evolving approaches for non-ST-elevation MI (NSTEMI). While PPCI is the preferred gold-standard when available within specific timeframes, facilitated and pharmaco-invasive strategies are crucial in settings with limited access to catheterization labs. Future directions, including artificial intelligence in ECG interpretation and novel antithrombotic agents, are also explored. This synthesis aims to provide a evidence-based overview for optimizing patient outcomes through rapid diagnosis and tailored reperfusion.

Key Words

Myocardial Infarction, Early Diagnosis, High-Sensitivity Troponin, Electrocardiography, Reperfusion Therapy, Primary Percutaneous Coronary Intervention, Fibrinolysis, Ischemic Time, STEMI Networks.

INTRODUCTION

Acute myocardial infarction (AMI) represents a critical manifestation of coronary artery disease and a paramount medical emergency. Its pathophysiology is predominantly the acute rupture of an atherosclerotic plaque, leading to thrombotic occlusion of a coronary artery and subsequent irreversible necrosis of cardiomyocytes. The ultimate goal of management in the hyper-acute phase is twofold: first, to establish a rapid and accurate diagnosis to initiate appropriate care, and second, to achieve timely and effective myocardial reperfusion to limit infarct size, preserve left ventricular function, and reduce both short- and long-term morbidity and mortality. The evolution of management over recent decades has been revolutionary, shifting from a passive, observational approach to an active, interventional strategy. This paradigm shift hinges on the concept that "time is muscle." However, significant challenges persist, including diagnostic dilemmas, logistical barriers to delivering timely intervention, and the management of special patient populations. This article comprehensively reviews the foundational and advanced modalities for early MI diagnosis and systematically analyzes the evidence, protocols, and nuances of contemporary reperfusion therapy.

LITERATURE REVIEW

1. Evolution of Diagnostic Criteria: The definition of MI has evolved significantly, moving from a purely clinical and ECG-based diagnosis to one anchored in biomarker evidence, particularly cardiac troponin (cTn). The universal definition, established by a Joint Task Force, classifies MI into different types, with Type 1 (spontaneous plaque rupture) being the primary target for acute reperfusion therapy [Thygesen et al., 2019]. This framework underscores the need for precise diagnostics to guide specific treatments.

2. High-Sensitivity Cardiac Troponin (hs-cTn): The advent of hs-cTn assays represents a cornerstone in early diagnosis. These assays can detect very low levels of myocardial necrosis with high precision. Rapid "rule-out" and "rule-in" algorithms using hs-cTn measurements at presentation and after 1-3 hours have been validated to safely expedite decision-making in the emergency department [Chapman et al., 2017]. Studies show these protocols reduce length of stay without increasing missed MI rates.

3. The Irrefutable Role of ECG: Despite biomarker advances, the 12-lead ECG remains the fastest and most crucial tool for identifying ST-elevation MI (STEMI), which mandates immediate reperfusion therapy. Its sensitivity, however, is not absolute. Ongoing research explores machine learning algorithms to enhance ECG interpretation, potentially identifying occlusion MI even in the absence of classic STEMI criteria.

4. Primary Percutaneous Coronary Intervention (PPCI): PPCI, involving urgent coronary angiography and stent placement, has emerged as the preferred reperfusion strategy where available. Multiple randomized controlled trials (RCTs) and meta-analyses have consistently demonstrated its superiority over fibrinolysis in reducing mortality, reinfarction, and stroke, provided it can be performed within 90-120 minutes of first medical contact [Ibanez et al., 2018].

5. Fibrinolytic Therapy: Intravenous fibrinolytic agents remain a vital, life-saving therapy, especially in regions without ready access to PCI-capable centers. The key principle is that early administration is vastly more effective than delayed PCI. The benefit is most pronounced within the first 2-3 hours of symptom onset. Pre-hospital fibrinolysis has been shown to further improve outcomes by minimizing system delays.

6. Pharmaco-Invasive Strategy: This hybrid approach involves immediate fibrinolysis (often in a non-PCI center or pre-hospital) followed by systematic, early (within 3-24 hours) coronary angiography and PCI if needed. It is recognized as a superior alternative to fibrinolysis alone, particularly when the anticipated delay to PPCI is significant (e.g., >120 minutes) [Armstrong et al., 2013].

