Risk profile and prognosis of myocardial infarction in young adults: a comparative study

Sofiene Haboubi[1,2]*, Meriem Ghozzia[1,2], Elyes Lagha[1,2], Mohamed Amine Soula[1,2], Rami Tlili[1,2], Meriam Drissa[1,2], Youssef Ben Ameur[1,2]

Abstract

Myocardial infarction in young adults is increasingly recognised as a distinct clinical entity, with limited data from North African populations. This study aimed to compare risk profiles and outcomes of ST-segment elevation myocardial infarction (STEMI) between young and older patients.

Methods: We conducted a retrospective comparative study including patients who experienced a first STEMI. Patients were stratified into two groups based on an age of 50 years. All data were analysed from medical records, and follow-up was a minimum of 12 months. The primary endpoint was cardiovascular mortality, and the secondary endpoint included a composite of non-fatal myocardial infarction, hospitalisation for acute heart failure and stent thrombosis or restenosis.

Results: Among 206 patients included, younger patients had higher rates of smoking (84.9% vs 60%, $p < 0.05$), chronic heavy alcohol use (30.2% vs 7%, $p < 0.05$) and family history of coronary artery disease (22.6% vs 7%, $p < 0.05$). Cardiovascular mortality was higher in older patients (11% vs 0.9%, $p < 0.01$), whereas the incidence of cardiovascular events was similar between the two groups (25.5% vs 26%, $p = 0.96$).

Conclusion: Young STEMI patients have a significant risk of adverse outcomes despite distinct risk profiles, warranting targeted strategies.

Keywords

myocardial infarction, coronary artery disease, young adults, atherosclerosis

Introduction

Myocardial infarction (MI) remains one of the leading causes of morbidity and mortality worldwide, with an increasing incidence among younger individuals, especially in developing countries [1,2]. Despite major advances in reperfusion strategies and secondary prevention, ST-segment elevation myocardial infarction (STEMI) continues to be associated with substantial short- and long-term morbidity and mortality. Young adults account for a substantial proportion of MI hospitalisations in these regions, raising concern regarding long-term outcomes and the associated socioeconomic burden.

Although risk factor profiles, clinical presentations and outcomes may differ between young and older patients with MI, contemporary data on young patients, particularly in North African populations, remain scarce [2]. Furthermore, the pathophysiology of MI in younger individuals is often multifactorial, involving a higher prevalence of modifiable lifestyle-related factors and a greater contribution of non-atherosclerotic mechanisms compared with older patients.

This study aimed to characterise the clinical and angiographic profiles, management, outcomes and determinants of STEMI in young Tunisian patients compared with older patients and to assess whether these differences support a distinct clinical profile requiring tailored preventive and therapeutic strategies.

*Corresponding author: Sofiene Haboubi; E-mail address: habsof01@gmail.com

[1]Department of Cardiology, Mongi Slim Hospital, La Marsa 2070, Tunisia
[2]Faculty of Medicine of Tunis, University of Tunis El Manar, Tunis 1007, Tunisia

Patients and Methods

1. Study population

This retrospective monocentric comparative study included consecutive patients admitted with a first STEMI within 48 hr of symptom onset between January 2020 and January 2024. All patients underwent percutaneous coronary intervention (PCI) during the index hospitalisation (primary PCI, rescue PCI or following successful thrombolysis) and were followed for a minimum of 12 months.

Patients were stratified according to age: >50 years and ≤50 years. Age thresholds used to define 'young' in cardiovascular disease are inconsistent, typically set at ≤45 years and extended to ≤55 years in studies focusing on women [3]. In light of recent data showing an increase in MI hospitalisations among women <50 years, unlike men of similar age, we defined young patients as ≤50 years, irrespective of sex.

Exclusion criteria included prior known coronary artery disease (CAD), presentation with non-ST-segment elevation myocardial infarction (NSTEMI), known cardiomyopathy or reduced left ventricular ejection fraction (LVEF) ≤40%, a final retained diagnosis of myocarditis during hospitalisation, advanced chronic kidney disease (eGFR <30 mL/min) and active malignancy with life expectancy <6 months [1,4].

This study was conducted in accordance with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines.

2. Data collection at presentation

Clinical records, including physician notes, laboratory tests, imaging studies, procedural results and discharge summaries, were reviewed.

Cardiovascular risk factors were defined as follows: family history of premature CAD (first-degree relative <55 years in men, <60 years in women); diabetes mellitus (prior diagnosis, HbA1c ≥6.5%, fasting glucose ≥7.0 mmol/L or on treatment); hypertension (≥140/90 mmHg, prior diagnosis or on treatment); dyslipidaemia (prior diagnosis, lipid-lowering therapy or abnormal lipid profile); obesity (BMI ≥30 kg/m²); active smoking (within 12 months); substance use (cannabis or cocaine) and chronic heavy alcohol use (CHAU) (>14 units/week in women and >21 units/week in men). A history of cerebrovascular accident and chronic kidney disease (eGFR <60 mL/min/1.73 m² for ≥3 months) was also recorded [4].

Baseline clinical presentation included infarct territory, haemodynamic status and acute complications [1,4].

3. Angiographic findings and treatment

Angiographic data were prospectively collected using CardioReport software. Coronary flow was assessed according to the thrombolysis in myocardial infarction (TIMI) classification. Significant coronary stenosis was defined as ≥70% luminal narrowing in major epicardial vessels or ≥50% in the left main coronary artery [4]. The infarct-related artery (IRA) and extent of vessel disease were determined from angiographic analysis.

In accordance with STEMI guidelines, all patients received loading doses of aspirin (300 mg) and a P2Y12 inhibitor (clopidogrel 300–600 mg or ticagrelor 180 mg), along with unfractionated heparin (50–70 U/kg) following STEMI confirmation [4]. PCI strategy was recorded as either stent implantation or a stentless conservative approach for culprit lesion management. Stents were classified as bare-metal or drug-eluting stents [1,4]. The use of glycoprotein IIb/IIIa inhibitors and aspiration thrombectomy was left to operator discretion, mainly in cases of high thrombus burden or as bail-out therapy [1,4].

Procedural success was defined as residual stenosis <30% with restoration of TIMI 3 flow [1]. In patients with post-PCI reduced LVEF ≤ 40%, guideline-directed medical therapy for heart failure was initiated according to current recommendations [5].

