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EDITORIAL

The Evolving Paradigm of Myocardial Infarction in the Era of Artificial Intelligence

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Abstract

The classification and treatment of myocardial infarction (MI) have evolved significantly over the past few decades, with the ST-segment elevation myocardial infarction (STEMI)/non-STEMI (NSTEMI) paradigm dominating clinical practice. While STEMI, identified by ST-segment elevation (STE) on electrocardiogram (ECG), has been the hallmark for urgent reperfusion therapy, this model misses a substantial number of patients with occlusive myocardial infarction (OMI) who do not exhibit STE. Recent evidence reveals that up to 25% of NSTEMI patients have OMI, leading to higher mortality due to delayed reperfusion. The emerging OMI/NOMI (Occlusive vs. Non-Occlusive MI) paradigm offers a more nuanced approach, incorporating advanced ECG interpretation and tools like point-of-care echocardiography and artificial intelligence (AI). AI has shown promise in detecting subtle ECG changes indicative of OMI, improving diagnostic accuracy and reducing misdiagnosis. This paradigm shift has important implications for clinical practice, calling for earlier identification of OMI and more inclusive treatment strategies to enhance patient outcomes.

Key words: myocardial infarction; ST-elevation; artificial intelligence; electrocardiogram

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Introduction

The classification and treatment of myocardial infarction (MI) have undergone a significant change over the last 30 years. The need for early identification of patients who benefit from reperfusion therapy heralded a shift from the Q-wave/non-Q-wave classification to the ST-segment elevation myocardial infarction (STEMI) and non-STEMI (NSTEMI) paradigm in which the electrocardiogram (ECG) became a crucial tool for early diagnosis (Kontos et al, 2022). In this paradigm ST-elevation (STE) becoming synonymous with occlusive myocardial infarction (OMI).

Now, patients with STE on ECG are moved rapidly to the catheter laboratory, 24/7, for primary angioplasty to the occluded artery. However, hiding in plain sight has been evidence that the absence of STE on ECG does not accurately rule out OMI, that these patients have an adverse prognosis, and are currently denied the potential benefit of primary angioplasty and timely reperfusion.

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The STEMI/NSTEMI Paradigm: A Historical Perspective

For a generation of cardiologists, the STEMI/NSTEMI dichotomy has been the dominant discourse for classifying and treating MI. This paradigm segregates patients with chest pain based on the presence or absence of STE on the ECG which is taken as a surrogate marker for the presence of a complete occluded epicardial coronary artery, warranting immediate reperfusion therapy with primary percutaneous coronary intervention (PCI) delivered, if possible, within 120 minutes. Patients with chest pain but absence of ST-elevation, so called NSTEMI on the other hand, are regarded to have partial, non-occlusive coronary thrombus, more limited myocardial damage and this mandates more relax approach to coronary angiography, recommended within 24 h in high-risk patients and 72 h in others in current guidelines (Byrne et al, 2023). In current UK practice however only 58% of patients receive an angiography within 72 h of presentation (NCAP, 2024).

The STEMI/NSTEMI paradigm brought significant advances in emergency cardiology, particularly with the advent of rapid reperfusion strategies such as thrombolysis and more recently PCI. The model provided a simplified framework for emergency healthcare providers, enabling quicker decision-making in high-stress settings. The "time is muscle" concept—emphasizing the importance of reducing reperfusion delays and the focus on "door-to-needle" and then "door-to-balloon" time became key drivers in improving patient outcomes with primary PCI services accessible 24/7 for almost all patients.

However, as data accumulated it became increasingly clear that the model is an imperfect representation of the underlying pathophysiology of MI. Studies showed that up to 25% of patients classified as NSTEMI in fact have OMI, leading to higher mortality rates due to delayed or missed reperfusion opportunities (Wang et al, 2009). However, cardiologists have essentially ignored this. One factor which may explain this is incorporation bias in which patients with STE on ECG and unobstructed coronary arteries are labelled as a false-positive STEMI whereas patients without STE, who have complete coronary occlusion are never re-classified from NSTEMI to missed STEMI (de Alencar et al, 2024a). The other is that early studies of reperfusion with thrombolysis did not show benefit in patients without STE. However, these were a very heterogenous group of patients and sub-group analysis did show evidence of benefit in high-risk subsets (Mehta et al, 2009). Thus, there is a need for early identification of such patients who would benefit from reperfusion therapies delivered in a timely manner akin to the STEMI patients and the growing recognition of the existence of "false negatives" in the STEMI/NSTEMI paradigm has led some clinicians to explore alternative approaches to diagnosis.

The OMI/NOMI Paradigm: A New Era of Diagnosis

The OMI/non-occlusive MI (NOMI) paradigm is based on the presence or absence of OMI rather than relying solely on ECG STE criteria. Unlike STEMI/NSTEMI,

which dichotomizes patients based on the ECG, the OMI/NOMI approach takes a more nuanced view mainly around advanced ECG interpretation and pattern recognition potentially with other tools such as point-of-care echocardiography and clinical features such as refractory ischemia to more accurately detected OMI (McLaren et al, 2024).

