CJC Open 7 (2025) 632–640

Original Article

Equity Gaps in the Diagnosis and Treatment of Occlusion Myocardial Infarction

Varunaavee Sivashanmugathas, BSc,[a] Mazen El-Baba, MD, MSc,[b] Marcella K. Jones, MD,[c] Alex Kiss, PhD,[d] H. Pendell Meyers, MD,[e] Stephen W. Smith, MD,[f] Lucas B. Chartier, MD, CM, MPH, MBA,[b] and Jesse T.T. McLaren, MD[c]

[a] *Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada*

[b] *Division of Emergency Medicine, Department of Medicine, University of Toronto, Toronto, Ontario, Canada*

[c] *Division of Emergency Medicine, Department of Family and Community Medicine, University of Toronto, Toronto Ontario, Canada*

[d] *Evaluative Clinical Sciences, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada*

[e] *Department of Emergency Medicine, Carolinas Medical Center, Charlotte, North Carolina, USA*

[f] *Department of Emergency Medicine, Hennepin County Medical Centre and University of Minnesota, Minneapolis, Minnesota, USA*

ABSTRACT

Background: Patients with occlusion myocardial infarction (OMI) who meet the ST-elevation myocardial infarction (STEMI) criteria experience inequitable delays in care, because of sociodemographic factors, such as age and sex. OMI patients who do not meet STEMI criteria and are admitted to the hospital as non-STEMI patients, experience further delays. However, whether equity gaps exist in OMI care remains unknown.

Methods: A retrospective chart review included patients with acute coronary syndrome admitted to the hospital through 2 academic emergency departments, in the period from January 1, 2021 to December 31, 2022. Patients were categorized as having one of the following: OMI (acute culprit with Thrombolysis In Myocardial Infarction [TIMI] 0-2 flow, or acute culprit with TIMI 3 flow, and a troponin I level > 10,000 ng/L; or if they had no angiogram, a troponin I level > 10,000 ng/L plus new regional wall-motion abnormality on echocardiogram); non-OMI (MI that did not meet the OMI threshold); or MI ruled out.

Results: Among 662 charts, 260 were OMI patients, 296 were non-OMI patients, and 106 were patients with MI ruled out. Of the 260 OMI patients, 116 were admitted to the hospital as STEMI patients (true-positive), and 144 (55.4%) were admitted as non-STEMI patients (false-negative). In bivariate analyses, true-positive STEMI patients with

RÉSUMÉ

Contexte : Les patients qui subissent un infarctus du myocarde par occlusion (IMO) et qui répondent aux critères définissant l'infarctus du myocarde avec élévation du segment ST (STEMI) connaissent des retards inéquitables dans les soins en raison de facteurs sociodémographiques, tels que l'âge et le sexe. Les patients qui présentent un IMO, qui ne répondent pas aux critères du STEMI et qui sont admis à l'hôpital en tant que patients ne présentant pas un STEMI (patients « non STEMI ») connaissent des retards encore plus longs. On ignore cependant si des inégalités existent dans les soins aux patients qui subissent un IMO.

Méthodologie : Nous avons procédé à un examen rétrospectif de dossiers de patients admis à l'urgence de deux centres hospitaliers universitaires pour un syndrome coronarien aigu entre le 1er janvier 2021 et le 31 décembre 2022. Les patients ont été répartis dans les catégories suivantes : IMO (cause aiguë avec thrombolyse dans l'infarctus du myocarde [IM] à un flux de 0 à 2 ou cause aiguë avec thrombolyse dans l'IM à un flux de 3, et taux de troponine I > 10 000 ng/L; ou si aucun angiogramme n'a été réalisé, taux de troponine I > 10 000 ng/L accompagné d'une nouvelle anomalie régionale du mouvement de la paroi à l'échocardiographie), non IMO (IM qui n'a pas atteint le seuil de l'IMO) ou IM exclu.

The diagnosis and treatment of acute coronary occlusion traditionally has been based on the ST-elevation myocardial infarction (STEMI) paradigm. The STEMI paradigm is the framework for acute coronary syndrome (ACS) quality metrics: all patients with ischemic symptoms need an electrocardiogram (ECG) within 10 minutes of their arrival to the emergency department (ED), and those patients who have ECGs that meet the STEMI criteria need emergent

Received for publication November 12, 2024. Accepted January 20, 2025.

Corresponding author: Jesse T.T. McLaren, Toronto General Hospital, 200 Elizabeth St., R. Fraser Elliott Building, Ground Floor, Room 480, Toronto, ON M5G 2C4, Canada.

E-mail: jesse.mclaren@gmail.com

@jonesmcella, @PendellM, @smithECGBlog, @chartierlucas, @ECGcases

See page 639 for disclosure information.

https://doi.org/10.1016/j.cjco.2025.01.016

atypical symptoms had a longer door-to-electrocardiogram (ECG) time ($P < 0.0001$) and a longer ECG-to-catheterization time ($P < 0.001$). False-negative STEMI patients had a longer door-to-ECG time for atypical symptoms ($P < 0.0001$), a longer ECG-to-catheterization time for atypical symptoms ($P = 0.003$), and were aged ≥75 years ($P = 0.006$).

Conclusions: True-positive STEMI patients had delayed ECGs and catheterization for those presenting with atypical symptoms. More than half of those with OMI were admitted as non-STEMI patients, with further reperfusion delays for older patients and those presenting with atypical symptoms. Shifting to the OMI paradigm highlights reperfusion delays and equity gaps in the management of ACS.