4. Follow-up

Early follow-up included in-hospital and 30-day outcomes, with assessment of adverse events including contrast-induced nephropathy (CIN), acute heart failure (AHF), stent thrombosis and cardiovascular mortality [4].

Patients were followed through outpatient visits or telephone contact. Follow-up assessments included symptom recurrence, functional status and clinical events including AHF, as well as major adverse cardiovascular events (MACE), defined as death, non-fatal stroke and non-fatal MI [6].

5. Study endpoints

The primary endpoint of the study was early and long-term cardiovascular mortality. Early mortality was defined as in-hospital and 30-day mortality , as long-term cardiovascular mortality was recorded during follow-up. Death was regarded as cardiac unless an unequivocal non-cardiac cause of death was established [6].

The secondary endpoint was a composite of hospitalisation for non-fatal MI, hospitalisation for AHF, stent thrombosis or in-stent restenosis at the target lesion or any stented coronary segment [6].

6. Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics (version 22.0). Continuous variables were compared using Student's *t* test or the Mann–Whitney *U* test, as appropriate. Categorical variables were analysed using the χ^2 test or Fisher's exact test. Factors associated with younger age among STEMI patients were assessed using logistic regression analysis, with results expressed as odds ratios (OR) and 95% confidence intervals (95% CIs). Cardiovascular mortality was analysed using Kaplan–Meier survival curves and compared between groups using the log-rank test. Cox proportional hazards models were constructed to evaluate the association between selected baseline variables and cardiovascular mortality. Multivariable models included clinically relevant covariates. Results are reported as hazard ratios (HR) with 95% CIs.

For the secondary composite endpoint, time-to-event analyses were based on the time to first occurrence of any component event. All tests were two-sided, and statistical significance was set at $p < 0.05$.

7. Ethics statement

This study adhered to the ethical principles set forth by the institutional ethics committee of Mongi Slim Hospital and complied with the Declaration of Helsinki.

Results

1. Baseline characteristics and risk factors

A total of 206 patients were enrolled, including 100 patients in Group 1 (G1) and 106 patients in Group 2 (G2) (Figure 1).

The mean age was 52.8 ± 11.6 years, with a predominance of males (82.5%) and a higher proportion of females in the older group. Smoking (72.8%), diabetes mellitus (49%) and hypertension (31.1%) were the most common cardiovascular risk factors. In older patients, diabetes (58%) and hypertension (39%) were more frequent. In contrast, younger patients exhibited higher rates of smoking (84.9%) and family history of CAD (22.6%). Lifestyle-related exposures were also more prominent in the younger group, including CHAU (30.2%) and cannabis use (11.3%).

All baseline characteristics are summarised in Table 1.

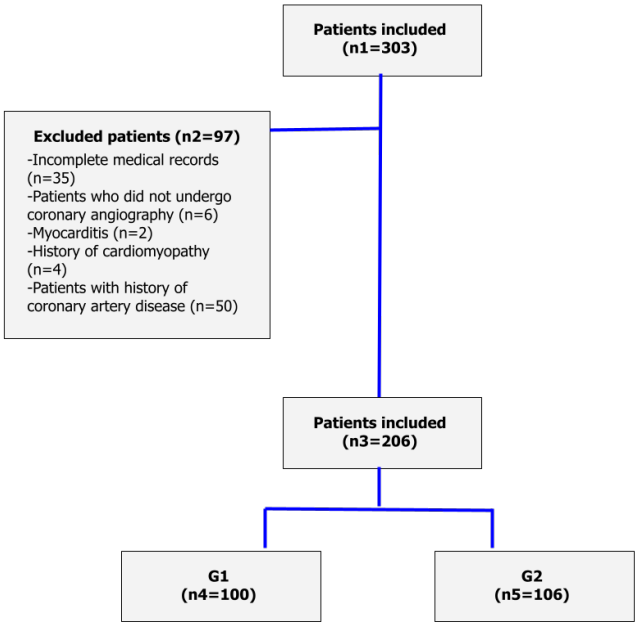

Figure 1 - Study flowchart. A total of 303 patients were initially screened for eligibility. Of these, 97 were excluded based on the predefined exclusion criteria. The final study population comprised 206 patients, stratified according to age into two groups: 100 patients in the older STEMI group (G1, age >50 years) and 106 patients in the younger STEMI group (G2, age ≤50 years). STEMI, ST-segment elevation myocardial infarction.

2. Clinical presentation

Most patients presented with ongoing (<12 hr) STEMI, accounting for 74.8% of the population, while 25.2% had subacute presentation (12–48 h). Time from symptom onset to first medical contact was shorter in younger patients compared with older patients (8.78 ± 12.25 vs 12.72 ± 14.62, $p < 0.05$). Anterior MI was the most common presentation in both groups (43% vs 44.3%, $p = 0.57$). AHF occurred at similar rates (20% vs 21.7%, $p = 0.76$). Cardiogenic shock (CS) requiring inotropic support was more frequent in older patients (11% vs 6.6%, $p = 0.25$), although the difference did not reach statistical significance (Table 2). The prevalence of reduced LVEF at initial evaluation was comparable between groups (34% vs 31.1%, $p = 0.89$). No significant difference was observed in low-density lipoprotein cholesterol (LDL-C) levels. Etiological investigations revealed prothrombotic conditions exclusively in the younger group, including two cases of hyperhomocysteinaemia, two cases of thrombophilia and one case of antiphospholipid syndrome (Table 2).

3. Angiographic findings and treatment

Angiographic findings and therapeutics are described in Table 3.

Primary PCI was performed in 62.6% of patients, with TIMI 0 flow observed in 34.5% before revascularisation. The left anterior descending coronary artery (LAD) was the most frequent culprit artery in both groups (44% vs 49.1%, $p = 0.45$), followed by the right coronary artery (RCA) (36% vs 29.2%, $p = 0.31$). Single-vessel disease was more prevalent in younger patients (57.5% vs 31%, $p < 0.05$), whereas multivessel disease predominated in older patients (66% vs 36.8%, $p > 0.05$). Non-atherosclerotic causes were significantly more frequent in the younger group (18.9% vs 5%, $p < 0.05$), including coronary vasospasm, spontaneous coronary artery dissection (SCAD) and embolic phenomena.