This shift has been driven by evidence showing that STE on ECG fails to detect a significant number of patients with OMI with a recent meta-analysis showing the sensitivity of STE-criteria for detecting OMI of just 44% (de Alencar et al, 2024b). Thus, over half of patients with OMI are "missed" if the STE criteria are applied as gatekeeper to emergency angiography and this fits with our own clinical experience as shown in Fig. 1 illustrating recent cases presenting to our institution. The OMI paradigm also challenges the long-held belief that only patients with STE benefit from immediate reperfusion. Research has demonstrated that patients without STE who have OMI have significant myocardial damage and increased major adverse clinical events and a doubling of mortality if not treated promptly (Aslanger et al, 2020; Khan et al, 2017).

It should be noted that no classification system is perfect and the main value of replacing one dichotomous system (STEMI, non-STEMI) with the alterative (OMI/NOMI) is regarding the decision around the need for rapid PCI. Whilst we may choose to dichotomise patients between OMI and NOMI it is worth considering that there is a continuum between absolute occlusion that is, at least in the short term, fixed or permanent without revascularisation, and an unstable/transient situation where the impaired coronary blood flow is intermittently or critically impaired but not absolutely occluded.

The Role of the ECG and Artificial Intelligence in OMI Detection

Whilst STE on ECG remains an indispensable tool in the diagnosis of MI its utility in the OMI paradigm has expanded beyond just interpretation of ST-segments. The work of Steve Smith, Pendell Myers and Emre Aslanger has promoted the recognition of patterns of ECG change associated with OMI/ACO including the de Winter T-wave pattern, Wellen's syndrome, subtle changes in reciprocal ST-segment depression and T-wave morphology (McLaren et al, 2024). These ECG patterns do not meet classical STE criteria but are indicative of OMI and should be given consideration for urgent coronary angiography and PCI.

However, these ECG patterns are difficult to teach, and recognition of the patterns is poor outside highly trained experts. AI is increasingly used in ECG to assist in diagnosis, stratification, and management and it has emerged as potentially powerful tool to improve the OMI detection (Martínez-Sellés and Marina-Breysse, 2023). An AI-algorithm trained on large ECG datasets of OMI accurately identify the subtle changes often missed or dismissed by clinicians. AI has improved sensitivity and specificity in detecting OMI, particularly when the ECG does not show STE. In a recent study an AI-algorithm achieved 86% sensitivity and 98% specificity in diagnosing OMI, outperforming both traditional ECG criteria and clini-