Résultats : Sur 662 dossiers, 260 appartenaient à des patients ayant subi un IMO, 296 à des patients dont l'IM n'avait pas atteint le seuil de l'IMO (patients « non IMO ») et 106 à des patients chez qui l'IM avait été exclu. Parmi les 260 patients ayant subi un IMO, 116 ont été admis à l'hôpital en tant que patients « STEMI » (vrai positif) et 144 (55,4 %), en tant que patients « non STEMI » (faux négatif). Dans les analyses bivariées, le temps entre l'admission et l'électrocardiogramme (ECG) ($p < 0{,}0001$) et entre l'ECG et le cathétérisme ($p < 0{,}001$) a été plus long chez les patients « STEMI » vrai positif présentant des symptômes atypiques. Chez les patients « STEMI » faux négatif présentant des symptômes atypiques, le temps a également été plus long entre l'admission et l'ECG ($p < 0{,}0001$) et entre l'ECG et le cathétérisme ($p = 0{,}003$), de même que chez ceux âgés d'au moins 75 ans ($p = 0{,}006$).

Conclusions : L'ECG et le cathétérisme ont été pratiqués tardivement chez les patients « STEMI » vrai positif lorsqu'ils présentaient des symptômes atypiques. Plus de la moitié des patients ayant subi un IMO ont été admis en tant que patients « non STEMI », et les retards de reperfusion ont été encore plus importants chez les patients plus âgés et chez ceux qui présentaient des symptômes atypiques. Le passage au paradigme de l'IMO met en lumière les retards de reperfusion et les inégalités dans la prise en charge du syndrome coronarien aigu.

reperfusion within 90 minutes.[1] Patients with non-STEMI require angiography within 2 hours for very high-risk features, and angiography within 24 hours for high-risk features.[2]

Recognition is increasing of both the gaps in ACS care and the opportunities for its improvement. First, not all patients with STEMI receive timely diagnosis and reperfusion, and these delays disproportionately affect populations depending on age, sex, racial background, language, and income.[3] These equity gaps include receiving a less timely ECG,[4] being less likely to undergo angiography[5-8] and undergoing less timely reperfusion for both STEMI and non-STEMI.[9,10] Some of these gaps have been attributed to differences in presenting symptoms[11-13] highlighting the need to consider high-risk anginal equivalents.[14]

Secondly, not all patients with acute coronary occlusion meet STEMI criteria on ECG. At least one quarter of patients admitted who are considered to have non-STEMI have a completely occluded coronary artery (and one third have a Thrombolysis In Myocardial Infarction [TIMI] grade 0/1 flow), with delayed angiography and a higher incidence of mortality.[15,16] A recent meta-analysis of STEMI criteria found that the sensitivity for acute coronary occlusion for this group is only 43.6%.[17] Not only are these occlusions missed prospectively, but they are also missed in hindsight; in the STEMI paradigm, no false negatives occur (which we call "the no-false-negative paradox"). As we found previously, 14% of code STEMIs were false positives, and discharge diagnoses were changed to highlight this, but 32% of patients with non-STEMI had occlusion myocardial infarction (OMI), and yet discharge diagnoses for these patients with "non-STEMI" were not changed to highlight missed occlusions.[18]

A paradigm shift has been proposed—from STEMI to OMI[19]—to identify patients whose ECGs do not meet STEMI criteria but who have OMI. Citing this work, the new American College of Cardiology expert consensus on chest pain in the emergency department warns that application of the STEMI criteria "will miss a significant minority of patients with acute coronary occlusion."[20] Cardiologists and emergency physicians increasingly are calling for ACS to be reclassified by presence or absence of occlusion in the patient, rather than by STEMI criteria on the ECG.[21-25]

The OMI paradigm has not yet been studied through an equity lens. The literature on myocardial infarction equity gaps dichotomizes patients as having STEMI vs being non-STEMI, which does not address non-STEMI patients with OMI (false negatives). Quality-improvement initiatives that seek to reduce STEMI equity gaps[26-29] may overlook gaps among OMI patients who are admitted with a non-STEMI classification. Conversely, OMI studies have highlighted "non-STEMI" patients with occluded arteries, but they have not examined whether these false negatives disproportionately affect certain groups. The closing of equity gaps and the shifting of paradigms from STEMI to OMI might therefore go hand in hand.

We have found previously that STEMI criteria miss the majority of OMIs,[18] which is consistent with findings of a recent meta-analysis.[17] In the current study, we assess the impact of sociodemographic factors on the diagnosis (door-to-ECG time) and treatment (door-to-catherization time) of OMI patients in the ED, to identify any disproportionate delays in delivery of care.

Methods

Study design and population

A retrospective chart review was conducted for patients admitted to the ED from January 1, 2021 to December 31, 2022. We collected data from 2 large academic EDs—Toronto General Hospital and Toronto Western Hospital. Ethics approval was granted by the University Health Network Research Ethics Board for this study (ID# 23-5065).

We included all patients admitted to the 2 hospitals through the ED with an admission and/or discharge diagnosis of ACS (including STEMI, non-STEMI, and unstable angina). We considered both admission and discharge diagnoses of ACS to capture those patients whose diagnosis was clarified after their admission, but we excluded patients with non-ACS diagnoses who developed in-hospital MI (acute MI $>$ 24 hours after admission).[30] We excluded patients who were taken directly to the catheterization laboratory via paramedic services or other hospital transfers, because the primary outcomes (ED door-to-ECG time, and ED ECG-to-catheterization time) focus on the diagnosis and management of ACS in the ED and cannot be applied to direct admissions. We also excluded patients who died or left the hospital against medical advice prior to investigations, and patients considered to be in need of palliative care. Patients were also excluded if the available information was insufficient to classify them based on the OMI criteria as described below.