Table 1 - Population risk profile

	General population ($n = 206$)	G1 ($n = 100$)	G2 ($n = 106$)	p
Mean age (years)	52.8 ± 11.6	62.2 ± 7.9	43.3 ± 5.2	$p < 0.05$
Female gender (%)	36 (17.5)	25 (25)	11 (10.4)	$p < 0.05$
Family history CAD (%)	31 (15)	7 (7)	24 (22.6)	$p < 0.05$
HTN (%)	64 (31.1)	39 (39)	25 (23.6)	$p < 0.05$
DM (%)	101 (49)	58 (58)	43 (40.6)	$p < 0.05$
CVA (%)	7 (3.4)	7 (7)	0 (0)	$p < 0.05$
Dyslipidaemia (%)	32 (15.5)	16 (16)	16 (15.1)	$p = 0.86$
Obesity (%)	17 (8.3)	6 (6)	11 (10.4)	$p = 0.25$
Former smoker (%)	11 (5.3)	5 (5)	6 (5.7)	$p = 0.83$
Current smoker (%)	150 (72.8)	60 (60)	90 (84.9)	$p < 0.0001$
CHAU (%)	39 (18.9)	7 (7)	32 (30.2)	$p < 0.0001$
Cannabis use (%)	14 (6.8)	2 (2)	12 (11.3)	$p < 0.05$
Cocaine use (%)	1 (0.5)	0 (0)	1 (0.9)	$p = 0.33$
CKD (%)	4 (1.9)	1 (1)	3 (2.8)	$p = 0.34$
AAD (%)	2 (1)	0 (0)	2 (1.9)	$p = 0.17$
AF (%)	5 (2.4)	5 (5)	0 (0)	$p < 0.05$

AAD, autoimmune disease; AF, atrial fibrillation; CHAU, chronic heavy alcohol use; CKD, chronic kidney disease; CVA, cerebrovascular accident; DM, diabetes mellitus; Family history CAD, family history of coronary artery disease; HTN, hypertension.

Overall, stenting was performed in 87.4% of cases, while a stentless strategy was used in 12.6%, with final TIMI 3 flow achieved in 93.2% of procedures. Stenting strategy was more frequent in older patients (95% vs 80.2%, $p = 0.08$), whereas a stentless conservative approach was more common in younger patients (19.8% vs 5%, $p < 0.05$). The use of glycoprotein IIb/IIIa inhibitors and thrombectomy was higher in younger patients (10.4% vs 3% and 3.8% vs 0%, $p < 0.05$).

In the general population, dual antiplatelet therapy was predominantly prescribed with clopidogrel (88.3%) and aspirin (96.6%). The remaining pharmacological treatments are summarised in Table 4.

4. Follow-up and clinical outcomes

Early cardiovascular mortality was significantly higher in older patients (7% vs 0.9%, $p < 0.05$). Other adverse events were comparable between groups, including AHF (9% vs 3.8%, $p = 0.46$), CIN (3% vs 0.9%, $p = 0.28$), stent thrombosis (1% vs 0.9%, $p = 0.96$) and stroke (3% vs 0%, $p = 0.07$) (Table 5).

During a mean follow-up period of 38.7 ± 19.3 months, there were no differences in symptom occurrence between groups. Smoking cessation was more frequent in younger patients (42.9% vs 16.1%, $p < 0.05$), whereas therapeutic adherence was similar between the two groups (80% vs 75.3%, $p = 0.98$). No significant differences were observed in LDL-C levels (0.8 vs 0.9 g/L, $p = 0.2$) or mean LVEF (49% vs 48.5%, $p = 0.78$) (Table 6).

Table 2 - Clinical presentation in general population.

	General population (*n* = 206)	G1 (*n* = 100)	G2 (*n* = 106)	*p*
Anterior MI (%)	90 (43.7)	43 (43)	47 (44.3)	0.57
Inferior MI (%)	81 (39.3)	42 (42)	39 (36.8)	0.08
LBBB (%)	3 (1.5)	3 (3)	0 (0)	0.07
Time from pain to first contact (hr)	10.7 ± 13.6	12.72 ± 14.62	8.8 ± 12.3	<0.05
Subacute STEMI presentation (%)	52 (25.2)	31 (31)	21 (19.8)	0.06
HR (bpm)	81.3 ± 16	81 ± 16.1	81.7 ± 16.0	0.75
CS (%)	18 (8.7)	11 (11)	7 (6.6)	0.26
AHF (%)	43 (20.9)	20 (20)	23 (21.7)	0.76
VT/VF (%)	9 (4.4)	3 (3)	6 (5.7)	0.35
AVB (%)	11 (5.3)	8 (8)	3 (2.8)	0.09
Resuscitated CA (%)	5 (2.4)	2 (2)	3 (2.8)	0.7
LVEF (%)	47.6 ± 12	47.2 ± 12.3	47.9 ± 11.7	0.67
Reduced LVEF ≤ 40% (%)	67 (32.5)	34 (34)	33 (31.1)	0.89
LDL-C (g/L)	1.2 ± 0.4	1.2 ± 0.5	1.2 ± 0.4	0.81
HbA1c (%)	7 ± 2.2	8.0 ± 2.7	6.4 ± 1.8	<0.05
Creatinine (µmol/L)	85.5 ± 49.4	89.7 ± 57.5	81.5 ± 40	0.24
Troponins (ng/L)	18 640 ± 14 989.6	19115 ± 16099.6	18232 ± 14043.2	0.7
Hyperhomocysteinemia (%)	2 (1)	0 (0)	2 (1.9)	0.05
Thrombophilia (%)	2 (1)	0 (0)	2 (1.9)	0.05
APS (%)	1 (0.5)	0 (0)	1 (0.9)	0.24

AHF, acute heart failure; APS, antiphospholipid syndrome; AVB, atrioventricular block; CA, cardiac arrest; CS, cardiogenic shock; HbA1c, glycated haemoglobin; hyperhomocysteinemia, elevated homocysteine levels; HR, heart rate; LBBB, left bundle branch block; LDL, low-density lipoprotein; LVEF, left ventricular ejection fraction; troponins, troponin levels; MI, myocardial infarction; RBBB, right bundle branch block; STEMI, ST-elevation myocardial infarction; VF, ventricular fibrillation; VT, ventricular tachycardia.