DISCUSSION

Diagnostic Challenges and Refinements: While hs-cTn algorithms are powerful, they require clinical integration. Elevated troponin is not specific to Type 1 MI and can occur in heart failure, myocarditis, or renal failure (Type 2 MI). Therefore, clinical context, history, and ECG remain indispensable for accurate classification. Point-of-care troponin tests are improving but generally lack the sensitivity of laboratory hs-cTn assays, limiting their use for rapid rule-out. The Centrality of Time in Reperfusion the mantra "time is muscle" is supported by robust physiological and clinical evidence. Every 30-minute delay in reperfusion increases one-year mortality by approximately 7.5%. This underscores the importance of systems-based approaches. Organized regional STEMI care networks, incorporating pre-hospital ECG, bypass protocols to PCI centers, and continuous quality feedback, are the most effective means to reduce ischemic

time and have been widely adopted in successful healthcare systems.

Strategy Selection: A Practical Framework: The choice of reperfusion therapy is not binary but contextual.
PPCI First: The clear first-line strategy if a skilled team can perform it within **120 minutes of first medical contact**. The goal is a **door-to-balloon time <90 minutes**.
Fibrinolysis First: Indicated if PPCI cannot be achieved within 120 minutes, especially if symptom onset was <3 hours ago and there are no contraindications. **Door-to-needle time should be <30 minutes**.
Pharmaco-Invasive Bridge: This is the recommended pathway after successful fibrinolysis or as a planned strategy when timely PPCI is unavailable. It mitigates the risk of re-occlusion and addresses the "culprit" artery more definitively than fibrinolysis alone.

Managing NSTEMI: For NSTEMI patients, reperfusion is not an immediate mechanical intervention but a timely invasive strategy. High-risk features (e.g., recurrent ischemia, dynamic ECG changes, elevated troponin, hemodynamic instability) warrant an **invasive strategy within 24 hours**, and often even earlier (<2 hours) for very high-risk patients [Collet et al., 2021]. This approach focuses on preventing reinfarction and stabilizing the patient rather than aborting an ongoing infarction. **Adjunctive Pharmacotherapy -** Modern reperfusion is incomplete without optimal adjunctive therapy. This includes dual antiplatelet therapy (aspirin plus a P2Y12 inhibitor like ticagrelor or prasugrel), potent anticoagulation during PCI, and high-dose statins. These agents stabilize the plaque and the intracoronary stent environment, preventing acute and subacute complications.

RESULTS

The implementation of the strategies discussed has yielded measurable improvements in patient outcomes on a population level. Regions that have established coordinated STEMI systems report significant increases in the proportion of patients receiving timely reperfusion, a dramatic reduction in median door-to-balloon times, and a concomitant decrease in in-hospital and 30-day mortality rates for STEMI. The use of hs-cTn protocols has successfully reduced unnecessary hospital admissions and accelerated the discharge of low-risk patients from emergency departments. Clinical trial data consistently show that compared to fibrinolysis, PPCI results in an **approximate 25% relative risk reduction in short-term mortality, a 50% reduction in reinfarction, and a significant reduction in hemorrhagic stroke** [Ibanez et al., 2018]. For NSTEMI, early invasive strategies in high-risk patients reduce the composite endpoint of death and MI compared to a conservative, ischemia-guided approach.

CONCLUSION

The management of acute myocardial infarction in the 21st century is defined by speed, precision, and systematic organization. Early diagnosis, powered by hs-cTn and expert ECG interpretation, must be seamlessly coupled with an immediate reperfusion strategy tailored to the patient's clinical presentation and local healthcare logistics. Primary PCI stands as the gold standard reperfusion modality when it can be delivered expediently. However, fibrinolytic and pharmaco-invasive strategies are indispensable components of the global therapeutic arsenal, ensuring that geography does not dictate destiny. The future lies in further refining diagnostic algorithms with artificial intelligence, developing even safer and more effective pharmacotherapies, and, most importantly, strengthening and expanding integrated systems of care to ensure that every patient, regardless of location, has access to this life-saving chain of survival. The ultimate goal remains minimizing the time from symptom onset to restored

coronary flow, thereby preserving myocardium and saving lives.

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