The included patients were categorized as having OMI, non-OMI (NOMI), or MI ruled out (MIRO). The diagnosis of OMI was based on the criteria used in prior studies,[17,28,31] and it included the presence of any one of the following: (i) acute culprit lesion with TIMI 0-2 flow; (ii) acute culprit lesion with TIMI 3 flow and a highly elevated troponin I level ($>$ 10,000 ng/L); or (iii) if no angiography was done, then a highly elevated troponin level with new or presumably new regional wall-motion abnormality on echocardiogram. The echocardiogram reports included comparison to prior echocardiogram results, to identify new regional wall-motion abnormalities; in cases in which no prior abnormalities existed, regional wall-motion abnormalities were considered new. The definition of "highly elevated" was based on levels that are highly predictive of total occlusion.[32] The diagnosis of NOMI was made for any type of acute MI (types 1-5 MI) that did not meet the OMI threshold. The MIRO classification was made if serial troponin levels were negative or did not rise beyond baseline. OMI patients were stratified further, into those who were admitted as STEMI patients (ie, true-positive STEMI) and those who were admitted as non-STEMI patients (ie, false-negative STEMI), based on the ED admission diagnosis.

Outcomes

The primary outcomes were median door-to-ECG time, median ECG-to-catherization time, and median door-to-catheterization times. Other outcomes were based on quality guidelines for timely diagnosis and intervention, including the proportion of patients who received an ECG within 10 minutes of arrival, and the proportion of patients who received cardiac catheterization within 90 minutes. We assessed differences in these outcomes within OMI patients by dichotomizing variables provided by the initial data request from medical records, as follows: chief complaint (chest pain and/or cardiac arrest vs atypical presentation); age ($<$ 75 years vs $\geq$ 75 years); sex (male vs female); language (first language English vs another first language); and income quintile (first quintile vs last quintile). The chief triage complaints, based on the main symptom entered by the triage nurse into the medical record, were dichotomized into chest pain or cardiac arrest vs all other symptoms considered to be atypical (eg, shortness of breath, abdominal pain, weakness). We then stratified OMI patients into those with true-positive STEMI and those with false-negative STEMI, based on whether the patient admission diagnosis was STEMI or not, and we analyzed the aforementioned differences in outcomes.

Data collection

Data were recorded in a standardized abstraction form using Excel (Microsoft, Redmond, WA). The initial data request from the hospital database gathered age, sex, first language, postal code, cardiac risk factors, ED chief complaint, arrival by ambulance, triage time, ED admission diagnosis, and hospital discharge diagnosis. Using postal codes, we obtained area-level income quintiles for each patient, based on publicly available national datasets.

The primary author (V.S.) then extracted the remaining data directly from patient charts, per training by the senior author (J.T.T.M.). We reviewed discharge summaries for the following factors: presence or absence of cardiac risk factors; laboratory values for first and peak troponin levels (high-sensitivity Troponin I; Alinity assay, Abbott Laboratories, Abbott Park, IL); coronary angiogram reports for presence or absence of culprit lesion and TIMI flow; and cardiac echocardiogram report for presence or absence of new regional wall-motion abnormality. Additionally, we noted the time stamps on the first ED ECG and the catheterization lab report (for patients who underwent coronary angiography) to calculate times for door to ECG, ECG to catheterization, and door to catheterization. Inter-rater reliability for OMI vs NOMI vs MIRO classification, based on Cohen's kappa test, was assessed by one author (M.E.-B.) who reviewed every 10th chart, blinded to the determination of the primary author (V.S.), and differences were resolved by a third author (J.T.T.M.).

Statistical analysis

We analyzed baseline sociodemographic characteristics and risk factors using descriptive statistics (percentages or medians with interquartile ranges). Similarly, we used descriptive statistics to report initial and peak troponin levels, automated ECG interpretation, echocardiogram and angiogram findings, and reperfusion therapy. To assess differences in outcomes by equity variables, we used bivariate analyses (χ^2 test) with a significance level set at 0.05.

Results

A total of 921 charts were retrieved based on inclusion criteria (Fig. 1). Prior to chart review, 83 patients were excluded because they were direct admissions, left the hospital against medical advice, or had a chart that was retrieved in error. We abstracted a total of 838 charts, of which 176 were excluded from the final study population for reasons that include insufficient information, in-hospital MI, death prior to investigations completed, and palliative care. We had a final total of 662 patients for our study population.

Table 1 illustrates the baseline characteristics of the included patients. The median age was 69.7 years, and 36.0%