The primary endpoint of cardiovascular mortality was higher in older patients, occurring in 11 cases (11%) compared with 1 case in younger patients (0.9%). Secondary endpoints occurred at similar rates in both groups (26% vs 25.5%, $p = 0.96$) (Table 7). Kaplan–Meier analysis demonstrated a significant difference in survival between groups ($p < 0.05$), with a hazard ratio of 0.09. Five-year survival was lower in older patients (87.7% vs 99%) (Figure 2).

5. Independent factors associated with younger age in MI

In multivariable analysis, smoking (OR 2.58, 95% CI 1.19–5.60, $p = 0.016$), CHAU (OR 4.13, 95% CI 1.63–10.5, $p = 0.003$) and family history of CAD (OR 2.85, 95% CI 1.08–7.50, $p = 0.034$) were independently associated with younger age among STEMI patients (Table 8).

6. Determinants of cardiovascular mortality in the overall population

Cox regression analysis, restricted to clinically relevant variables, showed that CS at presentation (HR 5.92, 95% CI 1.81–19.33, $p = 0.003$) and reduced LVEF (HR 7.04, 95% CI 1.45–34.17, $p = 0.015$) were associated with increased cardiovascular mortality. Age >50 years was also associated with a higher risk of cardiovascular death (HR 8.98, 95% CI 1.15–69.94, $p = 0.036$), supporting the prognostic impact of age in this population (Figure 3).

Table 3 - Angiographic findings in the general population

	General population (*n* = 206)	G1 (*n* = 100)	G2 (*n* = 106)	*p*
Primary PCI (%)	129 (62.6)	61 (61)	68 (64.2)	0.78
Rescue PCI (%)	16 (7.8)	10 (10)	6 (5.7)	0.15
Radial access (%)	184 (89.3)	90 (90)	94 (88.7)	0.76
High thrombotic burden (%)	28 (13.6)	8 (8)	20 (18.9)	<0.05
Coronary status				
Single-vessel (%)	92 (44.7)	31 (31)	61 (57.5)	<0.05
Multivessel (%)	105 (50.9)	66 (66)	39 (36.8)	<0.05
Syntax score	13.3 ± 11.9	16.7 ± 13.8	10.0 ± 8.9	<0.01
Culprit vessel				
LAD (%)	96 (46.6)	44 (44)	52 (49.1)	0.45
RCA (%)	67 (32.5)	36 (36)	31 (29.2)	0.31
LMCA (%)	3 (1.5)	2 (2)	1 (0.9)	0.9
Cx (%)	19 (9.2)	13 (13)	6 (5.7)	0.08
Pre-revascularisation TIMI				
0 (%)	71 (34.5)	33 (33)	38 (35.8)	0.14
II (%)	31 (15)	19 (19)	12 (11.3)	0.14
III (%)	95 (46.1)	41 (41)	54 (50.9)	0.14
Non-atheromatous causes				
Coronary spasm (%)	5 (2.4)	2 (2)	3 (2.8)	0.7
SCAD (%)	5 (2.4)	1 (1)	4 (3.8)	0.2
Thromboembolic (%)	15 (7.3)	2 (2)	13 (12.3)	<0.05
Revascularisation modalities				
DES (%)	86 (41.7)	42 (42)	44 (41.5)	0.89
BMS (%)	94 (45.6)	53 (53)	41 (38.7)	0.08
Glycoprotein IIb/IIIa inhibitors (%)	14 (6.8)	3 (3)	11 (10.4)	<0.05
Manual thrombectomy (%)	4 (1.9)	0 (0)	4 (3.8)	<0.05
No reflow (%)	7 (3.4)	4 (4)	3 (2.8)	0.63
Stentless strategy (%)	26 (12.6)	5 (5)	21 (19.8)	<0.05
Post-revascularisation TIMI				
0 (%)	5 (2.4)	3 (3)	2 (1.9)	0.15
II (%)	5 (2.4)	0 (0)	5 (4.7)	0.15
III (%)	192 (93.2)	95 (95)	97 (91.5)	0.15

BMS, bare-metal stent; CX, circumflex coronary artery; DES, drug-eluting stent; LAD, left anterior descending coronary artery; LMCA, left main coronary artery; PCI, percutaneous coronary intervention; RCA, right coronary artery; SCAD, spontaneous coronary artery dissection; TIMI, thrombolysis in myocardial infarction flow grading system.

Discussion

Our study highlights a distinct clinical and pathophysiological profile of STEMI in young patients, predominantly driven by lifestyle-related factors alongside a notable genetic predisposition. Despite