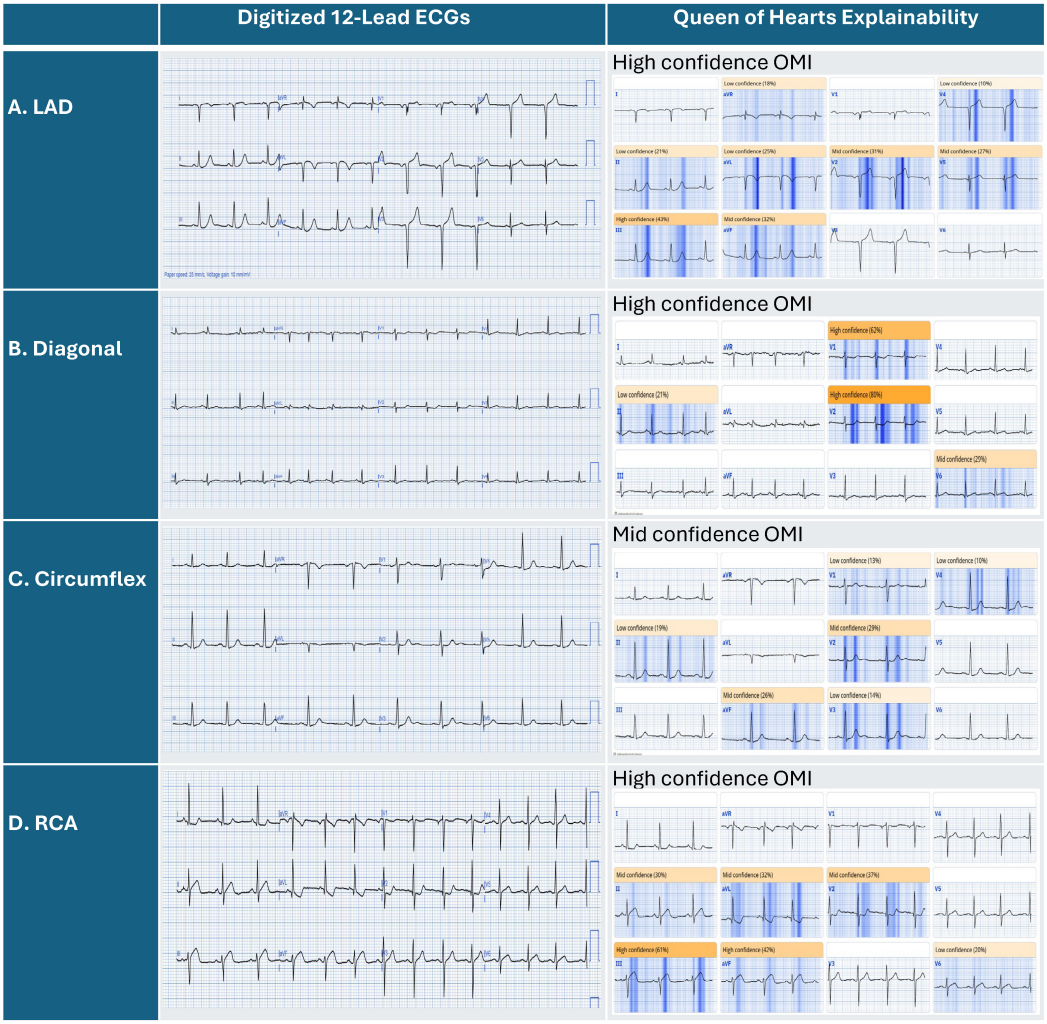

Fig. 1. Chest Pain patients initially managed as NSTEMI by clinicians. Informed consent for the publication of the Electrocardiogram (ECG) traces has been obtained. Standard index 12-lead ECG was digitized using the Queen of Hearts Occlusive Myocardial Infarction (QOH-OMI) smartphone application https://www.powerfulmedical.com/pmcardio-omi/. The AI-App reports whether the interpretation is OMI or not OMI and the level of confidence for the conclusion. It also highlights each ECG lead in the region of interest associated with an increased probability of OMI. Case (A), A 45-year-old man with chest pain, QOH reports OMI and angiography showed severe proximal left anterior descending (LAD) coronary occlusion with red thrombus and Thrombosis in Myocardial Infarction (TIMI) flow grade 1. Case (B), A 67-year-old woman with chest pain, artificial intelligence (AI) reports OMI and angiography showed acute occlusion of diagonal with TIMI0 flow. Case (C), A 48-year-old man with chest pain, AI reports OMI and angiography showed mid-circumflex occlusion with TIMI1 flow. Case (D), A 44-year-old man with chest pain, AI reports OMI, angiography showed acute occlusion of the right coronary artery (RCA). aVR, augmented vector right; aVL, augmented vector left; aVF, augmented vector foot.

cians (Al-Zaiti et al, 2023). It is our prediction that AI will transform the way clinicians interpret the ECG resulting in quicker and more accurate diagnosis of OMI. AI will can also help to identify patients with STE on ECG who do not have OMI (false positive) thus reducing unnecessary cardiac catheter laboratory primary angioplasty activations and improving resource utilization. The real value of AI is

likely to be the application of a more sensitive clinical tool for the recognition of the OMI since these models may be better at interpreting ECG changes that correlate with critical coronary flow interruption and identifying patients that would benefit from early PCI.

Conclusion

A shift from a STEMI/NSTEMI to an OMI/NOMI paradigm has significant implications for clinical practice. First, it calls for a shift in the way we classify and treat MI. Rather than focusing solely on STE clinicians should consider the possibility of OMI in patients with subtle ECG changes or clinical signs of refractory ischemia. Recognising that OMI can occur in the absence of STE is an important first step in the transformation of mental attitudes towards patient with chest pain. AI-guided ECG interpretation is a very promising step forward in the diagnosis of OMI and integrating it into routine clinical practice will enhance accuracy of ECG interpretation, reduce diagnostic delays, and improve patient outcomes. The STEMI paradigm has served the cardiology community well, but it is not sensitive enough to identify all patients with OMI. The OMI paradigm offers more inclusive approach incorporating advanced ECG interpretation potentially enhanced by AI to improve diagnostic accuracy. Implementation will require an investment in AI technology and there is need for evidence from randomised clinical trials to demonstrate that urgent reperfusion therapy is beneficial not just for the patients with STE on ECG but also those without STE but with OMI.

Key Points

- The ECG as a primary diagnostic tool for MI may miss patients with occlusive myocardial infarction (OMI) who for urgent reperfusion is indicated because they do not have ST elevation.
- Up to 25% of non-STEMI patients may have OMI and they have higher mortality due to missed or delayed reperfusion.
- The OMI model shifts focus from relying on ST-elevation towards recognition of ECG patterns, such as de Winter's T-wave or Wellen's syndrome which can indicate OMI even without STE.
- AI technology improves the sensitivity and accuracy of ECG interpretation, helping detect these subtle signs of OMI and reduce misdiagnosis with high sensitivity (86%) and specificity (98%), outperforming traditional ECG criteria and clinicians.
- AI can also help identify false positives (STE without OMI), reducing unnecessary procedures and optimizing resource use in emergency settings.
- AI-guided ECG interpretation promises to enhance diagnostic accuracy, reduce delays, and improve patient outcomes by identifying more cases of OMI that would benefit from urgent PCI.

Availability of Data and Materials

Not applicable.

Author Contributions

MD, CMEB and RGB contributed to literature review and manuscript draft and editing. RGB had the original conception of the work. All authors contributed to important editorial changes in the manuscript and authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Ethical approval was not required for this work. Written patient consent for publication of the ECG traces was obtained.

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Conflict of Interest

The authors declare no conflict of interest.

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