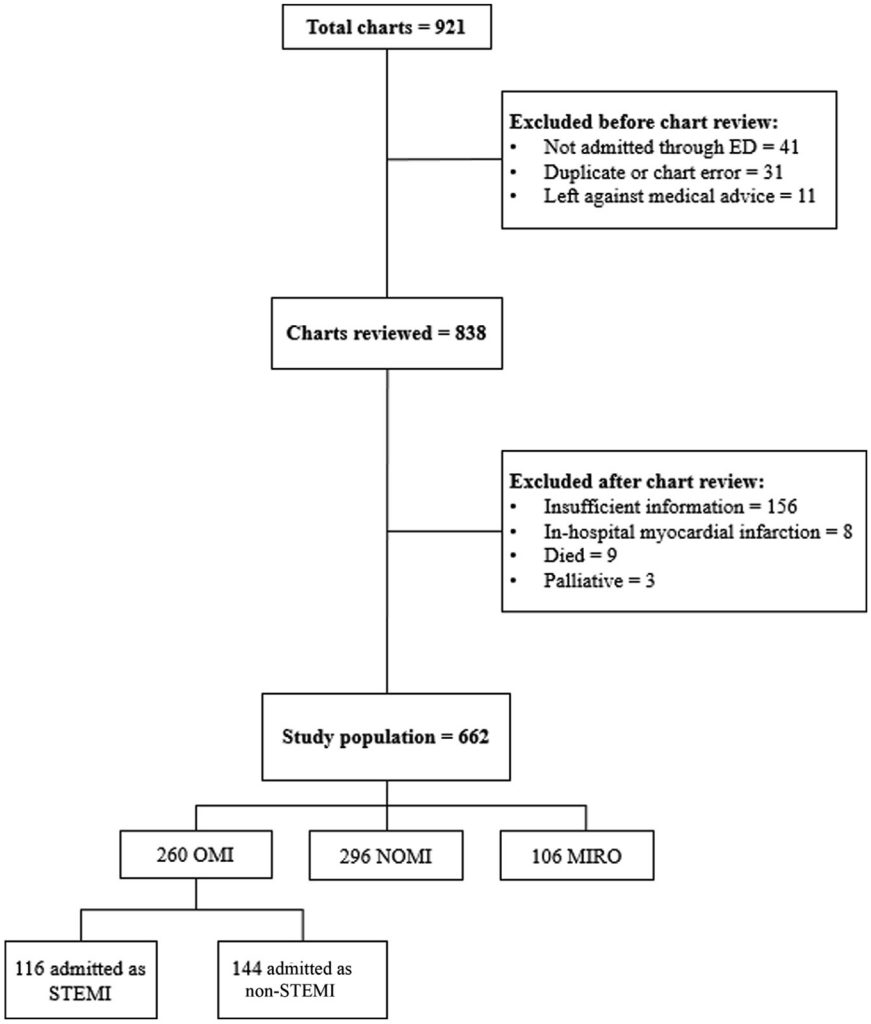

Figure 1. Study population. ED, emergency department; MIRO, myocardial infarction ruled out; NOMI, non-occlusion myocardial infarction; OMI, occlusion myocardial infarction; STEMI, ST-elevation myocardial infarction.

of the total sample of patients were female. Overall, the OMI group had a lower median age (66.9 vs 74.9 years) and a lower proportion of female patients (25.4% vs 47.6%), compared to patients with NOMI. Within OMI, those who were not admitted with classification as a STEMI patient (ie, false-negative patients) were more likely to have the cardiac risk factors of preexisting coronary artery disease, hypertension, and dyslipidemia, compared to those who were admitted as

Table 1. Baseline characteristics

Characteristic	All (n = 662)	OMI (n = 260)	STEMI (+) OMI / true-positive (n = 116)	STEMI (−) OMI / false- negative (n = 144)	NOMI (n = 296)	MIRO (n = 106)
Age, y	69.7 (59–80)	66.9 (56–78)	64.8 (54–75)	69.4 (57–80)	74.9 (63–85)	63.6 (53–73)
Female	238 (36.0)	66 (25.4)	32 (27.6)	34 (23.6)	141 (47.6)	31 (29.2)
English as first language	572 (86.4)	227 (87.3)	101 (87.1)	126 (87.5)	249 (84.1)	96 (90.6)
Highest income quintile	136 (20.5)	52 (20.0)	19 (16.4)	33 (22.9)	54 (18.2)	30 (28.3)
Lowest income quintile	145 (21.9)	65 (25.0)	28 (24.1)	37 (25.7)	67 (22.6)	13 (12.3)
CAD	274 (41.4)	89 (34.2)	28 (24.1)	61 (42.4)	119 (40.2)	66 (62.3)
DM	239 (36.1)	90 (34.6)	33 (28.4)	57 (39.6)	104 (35.1)	45 (42.5)
HTN	416 (62.8)	147 (56.5)	50 (43.1)	97 (67.4)	199 (67.2)	70 (66.0)
DLD	350 (52.9)	120 (46.2)	39 (33.6)	81 (56.3)	162 (54.7)	68 (64.2)
Smoker	142 (21.4)	78 (30.0)	35 (30.2)	43 (29.9)	43 (14.5)	21 (19.8)
CP/VSA	415 (62.7)	182 (70.0)	87 (75.0)	95 (66.0)	151 (51.0)	82 (77.4)
Arrived via EMS	304 (45.9)	113 (43.5)	53 (45.7)	60 (41.7)	166 (56.1)	25 (23.7)

Values are n (%) or median (interquartile range).

CAD, coronary artery disease; CP, chest pain; DLD, dyslipidemia; DM, diabetes mellitus; EMS, emergency medical services; HTN, hypertension; MI, myocardial infarction; MIRO, MI ruled out; NOMI, non-occlusion MI; OMI, occlusion MI; STEMI, ST-elevation MI; VSA, vital signs absent.

non-STEMI patients (all $P < 0.05$). Patients with false-negative STEMI classification were also more likely to present with atypical symptoms, compared with those of true-positive STEMI patients, although this trend was not statistically significant ($P = 0.15$).

The classification of patients as OMI, NOMI, and MIRO was based on the coronary angiograms, troponin levels, and echocardiograms (Table 2). Inter-rater agreement for classification was 0.942 (95% confidence interval [CI] 0.863-1). Of the 662 patients, 260 were classified as OMI patients, 296 as NOMI patients, and 106 as MIRO patients. Of the 260 OMI patients, 116 were admitted to the hospital as STEMI patients (44.6% true-positive) and 144 were admitted as non-STEMI patients (55.4% false-negative). The MIRO group had higher rates of angiography and/or reperfusion than the NOMI group, because the former included both false-positive STEMI patients (angiography without reperfusion) and patients with unstable angina from coronary artery disease (angiography with stent or coronary artery bypass grafting), whereas the latter included those admitted as non-STEMI patients with an identifiable cause of demand ischemia not requiring angiography (eg, tachyarrhythmia, sepsis, anemia) or a type 2 MI found on angiography not requiring reperfusion (eg, takotsubo syndrome, myocarditis, vasospasm, coronary artery dissection).