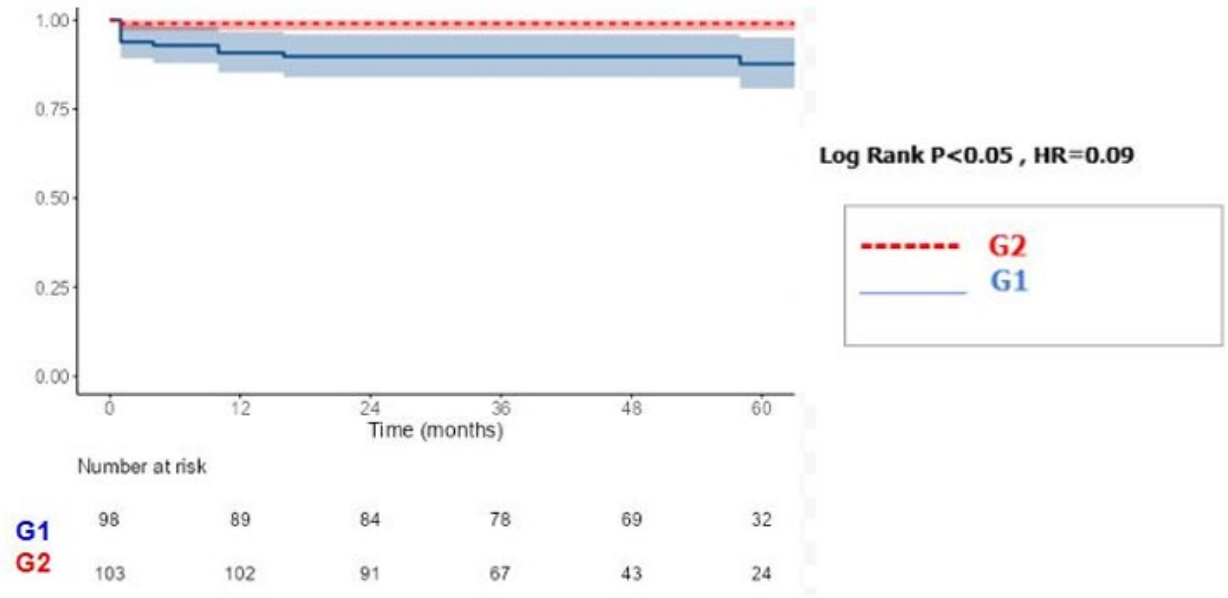

Figure 2 - Survival curves in young and old STEMI patients based on Kaplan–Meier estimates. Younger patients (G2) exhibited significantly higher survival rates compared with older patients (G1) (log-rank $p < 0.05$). HR, hazard ratio; STEMI, ST-segment elevation myocardial infarction.

Table 4 - Pharmacological treatment

	General population (*n* = 206)	G1 (*n* = 100)	G2 (*n* = 106)	*p*
Ticagrelor (%)	20 (9.7)	6 (6)	14 (13.2)	0.08
Clopidogrel (%)	182 (88.3)	93 (93)	89 (84)	0.2
Aspirin (%)	199 (96.6)	97(97)	102 (96.2)	0.45
B-blockers (%)	188 (91.3)	85 (85)	103 (97.1)	<0.05
ACEi (%)	163 (79)	79 (79)	84 (79.3)	0.32
ARNi (%)	1 (0.5)	0 (0)	1 (0.9)	0.33
MRA (%)	30 (14.6)	17 (17)	13 (12.3)	0.32
Statins (%)	196 (95.1)	97 (97)	99 (93.4)	0.1
SGLT2i (%)	39 (19)	12 (12)	27 (25.5)	<0.05
DOAC (%)	3 (1.5)	0 (0)	3 (2.8)	0.09
Acenocoumarol (%)	11 (5.3)	5 (5)	6 (5.7)	0.85

ACEi, angiotensin-converting enzyme inhibitors; ARNi, angiotensin receptor/neprilysin inhibitor; DOAC, direct oral anticoagulants; MRA, mineralocorticoid receptor antagonists; SGLT2i, sodium-glucose transport inhibitors.

Table 5. Early adverse events

	General population (*n* = 206)	G1 (*n* = 100)	G2 (*n* = 106)	*p*
Early CV mortality (%)	8 (3.9)	7 (7)	1 (0.9)	<0.05
Subacute stent thrombosis (%)	2 (1)	1 (1)	1 (0.9)	0.96
CIN (%)	4 (1.9)	3 (3)	1 (0.9)	0.28
Mechanical complications (%)	2 (1)	1 (1)	1 (0.9)	0.97
AF (%)	9 (4.4)	5 (5)	4 (3.8)	0.68
AHF **hospitalisation** (%)	13 (6.3)	9 (9)	4 (3.8)	0.46
Stroke (%)	3 (1.5)	3 (3)	0 (0)	0.07

AF, atrial fibrillation; AHF, acute heart failure; CIN, contrast-induced nephropathy; CV mortality, cardiovascular mortality.

these differences, the initial clinical presentation appears broadly similar across age groups. However, angiographic characteristics differ markedly, with younger patients exhibiting less complex, predominantly single-vessel disease, often amenable to more conservative strategies. Importantly, although mortality is lower in younger individuals, the rate of recurrent cardiovascular events remains comparable, underscoring a persistent residual risk in this population.

7. Risk factor profile in young patients

In line with previous studies, smoking emerged as the predominant cardiovascular risk factor in our cohort, particularly among younger patients [2,7]. Our study confirmed a significantly higher prevalence of active smoking in young individuals compared with older patients, consistent with large registries reporting a substantial burden of tobacco exposure in early-onset STEMI [2,7–9]. This finding likely reflects the increasing exposure to tobacco in our region, where smoking remains a major contributor to cardiovascular mortality [10].

Beyond smoking, our study identified a higher prevalence of lifestyle-related exposures in younger patients, including CHAU and substance use, supporting the central role of modifiable behavioural factors in premature coronary events. These observations are in agreement with previous data demonstrating a strong association between lifestyle factors and early-onset MI [11–13].

In contrast, traditional cardiovascular risk factors such as hypertension and diabetes were more prevalent among older patients in our cohort, as also observed in previous studies, reflecting the cumulative burden of long-standing atherosclerotic disease [2,14]. Nevertheless, their presence in younger patients, although less

Table 6 - Patients follow-up parameters

	General population (n = 198)	G1 (*n* = 93)	G2 (*n* = 105)	*p*
Angina				
CCS 2 (%)	23 (11.6)	9 (9.7)	14 (13.3)	0.8
CCS 3 (%)	4 (2.0)	2 (2.2)	2 (1.9)	0.8
Dyspnoea				
NYHA II (%)	22 (11.1)	10 (10.8)	12 (11.4)	0.29
NYHA III (%)	5 (2.5)	4 (4.3)	1 (1)	0.29
Smoking cessation (%)	60 (30.3)	15 (16.1)	45 (42.9)	<0.05
Therapeutic adherence (%)	154 (77.8)	70 (75.3)	84 (80)	0.98
HR (bpm)	68.9 ± 13.9	69 ± 12.9	68.8 ± 14.7	0.9
SBP (mmHg)	124.1 ± 21.8	124.8 ± 27.2	123.4 ± 15.8	0.65
LDL-C (g/L)	0.9 ± 0.3	0.8 ± 0.3	0.9 ± 0.3	0.2
LVEF (%)	48.7 ± 11.3	49 ± 12	48.5 ± 10.7	0.78
Mean follow-up duration (months)	38.7 ± 19.3	42.4 ± 21.9	35.2 ± 15.8	*p* < 0.05

CCS, Canadian Cardiovascular Society; HR, heart rate; LDL-C, low-density lipoprotein; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; SBP, systolic blood pressure.

Table 7 - Patients Outcomes.

	General population (*n* = 206)	G1 (*n* = 100)	G2 (*n* = 106)	*p*
Primary endpoint (%)	12 (5.8)	11 (11)	1 (0.9)	<0.01
Secondary endpoints (%)	53 (25.7)	26 (26)	27 (25.5)	0.96
Non-fatal MI (%)	42 (20.4)	18 (18)	24 (22.6)	0.4
AHF **hospitalisation** (%)	13 (6.3)	9 (9)	4 (3.8)	0.12
Stent thrombosis/ restenosis (%)	29 (14.1)	12 (12)	17 (16.0)	0.41

AHF, acute heart failure; MI, myocardial infarction.

Table 8 - Logistic regression analysis of factors associated with STEMI in young patients

Predictor	OR	*p*	95% CI
Family history of CAD	**2.85**	0.034	1.08–7.50
Female gender	0.95	0.9	0.38–2.38
HTN	0.77	0.45	0.39–1.52
DM	0.69	0.24	0.37–1.29
Current smoking	**2.58**	0.016	1.19–5.60
CHAU	**4.13**	0.003	1.63–10.5

CHAU, chronic heavy alcohol use; CI, confidence interval; DM, diabetes mellitus; CAD, coronary artery disease; HTN, hypertension; OR, odds ratio.

frequent, remains clinically relevant, as they contribute to endothelial dysfunction and accelerated atherogenesis, as highlighted in prior reports [2,7,8].

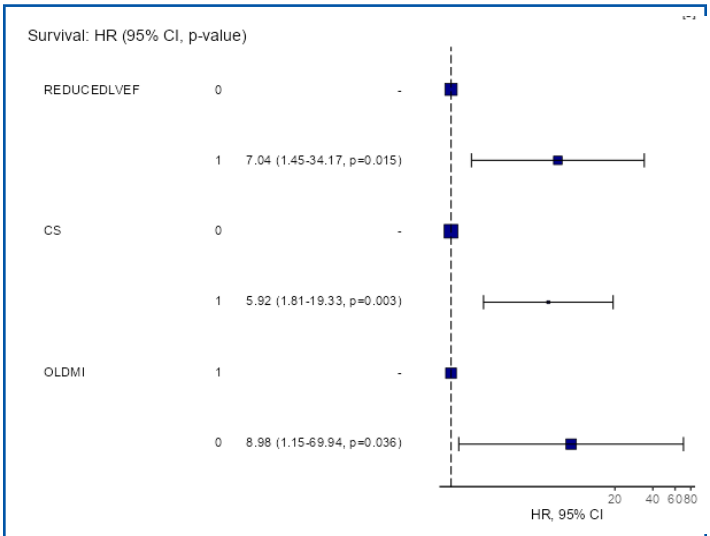

Figure 3 - Multivariable Cox survival regression plot. CS, reduced LVEF and age >50 years were independently associated with increased cardiovascular mortality. CI, confidence interval; CS: cardiogenic shock; HR, LVEF, left ventricular ejection fraction; MI: myocardial infarction.

Notably, our study demonstrated a significantly higher prevalence of family history of CAD in younger patients, suggesting an underlying genetic predisposition to premature coronary events. This observation is consistent with previous studies reporting a strong association between hereditary factors and early atherosclerosis [2,14,15]. In addition, our cohort identified cases of inherited and acquired thrombophilia exclusively in younger patients, further supporting the contribution of prothrombotic and genetic mechanisms in this population, as previously described [16,17].

These results suggest that STEMI in young patients follows a distinct risk profile, and, therefore, prevention strategies should be adapted rather than directly extrapolated from older populations, with a greater focus on modifiable lifestyle factors and early identification of at-risk individuals.

8. Pathophysiological considerations

Atherosclerosis remains the predominant underlying mechanism of MI across all age groups, including in younger individuals, as observed in our cohort [2,7,8]. In addition to traditional cardiovascular risk factors, younger patients are frequently exposed to accelerating factors that may promote premature atherogenesis, including lifestyle-related determinants as well as chronic inflammatory and autoimmune conditions contributing to endothelial dysfunction and vascular injury [16,17]. Genetic susceptibility, particularly involving lipid metabolism and thrombogenic pathways, may further modulate this early disease process [17,18].

Nevertheless, non-atherosclerotic mechanisms appear to be relatively more frequent in younger patients compared with older individuals [17,19]. In our population, these mechanisms were more commonly identified in younger patients and mainly included cases of coronary vasospasm, SCAD and thromboembolic events, reflecting a broader and more heterogeneous pathophysiological spectrum of

STEMI in this group. This supports the concept that STEMI in young patients represents a distinct entity, requiring a tailored diagnostic approach, particularly through the use of intracoronary imaging, to refine diagnosis strategies.

9. Angiographic profile and management

Our study demonstrated that younger patients exhibited significantly lower lesion complexity, more frequent single-vessel disease and lower SYNTAX scores compared with older individuals, consistent with previous studies highlighting less advanced atherosclerotic substrates in early-onset STEMI [14,15].

This angiographic profile likely contributes to the higher use of conservative, stentless strategies observed in younger patients in our cohort. Our study showed that such approaches were more frequently adopted in younger individuals, particularly in the presence of a high thrombotic burden and less complex lesions, reflecting a more selective and lesion-adapted interventional strategy. These findings are consistent with previous studies suggesting that plaque erosion and thrombotic lesions, more prevalent in younger patients, may be amenable to conservative management [21].

The EROSION trial further supports this concept, demonstrating the feasibility of a non-stenting strategy with intensive antithrombotic therapy in selected patients with acute coronary syndromes [21]. However, available data remain heterogeneous and sometimes conflicting, with other studies suggesting potential benefits of systematic stenting in selected high-risk lesions [21,22].

Importantly, in the absence of intracoronary imaging in our study, the underlying plaque morphology cannot be definitively established. Therefore, the use of stentless strategies in our cohort likely reflects individualised operator decision-making rather than a standardised therapeutic approach, underscoring the current lack of consensus in this setting.

Taken together, these findings reinforce the concept that STEMI in young patients is associated with a detached angiographic profile. This heterogeneity supports the need for a tailored interventional approach rather than a uniform strategy, with a central role for intracoronary imaging to guide decision-making and optimise patient-specific management.