Table 3 illustrates the diagnosis and treatment outcomes, and the ACS quality standard outcomes, for the patient population. For all patients with OMI, the median door-to-catheterization time was 521 minutes, with those admitted as STEMI patients (true-positive) having significantly shorter times (90 vs 1690 minutes, $P < 0.0001$) and being more likely to have a coronary angiogram within 90 minutes (49.1% vs 0.9%, $P < 0.0001$) than the patients with false-negative STEMI. These reflected differences in both diagnosis and treatment times. The median door-to-ECG time for all OMI patients was 18 minutes, but true-positive STEMI patients had significantly shorter door-to-ECG times (10 vs 24 minutes, $P < 0.0001$) and were also more likely than false-negative STEMI patients to receive an ECG within 10 minutes of arrival to the ED (49.1% vs 30.0%, $P = 0.002$). Similarly, true-positive STEMI patients had shorter ECG-to-catheterization times (71 vs 1608 minutes, $P < 0.0001$). No difference occurred between true-positive vs false-negative STEMI patients in terms of their arrival by ambulance ($P = 0.52$). Tables 4 and 5 show equity gaps from bivariate analyses for OMI patients stratified as admitted as STEMI patients (true-positive) and those admitted as non-STEMI patients (false-negative), respectively.

Among true positive patients (Table 4), those with atypical symptoms experienced longer door-to-catheterization times (151 vs 78.5 minutes, $P < 0.0001$), and they were less likely to receive catheterization within 90 minutes (25% vs 60%, $P = 0.002$). This difference reflected longer door-to-ECG times (36 vs 8 minutes, $P = 0.0001$) and longer ECG-to-catheterization times (117 vs 66 minutes, $P = 0.0001$). Patients who were less likely to have an ECG within 10 minutes included both those with atypical symptoms (21% vs 58%, $P = 0.0007$) and those with age > 75 years (18% vs 37%, $P = 0.003$). Differences for other equity variables did not reach the level of statistical significance.

Table 2. Classification of patients by occlusion myocardial infarction (OMI), non-occlusion MI (NOMI), and MI ruled out (MIRO)

Classification criteria	All (n = 662)	OMI (n = 260)	STEMI (+) OMI / true-positive (n = 116)	STEMI (−) OMI / false-negative (n = 144)	NOMI (n = 296)	MIRO (n = 106)
Coronary angiogram	497 of 662 (75.1)	245 of 260 (94.2)	113 of 116 (97.4)	132 of 144 (91.7)	165 of 296 (55.7)	87 of 106 (82.1)
PCI/CABG	336 of 662 (50.8)	234 of 260 (90.0)	110 of 116 (94.8)	124 of 144 (86.1)	50 of 296 (16.9)	52 of 106 (49.1)
First troponin, ng/L	170 (23 − 1437)	556 (62−4608)	443 (35−7044)	790 (99−3676)	202 (51−1156)	4 (2−9)
Peak troponin, ng/L	2533 (192 − 14,330)	19463 (9806−57,186)	43,283 (14,804−100,758)	13,328 (4940−32,935)	1228.5 (289−3607)	7 (3−17)
Echocardiogram performed	620 of 662 (93.7)	248 of 260 (95.4)	110 of 116 (94.8)	138 of 144 (95.8)	279 of 296 (94.3)	93 of 106 (87.7)
New RWMA on echocardiogram	288 of 620 (46.5)	194 of 248 (78.2)	100 of 110 (90.9)	94 of 138 (68.1)	89 of 279 (31.9)	5 of 93 (5.4)

Values are n (%) or median (interquartile range).

CABG, coronary artery bypass grafting; MI, myocardial infarction; PCI, percutaneous coronary intervention; RWMA, regional wall-motion abnormality; STEMI, ST-elevation myocardial infarction.

Table 3. Outcomes for patients with occlusion myocardial infarction (OMI), non-occlusion MI (NOMI), and MI ruled out (MIRO)

Outcomes	All (n = 662)	OMI (n = 260)	STEMI (+) OMI / True Positive (n = 116)	STEMI (-) OMI / False Negative (n = 144)	NOMI (n = 296)	MIRO (n = 106)
Door-to-ECG time, min	26 (9–55)	18 (6–39)	10 (4–28)	24 (8–47)	35 (16–70)	23 (8–54)
ECG-to-cath time, min	1536 (228–3429)	484 (73.25–1927)	71 (55–137)	1608 (981–3842)	2738 (1371–4288)	2662 (1243–4627)
Door-to-cath time, min	1591 (255–3536)	521 (93–2023)	90 (60–159)	1690 (1000–3927)	2782 (1393–4386)	2874 (12645200)
Door-to-ECG time < 10 min	177 of 648 (27.3)	97 of 252 (38.5)	55 of 113 (48.7)	42 of 141 (29.8)	46 of 293 (15.7)	34 of 101 (33.6)
Door-to-cath time < 90 min	72 of 496 (14.5)	58 of 245 (23.7)	57 of 113 (50.4)	1 of 132 (0.8)	5 of 165 (3.0)	9 of 86 (10.5)

Values are n (%) or median (interquartile range).

ECG, electrocardiogram; cath, catheterization; MI, myocardial infarction; STEMI, ST-elevation MI.

Among the false-negative patients (Table 5), longer door-to-catheterization times occurred for those who were elderly (2135 vs 1571 minutes, $P = 0.01$) and those who had atypical symptoms (2170 vs 1571 minutes, $P = 0.0008$). This difference reflected longer door-to-ECG times for elderly patients (42 vs 18 minutes, $P < 0.0001$) and longer ECG-to-catheterization times for elderly patients (2110 vs 1489 minutes, $P = 0.006$) and those with atypical symptoms (2110 vs 1466, $P = 0.003$). Those less likely to have an ECG within 10 minus included elderly patients (18% vs 36%, $P = 0.02$) and those with atypical symptoms (11% vs 40%, $P = 0.0004$). Differences for other equity variables did not reach the level of statistical significance.