10. Clinical outcomes

Consistent with existing literature, younger patients exhibited more favourable short- and long-term survival compared with older individuals, likely reflecting a lower burden of comorbidities and less extensive CAD [23–26].

This survival advantage is likely explained by a lower cumulative atherosclerotic burden, fewer comorbidities and less complex coronary disease, as reflected in the angiographic profile of younger patients. However, despite this favourable prognosis, our study demonstrated that the incidence of recurrent cardiovascular events – including non-fatal MI, hospitalisation for AHF and stent-related complications – remained comparable between younger and older patients.

These findings highlight a dissociation between survival and recurrence, as younger patients continue to experience a non-negligible risk of subsequent cardiovascular events despite lower mortality, consistent with current large-scale registry data [26,27]. This paradox may be partly explained by persistent exposure to modifiable risk factors, suboptimal long-term risk factor control and the presence of underlying genetic or metabolic predispositions in younger individuals.

In line with established data, CS at presentation and reduced LVEF were strong predictors of mortality [27–29]. Age also remained independently associated with worse outcomes, further supporting its prognostic significance in STEMI.

11. Implications for prevention strategies

These findings highlight the need for targeted prevention strategies in young patients, with a particular focus on modifiable lifestyle-related risk factors, including smoking and alcohol consumption, as well as early identification of individuals with a family history of coronary artery disease.

Taken together, our results support a more individualised approach to cardiovascular prevention, acknowledging that the risk profile of younger patients differs substantially from that of older populations and requires specific preventive interventions. Importantly, this approach should extend beyond primary prevention to include aggressive secondary prevention following the index event, with strict control of risk factors, optimisation of medical therapy and reinforcement of long-term adherence to lifestyle and pharmacological measures.

Limitations

Several limitations should be acknowledged. First, the monocentric design may limit the generalisability of our findings, while the retrospective nature of the study introduces potential selection and information biases. In addition, the relatively small sample size and limited number of events may have reduced the statistical power of our analyses. Finally, the absence of intracoronary imaging precludes a detailed mechanistic characterisation of coronary lesions.

Conclusions

CAD remains a leading cause of mortality, with a rising incidence of STEMI in younger adults. In our study, young patients were characterised by a predominance of lifestyle-related factors and genetic predisposition, along with less complex coronary disease. Despite significantly lower mortality, they experienced similar rates of recurrent cardiovascular events. These findings suggest that STEMI in younger individuals follows a different clinical pattern. Accordingly, prevention and management should be specifically adapted, with emphasis on lifestyle modification, early risk identification and aggressive secondary prevention.

Abbreviations

AHF, new-onset acute heart failure; CAD, coronary artery disease; CHAU, chronic heavy alcohol use; CIN, contrast-induced nephropathy; HR, hazard ratios; IRA, infarct-related artery; LAD, left anterior descending coronary artery; LDL-C, low-density lipoprotein cholesterol; LVEF, left ventricular ejection fraction; MACE, major adverse cardiovascular events; MI, myocardial infarction; NSTEMI, non-ST-segment elevation myocardial infarction; OR, odds ratios; PCI, percutaneous coronary intervention; RCA, right coronary artery; SCAD, spontaneous coronary artery dissection; STEMI, ST-segment elevation myocardial infarction; TIMI, thrombolysis in Myocardial Infarction.

Conflicts of Interest

The authors have each completed the International Committee of Medical Journal Editors Form for uniform Disclosure of Potential Conflicts of Interest. No authors have any potential conflict of interest to disclose.

Ethics compliance

We confirm that the article was conducted in compliance with ethical guidelines.

Acknowledgements

All individuals involved contributed to the elaboration of this work.

Funding body

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

REFERENCES

1. Bhatt DL, Lopes RD, Harrington RA. Diagnosis and treatment of acute coronary syndromes: a review. JAMA. 2022;327:662–675. doi: 10.1001/jama.2022.0358. Erratum in: JAMA 2022;327:662–675.

2. Liang MT, Pang Y, Gao LL, Han LJ, Yao HC. Clinical risk factors and outcomes of young patients with acute ST segment elevation myocardial infarction: a retrospective study. BMC Cardiovasc Disord. 2023;23(1):353. doi: 10.1186/s12872-023-03392-8.

3. Yang J, Biery DW, Singh A, Divakaran S, DeFilippis EM, Wu WY, et al. Risk factors and outcomes of very young adults who experience myocardial infarction: the partners YOUNG-MI Registry. Am J Med. 2020;133(5):605–612.e1. doi: 10.1016/j.amjmed.2019.10.020.

4. Byrne RA, Rossello X, Coughlan JJ, Barbato E, Berry C, Chieffo A et al. ESC Scientific Document Group. 2023 ESC Guidelines for the management of acute coronary syndromes: developed by the task force on the management of acute coronary syndromes of the European Society of Cardiology (ESC). Eur Heart J. 2023;44(38):3720–3826. doi: 10.1093/eurheartj/ehad191.

5. McDonagh T, Metra M, Adamo M, Gardner RS, Baumbach A, Böhm M et al. ESC Scientific Document Group. 2023 Focused Update of the 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: developed by the task force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) with the special contribution of the Heart Failure Association (HFA) of the ESC. Eur Heart J. 2023;44(37): 3627–3639. doi: 10.1093/eurheartj/ehad195.

6. Cutlip DE, Windecker S, Mehran R, Boam A, Cohen DJ, van Es GA, et al. Clinical end points in coronary stent trials: a case for standardized definitions. Circulation. 2007;115(17):2344–2351. doi: 10.1161/CIRCULATIONAHA.106.685313.

7. Gulati R, Behfar A, Narula J, Kanwar A, Lerman A, Cooper L, et al. Acute myocardial infarction in young individuals. Mayo Clin Proc. 2020;95(1):136–156. doi: 10.1016/j.mayocp.2019.05.001.

8. Shah N, Kelly AM, Cox N, Wong C, Soon K. Myocardial infarction in the "Young": risk factors, presentation, management and prognosis. Heart Lung Circ. 2016;25(10):955–60. doi: 10.1016/j.hlc.2016.04.015.

9. Moliterno DJ, Willard JE, Lange RA, Negus BH, Boehrer JD, Glamann DB, et al. Coronary-artery vasoconstriction induced by cocaine, cigarette smoking, or both. N Engl J Med. 1994;330(7):454–459. doi: 10.1056/NEJM199402173300702.

10. Saidi O, Hajjem S, Zoghlami N, Aounallah-Skhiri H, Ben Mansour N, Hsairi M, et al. Premature mortality attributable to smoking among Tunisian men in 2009. Tob Induc Dis. 2019;17:77. doi: 10.18332/tid/112666.

11. Gupta N, Washam JB, Mountantonakis SE, Li S, Roe MT, Lemos JA de, et al. Characteristics, management, and outcomes of cocaine-positive patients with acute coronary syndrome (from the National Cardiovascular Data Registry). Am J Cardiol. 2014;113(5):749–756. doi: 10.1016/j.amjcard.2013.11.023.

12. Ladha KS, Mistry N, Wijeysundera DN, Clarke H, Verma S, Hare GMT, et al. Recent cannabis use and myocardial infarction in young adults: a cross-sectional study. Can Med Assoc J. 2021;193(35):E1377–E1384. doi: 10.1503/cmaj.202392.

13. Ilic M, Grujicic Sipetic S, Ristic B, Ilic I. Myocardial infarction and alcohol consumption: A case-control study. PloS One. 2018;13(6):e0198129. doi: 10.1371/journal.pone.0198129.

14. Matsis K, Holley A, Al-Sinan A, Matsis P, Larsen PD, Harding SA. Differing clinical characteristics between young and older patients presenting with myocardial infarction. Heart Lung Circ. 2017;26(6):566–571. doi: 10.1016/j.hlc.2016.09.007.

15. Shah SS, Noor L, Shah SH, Shahsawar, Din SU, Awan ZA, et al. Myocardial infarction in young versus older adults: clinical characteristics and angiographic features. J Ayub Med Coll Abbottabad. 2010;22(2):187–190.

16. Libby P, Hansson GK. From focal lipid storage to systemic inflammation: JACC review topic of the week. J Am Coll Cardiol. 2019;74(12):1594–1607. doi: 10.1016/j.jacc.2019.07.061.

17. Maor E, Fefer P, Varon D, Rosenberg N, Levi N, Hod H, et al. Thrombophilic state in young patients with acute myocardial infarction. J Thromb Thrombolysis. 2015;39(4):474–480. doi: 10.1007/s11239-014-1166-2.

18. Ference BA, Ginsberg HN, Graham I, Ray KK, Packard CJ, Bruckert E, et al. Low-density lipoproteins cause atherosclerotic cardiovascular disease. 1. Evidence from genetic, epidemiologic, and clinical studies. A consensus statement from the European Atherosclerosis Society Consensus Panel. Eur Heart J. 2017;38(32):2459–2472. doi: 10.1093/eurheartj/ehx144.

19. Hayes SN, Kim ESH, Saw J, Adlam D, Arslanian-Engoren C, Economy KE, et al. Spontaneous coronary artery dissection: Current state of the science: A scientific statement from the American Heart Association. Circulation. 2018;137(19):e523–e557. doi: 10.1161/CIR.0000000000000564.

20. Zgheib H, Al Souky N, El Majzoub I, Wakil C, Sweidan K, Kaddoura R, et al. Comparison of outcomes in ST-elevation myocardial infarction according to age. Am J Emerg Med. 2020;38(3):485–490. doi: 10.1016/j.ajem.2019.05.023.

21. Xing L, Yamamoto E, Sugiyama T, Jia H, Ma L, Hu S, et al. EROSION Study (effective anti-thrombotic therapy without stenting: intravascular optical coherence tomography–based management in plaque erosion): a 1-year follow-up report. Circ Cardiovasc Interv. 2017;10(12):e005860. doi: 10.1161/CIRCINTERVENTIONS.117.005860.

22. Stone GW, Maehara A, Ali ZA, Held C, Matsumura M, Kjøller-Hansen L, et al. Percutaneous coronary intervention for vulnerable coronary atherosclerotic plaque. J Am Coll Cardiol. 2020;76(20):2289–2301. doi: 10.1016/j.jacc.2020.09.547.

23. Zasada W, Bobrowska B, Plens K, Dziewierz A, Siudak Z, Surdacki A, et al. Acute myocardial infarction in young patients. Polish Heart Journal (Kardiologia Polska). 2021;79(10):1093–1098. doi: 10.33963/KP.a2021.0099.

24. Fournier JA, Sánchez-González A, Quero J, Cortacero JA, Cabello A, Revello A, et al. Normal angiogram after myocardial infarction in young patients: A prospective clinical-angiographic and long-term follow-up study. Int J Cardiol. 1997;60(3):281–287. doi: 10.1016/s0167-5273(97)00115-0.

25. Rumboldt Z, Rumboldt M, Pesenti S, Polić S, Mirić D. Peculiarities of myocardial infarction at young age in Southern Croatia. Cardiol Rome Italy. 1995;40(6):407–411.

26. Wittlinger T, Seifert C, Simonis G, Gerlach M, Strasser RH. Prognosis in myocardial infarction of young patients: results of a prospective registry. Int J Cardiol. 2020;300:1–6. doi: 10.1016/j.ijcard.2019.10.037.

27. Cole JH, Miller JI 3rd, Sperling LS, Weintraub WS. Long-term follow-up of coronary artery disease presenting in young adults. J Am Coll Cardiol. 2003;41(4):521–528. doi: 10.1016/s0735-1097(02)02862-0.

28. Hosseini SK, Soleimani A, Karimi AA, Sadeghian S, Darabian S, Abbasi SH, et al. Clinical features, management and in-hospital outcome of ST elevation myocardial infarction (STEMI) in young adults under 40 years of age. Monaldi Arch Chest Dis. 2009;72(2):71–76. doi: 10.4081/monaldi.2009.331.

29. Nantumbwe, S.N., Gardiner, R., Kiernan, T.J. et al. Risk factors associated with ST-segment elevation myocardial infarctions among young patients treated in the Mid-West of Ireland: a case series report using secondary data. Ir J Med Sci. 2025;194:1267–1277. doi: 10.1007/s11845-025-03965-w.