Discussion

Our study examined equity gaps in the diagnosis and treatment of MIs through the OMI paradigm, an emerging framework that seeks to identify patients with occluded coronary arteries who may be missed by the current STEMI paradigm.

For true-positive STEMI patients, we found a median door-to-ECG time of 10 minutes, and a door-to-catherization time of 89.5 minutes, indicating that at least 50% of patients met quality benchmarks. The high peak troponin level of true-positive STEMI patients therefore does not appear to be linked to treatment delay but rather could indicate infarct severity or early troponin release from rapid reperfusion.[32] However, patients with atypical symptoms were significantly less likely to meet such benchmarks. An unsurprising finding is that these patients experienced a delay in door-to-ECG time; but we also found that such patients had a delay in ECG-to-catheterization time. This delay could disproportionately affect high-risk patients who are more likely to present with atypical symptoms, including the elderly and those with cardiac risk factors.[14] Although we did not find any differences in the median door-to-ECG time, we did find that those aged > 75 years were less likely to have an ECG within 10 minutes. Focusing on the proportion of patients who meet this quality metric, rather than the median door-to-ECG time, has been shown to reveal a greater proportion of patients who face inequities.[4] We did not find other equity gaps related to sex and language, as others have found for true-positive STEMI cases,[4] and this finding is a positive. Some studies have suggested that differences in age and symptom presentation may explain the sex gap.[13]

Even greater diagnostic and treatment delays occurred for the 55.4% of OMI patients who were admitted with a non-STEMI classification, which was further exacerbated by equity gaps. Patients with cardiac risk factors and those with atypical symptoms, who are at higher risk, were less likely to be admitted as STEMI patients. False-negative STEMI

Table 4. Equity gaps in management of patients with occlusion myocardial infarction admitted with an ST-elevation myocardial infarction classification (true-positive, n = 116)

Comparison	Door-to-ECG time, min	ECG-to-cath time, min	Door-to-cath time, min	ACS quality standards: Door-to-ECG time < 10 min	ACS quality standards: Door-to-cath time < 90 min
Chief complaint					
Atypical symptoms	36 (2–19)*	117 (66–215)*	151 (121–303)*	6 of 28 (21.4)*	7 of 28 (25.0)*
CP/VSA	8 (14–89)*	66 (54–111)*	79 (53–90)*	49 of 84 (58.3)*	50 of 84 (59.5)*
Age, y					
≥ 75	17 (7–60)	90 (60–170)	108 (71–179)	10 of 31 (32.3)*	13 of 30 (43.3)
< 75	9 (2–26)	68 (55–127)	88 (58–151)	45 of 81 (55.6)*	44 of 82 (53.7)
Sex					
Female	12 (5–33)	81 (59–143)	94 (70–175)	14 of 30 (46.7)	14 of 30 (46.7)
Male	10 (2–27)	69 (54–137)	88 (58–151)	41 of 82 (50.0)	43 of 82 (52.4)
Income quintile					
Lowest	19 (5–51)	87 (62–148)	110 (73–209)	10 of 27 (37.0)	11 of 27 (40.7)
Highest	7 (1–26)	63 (53–112)	70 (47–119)	11 of 19 (57.9)	12 of 19 (63.2)
Language					
Non-English	13 (7–56)	71 (62–284)	92 (67 –251)	6 of 12 (50.0)	6 of 12 (50.0)
English	10 (2–27)	71 (54–137)	89 (56–151)	49 of 98 (50.0)	51 of 99 (51.5)

Values are n (%) or median (interquartile range).

ACS, acute coronary syndrome; cath, catheterization; CP, chest pain; ECG, electrocardiogram; VSA, vital signs absent.

* < 0.05 based on χ^2 test.

Table 5. Equity gaps in management of patients with occlusion myocardial infarction admitted as with a non-ST-segment myocardial infarction classification (false-negative, n = 144)

Comparison	Door-to-ECG time, min	ECG-to-cath time, min	Door-to-cath time, min	ACS Quality Standards	
				Door-to-ECG time < 10 min	Door-to-cath time < 90 min
Chief complaint					
Atypical	42 (20−111)*	2110 (1315−4754)*	2170 (1357−5139)*	5 of 47 (10.6)*	0 of 38 (0)
CP/VSA	18 (6−34)*	1466 (821−3624)*	1571 (858−3413)*	37 of 93 (39.8)*	1 of 94 (0.01)
Age, y					
≥ 75	28 (15−52)	2110 (1342−4413)*	2135 (1398−4417)	9 of 50 (18.0)*	0 of 42 (0)
< 75	20 (6−40)	1489 (850−3335)*	1571 (887−3523)	33 of 90 (36.7)*	1 of 90 (0.01)
Sex					
Female	24 (8−48)	2031 (1359−4413)	2157 (1359−4417)	9 of 33 (27.3)	0 of 29 (0)
Male	22 (7−46)	1575 (865−3456)	1661 (894−3523)	33 of 107 (30.8)	1 of 103 (0.01)
Income quintile					
Lowest	19 (6−48)	1770 (907−3695)	1888 (976−3715)	13 of 36 (36.1)	0 of 0 (0)
Highest	20 (6−37)	1260 (906−2655)	1289 (943−3174)	11 of 31 (35.5)	0 of 0 (0)
Language					
Non-English	22 (8−56)	1709 (1129−3892)	1717 (1154−3979)	11 of 29 (37.9)	0 of 15 (0)
English	24 (7−45)	1586 (981−3842)	1671 (1000−3927)	86 of 220 (39.1)	1 of 116 (0.01)

Values are n (%) or median (interquartile range).

ACS, acute coronary syndrome; cath, catheterizaion; CP, chest pain; ECG, electrocardiogram; VSA, vital signs absent.

* < 0.05 based on χ^2 test.

patients had a greater door-to-ECG time and ECG-to-catheterization time, and they were less likely to meet the quality metrics of ECG within 10 minutes, or catheterization within 90 minutes. This finding was not related to any difference in mode of arrival.

Within the group of patients with false-negative STEMI classifications, those with atypical symptoms and those aged > 75 years experienced further delays in receipt of ECG and catheterization. This finding suggests not only that more than half of OMI patients are missed by the STEMI criteria, but also that they face additional delays based on their age and symptoms. Older patients are more likely to present with atypical symptoms, such as gastrointestinal or general weakness complaints, leading to delayed recognition of ACS.[33,34] However, we noted that OMI patients admitted as STEMI patients did not differ in age, whereas OMI patients admitted as non-STEMI patients did differ in age. This finding may indicate that age may play a role in delays to catheterization that is independent of atypical presentation, particularly in these OMI patients who are missed by the current STEMI paradigm. By moving to the OMI paradigm, we may be able to more accurately identify these "false-negative" patients and reduce both reperfusion delays and equity gaps in the management of ACS.

Limitations

Given that this study was a retrospective chart review, it was subject to inherent limitations associated with the study design. These limitations include missing and/or insufficient information, resulting in the exclusion of 156 patients. Full angiographic information, including TIMI flow, is required to adjudicate the patient outcome of OMI vs NOMI. For example, although an acute culprit lesion with a peak troponin level of 20,000 ng/L would be classified as OMI, regardless of the TIMI flow at the time of the angiogram, an acute culprit lesion with a peak troponin of 4000 ng/L would be classified as OMI vs NOMI depending on the TIMI flow (OMI if reduced flow and NOMI if normal flow). Therefore, the latter would be excluded if TIMI flow data were missing. Despite the limitations from these exclusions, the resulting dataset is more patient-centred, rather than being reliant on admission or discharge diagnoses of STEMI and non-STEMI.

Despite the inclusion of patients from 2 large hospitals over a 2-year period, upon stratification into OMI vs NOMI categories, and further subdivision into the OMI groups "true positive" and "false negative," the sample sizes for each subgroup ultimately were small. The small sizes of the samples limited the ability to conduct multivariable regression analyses, to adjust for confounding; they also limited the power of our study. Possibly, equity gaps were present that we were unable to detect. Future larger studies may uncover further equity gaps among OMI patients, and multivariable analysis on a larger dataset may help to explore the relationships among multiple equity factors (age, sex, language, income), symptoms, and treatment delays.

Additionally, our study was conducted across 2 academic hospitals, which may affect the variability of the sample population and the ability to extrapolate to populations served by community hospitals. We also chose to dichotomize the age and income variables, to match the other binary variables, which may have led to a loss of variability in the age and income data.

Conclusion

In summary, our study examined equity gaps in ACS management using the OMI framework. We discovered that older patients with OMI were less likely to meet the quality metric of a 10-minute door-to-ECG time. Further, OMI patients not admitted as STEMI faced catheterization delays, particularly owing to their age, with older patients experiencing longer door-to-catheterization times. Shifting to the OMI paradigm from the STEMI framework highlights these reperfusion delays and the equity gaps in the management of ACS.

Ethics Statement

Ethics approval was granted by the University Health Network Research Ethics Board for this study (ID# 23-5065).

Patient Consent

The authors confirm that patient consent is not applicable to this article. This is a retrospective study using de-identified data; therefore, the institutional review board did not require consent from the patients.

Funding Sources

This study was funded by University Health Network Emergency Department's Summer Training And Research in Emergency Medicine (STAR-EM): https://www.uhnemresearch.com/programs-1.

Disclosures

H.P.-M. reports being a paid consultant to Rapid AI and Baxter/Veritas, and holding stock in Powerful Medical. S.W.S. reports receiving personal fees from Cardiologs, HEARTBEAM, Rapid AI, and Baxter/Veritas, and holding stock in Powerful Medical and Pulse AI. The other authors have no conflicts of interest to disclose.

References

1. O'Gara PT, Kushner FG, Ascheim DD, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation 2013;127:e362-425.
2. Amsterdam EA, Winger NK, Brindis RG, et al. 2014 AHA/ACC guideline for the management of patients with non—ST-elevation acute coronary syndromes: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2014;64:e139-228.
3. Rashid S, Simms A, Batin P, Kurian J, Gale CP. Inequalities in care in patients with acute myocardial infarction. World J Cardiol 2015;7:895-901.
4. Yiadom MYAM, Gong W, Patterson BW, et al. Fallacy of median door-to-ECG time: hidden opportunities for STEMI screening improvement. J Am Heart Assoc 2022;11:e024067.
5. Moledina A, Tang KL. Socioeconomic status, mortality, and access to cardiac services after acute myocardial infarction in Canada: a systematic review and meta-analysis. CJC Open 2021;3:950-64.
6. Shroder SL, Richter M, Shroder J, et al. Socioeconomic inequalities in access to treatment for coronary heart disease: a systematic review. Int J Cardiol 2016;219:70-8.
7. Casale SN, Auster CJ, Wolf F, Pei Y, Devereux RB. Ethnicity and socioeconomic status influence use of primary angioplasty in patients presenting with acute myocardial infarction. Am Heart J 2007;154:989-93.
8. Calmac L, Bataila V, Ricci B, et al. Factors associated with use of percutaneous coronary intervention among elderly patients presenting with ST segment elevation acute myocardial infarction (STEMI): results from the ISACS-TC registry. Int J Cardiol 2016;Suppl 217:S21-6.
9. Montoy JCC, Shen YC, Hsia RY. Trends in inequities in the treatment of and outcomes for women and minorities with myocardial infarction. Ann Emerg Med 2022;80:108-17.
10. Pacheco C, Boivin-Proulx LA, Bastiany A, et al. Impact of STEMI diagnosis and catheterization laboratory activation systems on sex- and age-based differences in treatment delay. CJC Open 2021;3:P723-32.
11. Berger JS, Elliot L, Gallup D, et al. Sex differences in mortality following acute coronary syndromes. JAMA 2009;302:874-82.
12. Dey S, Flather MD, Devlin G, et al. Sex-related differences in the presentation, treatment and outcomes among patients with acute coronary syndromes: the Global Registry of Acute Coronary Events. Heart 2009;95:20-6.
13. Canto JG, Rogers WJ, Goldberg RJ, et al. Association of age and sex with myocardial infarction symptom presentation and in-hospital mortality. JAMA 2012;307:813-22.
14. Brieger D, Eagle KA, Goodman SG, et al. Acute coronary syndromes without chest pain, an underdiagnosed and undertreated high-risk group. Chest 2004;126:561-9.
15. Khan AR, Golwala H, Tripathi A, et al. Impact of total occlusion of culprit artery in acute non-ST elevation myocardial infarction: a systematic review and meta-analysis. Eur Heart J 2017;38:3082-9.
16. Hung CS, Chen YH, Huang CC, et al. Prevalence and outcome of patients with non-ST segment elevation myocardial infarction with occluded "culprit" artery—a systemic review and meta-analysis. Crit Care 2018;22:34.
17. De Alencar JN, Sheffer MK, Correia BP, et al. Systematic review and meta-analysis of diagnostic test accuracy of ST-segment elevation for acute coronary occlusion. Int J Cardiol 2024;402:131889.
18. McLaren JTT, El-Baba M, Sivashanmugathas V, et al. Missing occlusions: quality gaps for ED patients with occlusion MI. Am J Emerg Med 2023;73:47-54.
19. Meyers HP, Bracey A, Lee D, et al. Comparison of the ST elevation myocardial infarction (STEMI) vs. NSTEMI and occlusion MI (OMI) vs. NOMI paradigms of acute MI. J Emerg Med 2021;60:273-84.
20. Kontos MC, de Lemos JA, Deitelzweig SB, et al. 2022 ACC expert consensus decision pathway on the evaluation and disposition of acute chest pain in the emergency department: a report of the American College of Cardiology Solution Set Oversight Committee. J Am Coll Cardiol 2022;80:1925-60.
21. Tziakis D, Chalikias G, Al-Lamee R, Kaski JC. Total coronary occlusion in non ST elevation myocardial infarction: time to change our practice? Int J Cardiol 2021;329:1-8.
22. Sankardas MA, Ramakumar V, Farooqui FA. Of occlusions, inclusions, and exclusions-time to reclassify infarctions? Circulation 2021;144:333-5.
23. Zoni CR, Mukherjee D, Gulati M. Proposed new classification for acute coronary syndrome: acute coronary syndrome requiring immediate reperfusion. Catheter Cardiovasc Interv 2023;101:1177-81.
24. Avdikos GMichas G, Smith SW. From Q/non-Q myocardial infarction to STEMI/NSTEMI: Why it's time to consider another simplified dichotomy; a narrative literature review. Arch Acad Emerg Med 2022;10:e78.
25. McLaren JTT, de Alencar JN, Aslanger EK, Meyers HP, Smith SW. From ST-segment elevation MIO to occlusion MI: the new paradigm shift in acute myocardial infarction. JACC Adv 2024;3:101314.

26. Saban M, Shachar T, Salama R, Darawsha A. Improving STEMI management in the emergency department: examining the role of minority groups and sociodemographic characteristics. Am J Emerg Med 2020;38:1102-9.

27. Huded CP, Dalton JE, Kumar A, Krieger N. Relationship of neighborhood deprivation and outcomes of a comprehensive ST-segment–elevation myocardial infarction protocol. J Am Heart Assoc 2021;10:e024540.

28. Hsia RY, Krumholz H, Shen YC. Evaluation of STEMI regionalization on access, treatment, and outcomes among adults living in nonminority and minority communities. JAMA Netw Open 2020;3:e2025874.

29. Jaffer S, Noble M, Pozgay A, et al. The development of a chest-pain protocol for women presenting to the emergency department. CJC Open 2023;6:517-29.

30. Bradley SM, Borgerding JA, Wood GB, Maynard C, Fihn SD. Incidence, risk factors, and outcomes associated with in-hospital acute myocardial infarction. JAMA Netw Open 2019;2:e187348.

31. Meyers HP, Bracey A, Lee D, et al. Accuracy of OMI ECG findings versus STEMI criteria for diagnosis of acute coronary occlusion myocardial infarction. Int J Cardiol Heart Vasc 2021;33:100767.

32. Hallen J, Buser P, Schwitter J, et al. Relation of cardiac troponin I measurement at 24 and 48 hours to magnetic resonance-determined infarct size in patients with ST-elevation myocardial infarction. Am J Cardiol 2009;104:1472-7.

33. Grosmaitre P, Le Vavasseur O, Yachouh E, et al. Significance of atypical symptoms for the diagnosis and management of myocardial infarction in elderly patients admitted to emergency departments. Arch Cardiovasc Dis 2013;106:586-92.

34. Taylor TG, Stickney RE, French WJ, et al. Prehospital predictors of atypical STEMI symptoms. Prehosp Emerg Care 2022;26:756-63.